A STUDY FOR THE

MAINE DEPARTMENT OF TRANSPORTATION

WATER QUALITY EFFECTS OF USING TIRE CHIPS BELOW THE GROUNDWATER TABLE

Technical Services Division
Technical Paper
August 26, 1996

Prepared by:
Lisa A. Downs
Dana N. Humphrey
Lynn E. Katz
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DEPARTMENT
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COLLEGE OF
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June 29, 1998

Mr. Michael Blumenthal
Executive Director
Scrap Tire Management Council
1400 K Street, N.W.
Washington, DC 20005

Dear Michael:

Enclosed for your files is the final report of Phase I of a study on "Water Quality Effects of Using Tire Chips Below the Groundwater Table." The conclusions in this report relative to the presence of volatile and semivolatile organic compounds are tentative. The presence of organics will be clarified in the report for Phase II of this study which should be available late in the summer.

Please call me if you have any questions.

Sincerely,

Dana N.

Dana N. Humphrey, Ph.D., P.E.
Professor of Civil Engineering

THE LAND GRANT UNIVERSITY AND SEA GRANT COLLEGE OF MAINE

For Technical Report Standard Title Page (Form DOT F 1700.7)

Abstract:

The purpose of this project was to gather the data necessary to determine the environmental acceptability of placing tire chips below the groundwater table. The study was divided into three parts: (1) laboratory TCLP leaching tests; (2) laboratory reactor simulation of ground conditions; and (3) small scale field trials with 1.5 tons of steel belted tire chips buried below the groundwater table in glacial till, marine clay, and peat.

The TCLP tests showed that tire chips are not a hazardous waste. The levels of TCLP regulated metals and organics were well below their TCLP limits. The reactor study showed that barium, chromium, copper, lead, iron, manganese, and zinc leached from tire chips. Low levels of some volatile and semivolatile compounds also leached from tire chips.

The small scale field trials showed that the levels of metals with a primary drinking water standard were all below their applicable limits. The levels of iron and manganese, which have secondary drinking water standards indicating that they are of aesthetic concern, were increased to well above their applicable standard. Thus, tire chips should be used below the groundwater table only where higher levels of iron and manganese can be tolerated. Zinc was also increased by tire chips, however, the levels were well below its secondary drinking water standard. Low levels of some volatile and semivolatile compounds were detected. However, scatter of the data made it impossible to determine if the levels were high enough to constitute a potential health hazard. Monitoring of organic levels will be continued to clarify the presence or absence of a potential hazard.

Key words: tires, tire chips, tire shreds, waste materials, environmental considerations, groundwater

WATER QUALITY EFFECTS
OF USING TIRE CHIPS BELOW THE GROUNDWATER TABLE

By: Lisa A. Downs, Dana N. Humphrey, Lynn E. Katz, and Chet A. Rock

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EXECUTIVE SUMMARY

Many of the 240 million scrap tires generated in the United States each year are disposed of in landfills or open piles. This uses valuable landfill space, creates fire hazards, and provides a breading place for disease carrying mosquitoes. Alternate uses of scrap tires have been sought including using tires cut into chips as lightweight and insulating fills in roadways, embankments, and retaining walls. These applications may bring tire chips in direct contact with groundwater, raising concerns of possible contamination. The focus of this research was to evaluate the effects of tire chips placed below the water table on groundwater quality.

This study was divided into three parts: (1) laboratory toxicity characteristics leaching procedure (TCLP) tests; (2) laboratory reactor simulation of ground conditions; and (3) small scale field trials. The TCLP tests were used to evaluate potential pollutants from tire chips. The laboratory simulation of ground conditions was a batch reactor study that compared the long-term leachability of tire chips and soil. Finally, small scale field trials were used to evaluate the long-term effect on groundwater quality of using tire chips as a construction material. In these trials 1.5 tons of tire chips were buried below the water table in each of three Maine soil types: marine clay, glacial till, and peat.

TCLP tests are used to determine if a waste is a significant hazard to human health due to leaching of toxic compounds. In addition, TCLP results can be used to give an indication of potential pollutants that may leach from a waste. In this study, the following four tire chip samples were subjected to TCLP testing: unwashed mixed glass and steel belted chips, washed mixed steel and glass belted chips, unwashed glass belted chips, and washed glass belted chips. Samples were tested washed and unwashed to examine the possibility that pollutants from tire chips could be due to dirt and debris on the surface of the tires rather than the tire itself. Prior to testing, the tire chip size was reduced to passing the 9.5-mm (0.375-in.) sieve as required by the TCLP test protocol.

TCLP results showed that tire chips are not a hazardous waste since concentrations of metals and organics were well below applicable TCLP regulatory limits. Arsenic, mercury, selenium, and silver were below detection limits for all samples. However, low levels of barium, cadmium, chromium, and lead were detected in leachate extracts from each of the four samples. Thus, tire chips have the potential to leach these compounds. The presence of these compounds was investigated further in subsequent laboratory and field tests. The only TCLP regulated organic compound found in the TCLP extracts was 1,2-dichloroethane with concentrations ranging from ND[1] to 7 μg/L, which is well below the TCLP regulatory limit of 500 μg/L. Several compounds not regulated by TCLP were also found in the extracts. The volatile compound dichloromethane was found at concentrations ranging from 5 to 10 μg/L. In addition, five semivolatile compounds were tentatively identified: 1-(2-butoxyethoxy)-ethanol (ND to 143 μg/L); benzothiazole (200 to 286 μg/L); 1H-isoindole-1,3(2H)-dione (ND to 286 μg/L); 2(3H)-benzothiazolone (100 to 286 μg/L); 2,5-cyclohexadiene-1,4-dione (ND to 114 μg/L); and 4-(2-benzothiazolythio)-morpholine (ND to 143 μg/L). Thus, tire chips have the potential to leach some organic compounds. The presence of these compounds was investigated further in subsequent laboratory batch reactor and field tests.

The laboratory simulation of ground conditions was a batch reactor study. The study was designed to allow direct comparison of the levels of metals and organic compounds that leach from tire chips to the levels that leach from soil. Eight reactors were set up. The reactors were 20 L (5 gal) Pyrex glass jars. Three reactors were controls that contained only soil and water. The three soil types were marine clay, glacial till, and peat. The soil was obtained from each of the three sites chosen for the small scale field trials. Another three reactors were set up with tire chips, soil, and distilled water, one corresponding to each of the control reactors. Two additional reactors contained only tire chips and distilled water. The reactors were stored at ambient temperature in the dark for approximately ten months. The reactors were not mixed or disturbed during that time. At the completion of the storage period, water and soil samples were collected from the reactors. The water samples were analyzed for total and dissolved metal, and volatile and semivolatile organic compounds. The soil samples were digested and analyzed for total metals.

Leaching of metals from tire chips was examined by analyzing soil and water samples taken from the reactors. Results from the soil digestates showed that presence of tire chips increased the concentrations in the clay of manganese, in the till of copper and zinc, and in the peat of barium, chromium, copper, lead, iron, manganese, and zinc. This was evidenced by the concentrations of these metals being higher in digested soil samples taken from reactors with mixtures of soil and chips than for digested soil samples taken from the corresponding control reactors (no tire chips). It appears that peat has a greater tendency to sorb metals released from tire chips than either clay or till.

The water sample results from the laboratory batch reactors showed that the concentration of several metals were increased by leaching from tire chips or leaching from soil due to the environmental conditions created by placing tire chips in contact with soil and water. In some of the tire chip or tire chip/soil mixture reactors, the concentrations of arsenic, barium, chromium, and copper were increased but the levels

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[1] ND = not detected

were well below the applicable primary drinking water standards. For all reactors, the levels of cadmium, mercury, and lead were below the test method detection limit. The concentration of iron and manganese were above their secondary, or aesthetic, drinking water standards in reactors containing tire chips or tire chip/soil mixtures. The concentration of zinc was increased, but the levels were well below its secondary drinking water standard. Tire chips also increased the pore water concentrations of calcium, magnesium, and sodium which do not have drinking water standards. The source of the increased levels of chromium, iron, manganese, and zinc appeared to be the tire chips. For barium, calcium, magnesium, and sodium, it could not be determined if the increased levels were due directly to the tire chips or leaching from the soil in response to environmental conditions created by the tire chips. These results suggest that tire chips will not cause primary drinking water standards to be exceeded. However, it is likely that tire chips will cause the secondary drinking water standards for iron and manganese to be exceeded. These laboratory results should be confirmed for field conditions.

The water taken from the reactors was also analyzed for volatile and semivolatile organic compounds. The following volatile compounds and range of concentrations were found in the samples from the tire chip and tire chip/soil mixture reactors but were not found in the reactors containing only soil: benzene (2.5 to 5 μg/L) and cis-1,2-dichloroethene (ND to 3.2 μg/L). The following compounds were below detection limits for all but one sample: bromomethane (one sample had 1.6 μg/L); 1,1-dichloroethane (one sample had 0.6 μg/L); trichloromethane (one sample had 0.8 μg/L); and naphthalene (one sample had 5.3 μg/L). Additional testing would be required to determine if these compounds are leached from tire chips at very low concentrations or if the results could be attributed to testing anomalies. Dichloromethane was found at concentrations ranging from 0.5 to 1.8 μg/L in the soil reactors compared to ND to 1 μg/L in the tire chip and tire chip/soil mixture reactors. Likewise, toluene was found at concentrations ranging from 0.9 to 1.1 μg/L in the soil reactors and the blank, compared to 1.1 to 3.6 μg/L in the tire chip and tire chip/soil mixture reactors. Further testing would be required to determine if dichloromethane and toluene are released from tire chips at low concentrations or if the results could be attributed to testing anomalies. None of the volatile compounds were above drinking water standards (where applicable). Dichloromethane was the only volatile organic compound found in the reactor study that was also found in the TCLP extracts

Some semivolatile compounds were detected in the reactor study. Aniline was detected in water taken from the reactors with tire chips and tire chip/soil mixtures at concentrations ranging from ND to 47.7 μg/L. In addition, the following semivolatile compounds were tentatively identified in some of the water samples taken from reactors with tire chips and tire chip/soil mixtures: 4-acetyl-morpholine, benzoic acid, and 2(3H)-benzothiazolone. The estimated concentration of these compounds ranged from non-detect to 600 μg/L. The compound 2(3H)-benzothiazolone was also found in the TCLP extracts.

Small scale field trials were constructed to examine the effect of tire chips on groundwater quality in three Maine soil types: glacial till, marine clay, and peat. At each site a backhoe was used to excavate a 1.7 m (5.5 ft) to 1.8 m (6 ft) deep trench. The trenches were typically 0.6 m (2 ft) to 0.9 m (3 ft) wide, and 3.3 m (10.8 ft) to 4.6 m (15 ft) long. Approximately 1.4 metric tons (1.5 U.S. short tons) of tire chips were placed in each trench. The tire chips were a mixture of steel and glass belted chips with a majority of the chips having steel wires protruding from the cut edges. About 0.3 m (1 ft) of soil was placed over the tire chips. At the peat site, the tire chips were below the water table for the entire year, however, at the clay and till sites, the water table dropped during the summer resulting in the upper part of the tire chip zone being above the water table for part of the year. At each site, a control well was installed upgradient of the trench, one well was installed directly in the tire chips filling the trench, and wells were installed about 0.6 m (2 ft) and 3 m (10 ft) downgradient of the trench. At the peat site, an additional two wells were installed 0.6 m (2 ft) downgradient of the trench.

Water samples taken from the small scale field trials showed that tire chips increased the levels of some metals with a primary drinking water standard but the concentrations were all below their applicable regulatory limits. Dissolved barium levels as high as 57 µg/L were measured in samples taken from the tire chip filled trenches, however, the drinking water standard for barium is 2000 µg/L, so the measured levels are much too low to be of concern. Dissolved chromium levels ranged from <2 to 7 µg/L in the tire chip filled trenches compared to <2 to 3 µg/L in the control wells. Thus, tire chips may slightly elevate the levels of chromium but the levels are well below the drinking water standard of 100 µg/L. The levels of dissolved arsenic, cadmium, and lead were below the method detection limit for all wells. The levels of dissolved copper were generally below the detection limit or the concentration was higher in the control well that in the well in the tire chips. In summary, for the near neutral pH conditions present in this study, there is no concern that tire chips will release harmful levels of metals with a primary drinking water standard.

The field trials showed that the levels of iron and manganese, which have secondary drinking water standards indicating that they are of aesthetic concern, were increased to levels considerably above their repsective standard. Levels of dissolved iron ranged from 4210 to 71700 µg/L in the tire chip filled trenches, which is well above its secondary drinking water standard of 300 µg/L. For comparison, the iron levels in the control wells ranged from 18 to 3160 µg/L. Levels of dissolved manganese ranged from 724 to 3430 µg/L in the tire chips compared to its drinking water standard of 50 µg/L and levels in the control wells of 27 to 666 µg/L. The elevated levels of manganese showed some tendency to migrate downgradient, however, this was not the case for iron. Thus, tire chips should be used below the groundwater table only where higher levels of iron and manganese can be tolerated. Zinc was also increased by tire chips, however, the levels were well below its secondary drinking water standard. Dissolved zinc levels in the tire chips ranged from 5 to 123 µg/L which is much less than its drinking water standard of 5000 µg/L. For comparison, the zinc levels in the control wells ranged from <2 to 9 µg/L. The levels of silver, aluminum, calcium, magnesium, and sodium were not significantly affected by the presence of the tire chips.

Low levels of some volatile organic compounds were detected. Dichloromethane was detected in all samples, including the control wells and blanks. Additional sampling will be performed to determine if this is a laboratory contamination problem. The following additional volatile compounds were detected in wells located in the tire chip filled trench: 1,1 dichloroethane (ND to 14.3 µg/L); cis-1,2-dichloroethane (6 to 85.5 µg/L); 1,1,1-trichloroethane (ND to 5.6 µg/L); benzene (ND to 1.8 µg/L); trichloroethene (ND to 0.6 µg/L); and toluene (ND to 1.8 µg/L). There is some consistency with the laboratory reactor study which also found low levels of 1,1-dichloroethane, cis-1,2-dichloroethane, benzene, and toluene. For compounds with a drinking water standard, the levels were below the standard except for one sampling date for cis-1,2-dichloroethene when the standard was slightly exceeded. A few other compounds were found in the laboratory blanks at concentrations higher than in the sample wells. These were attributed to laboratory contamination.

Semivolatile organic compounds were also detected at low levels in some wells. The following compounds were present in two or more samples: aniline (ND to 91 µg/L); phenol (ND to 55.2 µg/L); p-cresol (ND to 86 µg/L); benzoic acid (ND to 100 µg/L); and 2(3H)-benzothiazolone (ND to 100 µg/L). This is consistent with the laboratory reactor study which found aniline, benzoic acid, and 2(3H)-benzothiazolone as well as 4-acetylmorpholine which was not found in the field. However, further sampling is required to clarify the level of release of these compounds. In addition, the following compounds were reported in one well on a single sampling date: cyclohexanol (one sample had 40 µg/L); benzothiazole (one sample had 50 µg/L); 2,6-bis-(1,1-dimethylethyl)-2,5-cyclohexadiene-1,4-dione (one sample had 40 µg/L); 1H-isoindole-1,3(2H)-dione (one sample had 40 µg/L); 4-(2-benzothiazolylthio)-morpholine (one sample had 50 µg/L); N-(1,1-dimethylethyl)-formanide (one sample had 30 µg/L); and butanoic acid (one sample had 100 µg/L). Further sampling will be required to determine if these compounds are present in trace amounts or if their presence in a single sample is an experimental anomaly.

In summary, for near neutral pH environments, there is no concern that tire chips will release harmful levels of metals with a primary drinking water standard. However, tire chips placed below the water table do leach iron and manganese at levels that will cause their secondary (aesthetic) drinking water standards to be exceeded. Thus, tire chips should be used below the groundwater table only where higher levels of iron and manganese can be tolerated. Tire chips placed below the water table leach low levels of some volatile and semivolatile organic compounds. However, the short monitoring period and scatter of the data made it impossible to determine if the levels were high enough to constitute a potential health hazard. Monitoring of organic levels will be continued to clarify the presence or absence of a potential hazard.

ACKNOWLEDGMENTS

The authors thank the Maine Department of Transportation and the University of Maine Department of Civil and Environmental Engineering for their support of this research.

For analytical and laboratory support the authors thank the University of Maine Environmental Chemistry Laboratory and the Plant, Soil, and Environmental Sciences Laboratory. The authors give special thanks to Therese Anderson, Laboratory Manager of the Environmental Chemistry Laboratory. The University of Connecticut's Environmental Research Institute is thanked for performing most of the chemical analyses for organic compounds. The authors gratefully acknowledge the support and patience of Will Manion, Pam Oakes, Stephanie Dall, and Ellen Manzo throughout this research and preparation of this report. In addition, the authors thank the graduate and undergraduate students who assisted with the laboratory and field portions of this study.

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Approximately 240 million scrap tires are generated in the United States each year (EPA, 1991). The most common disposal methods for scrap tires are landfilling and placement in open piles. Recent estimates indicate that there are between two and three billion scrap tires in piles scattered about the United States (EPA, 1991). The world's largest known tire pile which consists of approximately 34 million tires is in Stanislaus County, California (McPhee, 1993).

Tires represent one percent of municipal solid waste. Landfill space is becoming increasingly limited and valuable and, due to their size and shape, tires use a disproportionate amount of space. They tend to trap landfill gases, and may come to the surface and penetrate the landfill cap after landfill closure. In addition, the value of the tire as fuel or a recycled material is lost. Each scrap passenger tire contains over two and a half gallons of petroleum (McPhee, 1993). Most landfills are now refusing to accept tires or will accept only shredded tires (Dennis, 1991).

Problems resulting from storage of scrap tires in open piles include degradation of the landscape, serious fire hazards, and health problems caused by mosquito vectored diseases. Fires are a major concern with tire piles since they can burn for days, weeks, or even months and are notoriously difficult to extinguish. Tire fires emit clouds of noxious black smoke, carbon black, gas, oil, polynuclear aromatic hydrocarbons (PAHs), sulfur oxides, nitrogen oxides, carbon monoxide, arsenic, cadmium, chromium, lead, zinc, dioxins, furans, polychlorinated biphenyls (PCBs), and benzene (McPhee, 1993; Takallou, 1992; SCS Engineers, 1989). These contaminants are released during burning to the air, water, and soil. Tire pile fires should not be fought with water because the oil released during a tire fire will be carried with the water and can become a threat to surface water and groundwater as well as a soil contaminant (McPhee, 1993; Takallou, 1992).

Another concern with tire storage in piles is disease. Tire piles are excellent habitats for many small vermin, such as rats, and scrap tires are ideal breeding grounds for mosquitoes. Due to their shape, scrap tires will hold water and will never dry out. Mosquito vectored diseases of concern include yellow fever, La Crosse virus, Sepik fever, Ross River fever, St. Loius enchephalitis, and Japanese encephalitis (McPhee, 1993; SCS Engineers, 1989). One Ohio study showed that 80 percent of the children suffering from one such mosquito vectored disease lived within 100 yards of a tire pile (Takallou, 1992).

Many of the problems created by storage of scrap tires in tire piles can be solved by recycling or reuse of scrap tires. Many uses for scrap tires have been suggested. Examples include use as tire derived fuel, processing into crumb rubber, use of whole tires in highway applications, and placement in ocean waters to make artificial reefs. Scrap tires that have been cut into 75 mm by 300 mm chips can serve as lightweight or insulating fill in roadways, embankments, and retaining walls. Tire chips offer an advantage in wet and swampy areas because they are much lighter than traditional fills, such as gravel, which can cause excessive settlement of underlying soils. In addition, tire chips are good thermal insulators which can reduce the depth of frost penetration beneath roads in cold climates.

More than 300,000 scrap tires have been used as tire chip fill in three small test projects in Maine roads (Humphrey and Nickels, 1994; Humphrey and Eaton, 1995). However, this application brings tire chips into direct contact with groundwater raising potential concerns of contamination. Water quality monitoring has been performed at two tire chip fill installations above the groundwater table: in Richmond, Maine (Humphrey and Katz, 1995a) and in North Yarmouth, Maine (Humphrey, et al., 1997). The focus of this research was to investigate the water quality effects of tire chips placed below the groundwater table.

1.2 SCOPE OF STUDY

The primary goal of this project was to evaluate the effect on water quality of tire chip fills placed below the groundwater table. This goal was met using three objectives. The first objective was to evaluate the long-term effects of using tire chips in construction applications below the groundwater table using small scale field trials. Since tire chips could be especially useful in applications below the groundwater table it was necessary to evaluate their effects on groundwater quality. The second objective was to simulate field conditions in the laboratory. This objective was met using a reactor study. The purpose of the reactor study was to allow direct comparison of the concentrations of contaminants contributed by tire chips to the concentration of contaminants present under control conditions using only soil. The third objective was to use the toxicity characteristic leaching procedure (TCLP) (EPA Method 1311) to determine potential contaminants from tire chips.

1.3 THESIS ORGANIZATION

This thesis is organized in seven chapters including the introduction. Chapter 2 is a review of previous research on the environmental effects of using tire chips in construction applications. In addition, Chapter 2 describes the chemical makeup of rubber tires. Chapter 2 is divided into sections on tire ingredients, laboratory studies, and field studies. Chapter 3 describes the methods used in this study. The sample collection, handling, and storage techniques are discussed, along with analytical methods used. The methods used for the laboratory leaching tests, laboratory simulation of ground conditions, and small scale field trials are presented. The results of the toxicity characteristic leaching procedure testing are presented in Chapter 4. The reactor study results are presented in Chapter 5. Chapter 6 presents the results of the small scale field trials. A summary of this research is presented in Chapter 7.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This literature review begins with a summary of the chemical composition of tires. This forms the basis for identifying compounds that could possibly leach from tires into the groundwater. Compounds found in water samples from subsequent laboratory and field testing portions of this project will be compared to the chemical makeup of tires to evaluate the possibility of tires being the source of the contaminants. Previous field and laboratory leaching studies on scrap tires and tire chips are summarized. The summary will be the basis for comparison of the results of previous studies to the results of this study. The three major studies summarized are the Minnesota Pollution Control Agency Study performed by Twin City Testing Corporation (1990), the Wisconsin Department of Transportation Study performed by Edil et al. (1990 and 1992), and the Scrap Tire Management Council Study performed by Radian Corporation (1989). Additional work includes the Virginia Department of Transportation Study by Ealding (1992) and the Illinois Department of Energy and Natural Resources Study by DTC Laboratories, Incorporated (1990). Also, data from the Tire Pond in Hamden, Connecticut (Environmental Consulting Laboratory, 1987) and toxicity studies by Abernethy (1994) and Nelson (1994) are discussed. These studies include laboratory leaching, field, biological, and toxicity components.

The levels of pollutants from scrap tires are compared to EP Toxicity regulatory limits, Toxicity Characteristic Leaching Procedure (TCLP) regulatory limits, and to drinking water standards. Tables 2.1 and 2.2 present TCLP regulatory limits for metals and organics. Tables 2.3a, 2.3b, and 2.4 present EPA drinking water standards for metals and organics. Maine's drinking water standards are the same as those used by EPA (State of Maine, 1994). Regulated pesticides and herbicides have been excluded from these tables because they are not a concern with scrap tire or tire chip leaching.

This chapter is organized in six sections. The introduction is followed by sections discussing tire ingredients, laboratory studies, field studies, and biological and toxicity studies. The final section of the chapter is an evaluation of previous studies.

Table 2.1

TCLP Regulatory Limits for Metals

(Adapted from LaGrega et al., 1994)

Compound	**Regulatory Level in TCLP Extract (mg/L)**
Arsenic	5.0
Barium	100.0
Cadmium	1.0
Chromium	5.0
Mercury	0.2
Lead	5.0
Selenium	1.0
Silver	5.0

Table 2.2

TCLP Regulatory Limits for Organics

(Adapted from LaGrega et al., 1994)

Compound	Regulatory Level in TCLP Extract (mg/L)
Benzene	0.5
Carbon Tetrachloride	0.5
Chlorobenzene	100.0
Chloroform	6.0
o-Cresol*	200.0
m-Cresol*	200.0
p-Cresol*	200.0
1,4-Dichlorobenzene	7.5
1,2-Dichloroethane	0.5
1,1-Dichloroethylene	0.7
2,4-Dinitrotoluene	0.13†
Hexachlorobenzene	0.13†
Hexachloro-1,3-butadiene	0.5
Hexachloroethane	3.0
Methyl Ethyl Ketone	200.0
Nitrobenzene	2.0
Pentachlorophenol	100.0
Pyridine	5.0†
Tetrachloroethylene	0.7
Trichloroethylene	0.5
2,4,5-Trichlorophenol	400.0
2,4,6-Trichlorophenol	2.0
Vinyl Chloride	0.2

Notes: * If o-, m-, and p-cresol concentrations cannot be differentiated, the total cresol concentration is used. The regulatory level for total cresol (D026) is 200 mg/L.

†Quantitation limit (i.e., the minimum concentration that current laboratory procedures can reproducibly measure).

Table 2.3a

Primary Drinking Water Standards for Metals

(Adapted from Fetter, 1992; Viessman and Hammer, 1985; and 40 CFR 141)

Compound	**Level (µg/L)**
Arsenic	50
Barium	2000
Cadmium	5
Chromium	100
Copper	1300
Lead	15
Mercury	2
Nickel	100
Selenium	50

Table 2.3b

Secondary Drinking Water Standards for Metals

(Adapted from Fetter, 1992; Viessman and Hammer, 1985; and 40 CFR 141)

Compound	**Level (µg/L)**
Aluminum	50-200
Iron	300
Silver	50
Manganese	50
Zinc	5000

Table 2.4

Drinking Water Standards for Organics

(Adapted from Fetter et al., 1992 and 40 CFR 141)

Compound	EPA Regulatory Level (µg/L)
Benzene	5
Carbon Tetrachloride	5
Dibromochloropropane	0.2
1,2-Dibromoethane	0.05
o-Dichlorobenzene	600
p-Dichlorobenzene	75
1,2-Dichloroethane	5
1,1-Dichloroethylene	7
cis-1,2-Dichloroethylene	70
trans-1,2-Dichloroethylene	100
Dichloromethane	5
1,2-Dichloropropane	5
Ethylbenzene	700
Hexachlorobenzene	1
Monochlorobenzene	100
Pentachlorophenol	1
Styrene	100
Tetrachloroethylene	5
Toluene	1000
1,2,4-Trichloro-benzene	70
1,1,1-Trichloroethane	200
1,1,2-Trichloro-ethane	5
Trichloroethylene	5
Vinyl Chloride	2
Xylenes (total)	10000

2.2 TIRE INGREDIENTS

Tires are a composite product made of rubbery components, chemicals, fillers, and cords. They are designed to meet the mobility requirements of vehicles: load carrying capability, vehicle control, vehicle handling, ride smoothness, traction, and durability. The tire components (tread or cap, innerliner, sidewall, carcass, and bead) are made up of individual compounds. A cross-section of a passenger tire is presented as Figure 2.1. Each component has a set of performance requirements. The production of the components requires the selection of elastomers, vulcanization chemicals, materials for processing and manufacturing, and materials for in-service performance (Waddell et al., 1990). Vulcanization is the process of chemically treating crude or synthetic rubber to improve its elasticity, strength, and durability.

Tires are made up of natural and/or synthetic rubbers; chemicals that function as antidegradants, curatives, and processing aids; reinforcing fillers such as carbon black, silica, or clay; and textile, fiberglass, or steel wire (usually brass or bronze coated) cords (Waddell et al., 1990). Steel tire cord and beadwire is made from high carbon steel which typically contains the following minor constituents: carbon, manganese, silicon, phosphorus, sulfur, and trace amounts of copper, chromium, and nickel (Dunlop Tire Corporation, 1990). Zinc, copper, and tin are often present as coating on the wire. The percentages of each of these components in tire cord and beadwire are listed in Table 2.5.

In a material safety data sheet (MSDS) for scrap tires (whole) the chemical name is given as rubber compound (mixture) containing natural and synthetic rubber that is physically/chemically bound with carbon black, clay, titanium dioxide, zinc oxide, sulfur, and petroleum hydrocarbons. A copy of the MSDS is included as Appendix A. The

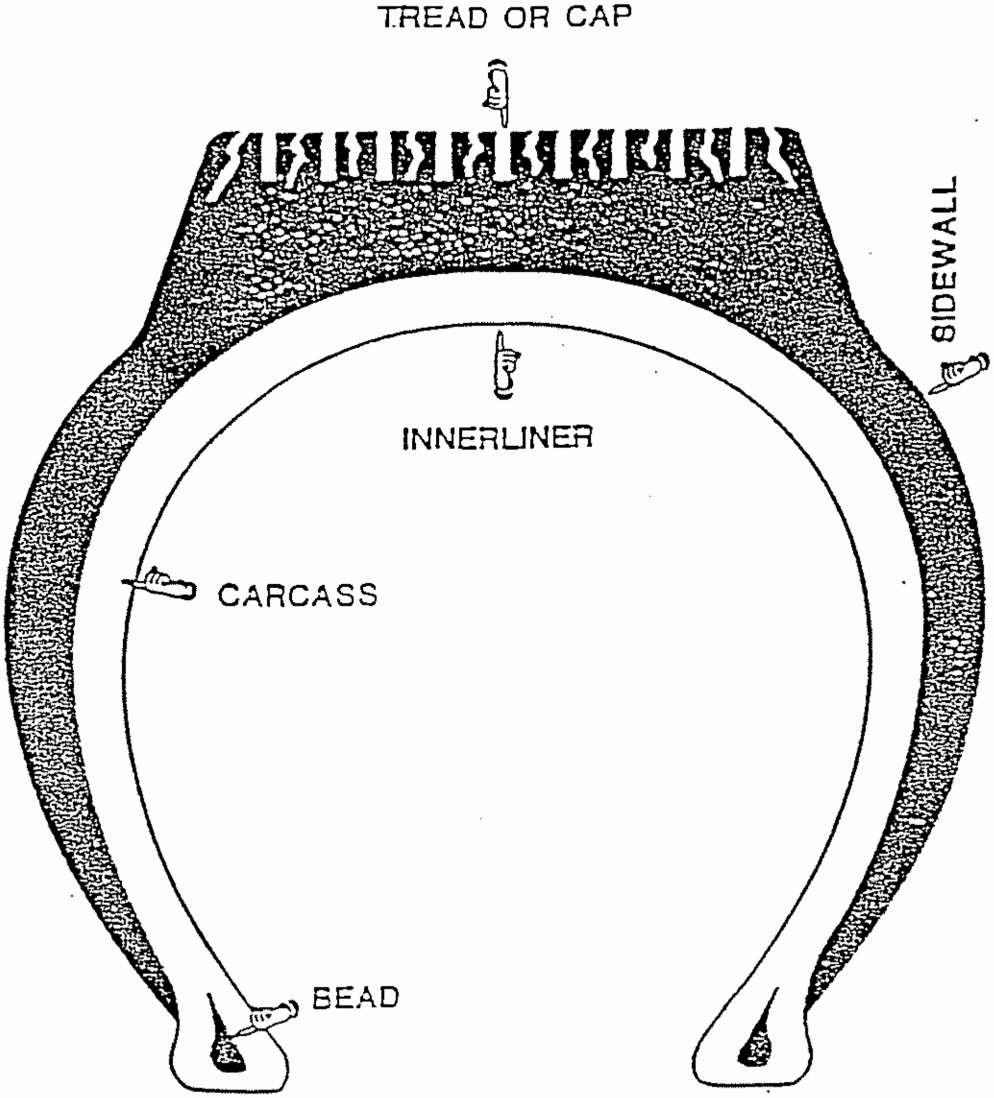


Figure 2.1
Cross Section of a Passenger Tire
(from Takallou, 1992)

Table 2.5
Steel Composition of Tire Cord and Beadwire
(Dunlop Tire Corporation, 1990)

Compound	**Tire Cord (%)**	**Beadwire (%)**
Carbon	0.67 - 0.73	0.60 min.
Manganese	0.40 - 0.70	0.40 - 0.70
Silicon	0.15 - 0.30	0.15 - 0.30
Phosphorus	0.03 max.	0.04 max.
Sulfur	0.03 max.	0.04 max.
Coating	**Brass**	**Bronze**
	66 % Copper	98 % Brass
	34 % Zinc	2 % Tin

hazardous ingredients and their percentages as listed on the MSDS are as follows: carbon black 16 - 36 %; clay <1.0 %; titanium dioxide <1.5 %; zinc oxide <2.0 %; sulfur <1.5 %, and petroleum hydrocarbons 5 - 13 %. All of these ingredients are listed with health hazard status of irritant, with the exception of petroleum hydrocarbons which are listed as irritants and carcinogens.

The classes of chemicals used in the rubber industry are presented in Table 2.6 and are discussed further in the following paragraphs. Examples of compounds in each of these classes are presented in Appendix B.

Antidegradants account for the largest volume of chemicals used in the rubber industry (Fishbein, 1991). Antidegradants include antioxidants and antiozonants. Antioxidants act by interrupting chemical chain reactions or by preventing free-radical function. Antidegradants protect the polymer during processing and protect the finished product from weathering. Accelerators are rubber additives that speed the vulcanization

Table 2.6

Classes of Chemicals Used in the Rubber Industry

(Adapted from Fishbein, 1991)

Antidegradants	Accelerators
Activators	Retarders
Processing Aids	Plasticizers
Bonding Agents	Reinforcing Agents, Fillers, Diluents
Miscellaneous Agents	Solvents

process by aiding the cross-linking of rubber polymer chains with sulfur. Activators are used to form intermediate complexes to make accelerators more effective. Retarders are used to prevent early vulcanization of the rubber during mixing, calendering, or other processing steps. Calendering is the process by which materials are pressed between rollers or plates into thin sheets. Plasticizers are used to reduce the viscosity of rubber, which aids in processing and incorporating fillers and other compounding ingredients. Processing aids are used to make cured rubber softer and more readily mixed, extended, or calendered. Reinforcing agents and fillers are used to improve tensile strength, to improve abrasion resistance, and to reduce costs. Bonding agents are used to bond rubber to the steel or textile used in the construction of tires. A wide variety of organic solvents are used in rubber compounding and processing. The miscellaneous agents group includes flame retardants, emulsifiers, mould release agents, and colourants (Fishbein, 1991).

Because many of the chemicals used in tire manufacturing are potentially hazardous, one of the concerns with scrap tire disposal is the potential leaching of these compounds. As a result a number of leaching studies have been performed.

2.3 LABORATORY LEACHING STUDIES

2.3.1 Minnesota Pollution Control Agency Study

Twin City Testing Corporation (TCT) conducted a study for the Waste Tire Management Unit of the Minnesota Pollution Control Agency (Minnesota Pollution Control Agency, 1990). This study emphasized laboratory leaching tests. The project also included limited field studies and biological surveys that will be discussed later in Sections 2.4.1 and 2.5.1.

Tire materials and a typical bituminous concrete sample were subjected to a variety of rigorous leaching environments. The purpose of the bituminous concrete sample was to allow comparison of scrap tire leachability to leachability of a common road construction material. To prepare samples, seven old tires (15 to 20 years old) and seven new tires (5 to 10 years old) were collected from a tire dump. The old and new tire samples contained both steel and glass belted tires. Separate composite samples of old and new tires were prepared as follows: two inch cross-sections were cut from each tire, then each cross-section was cut into four pieces. One piece was put into each of four composite samples, resulting in four composite samples of old tires and four composite samples of new tires with seven tire pieces in each sample. The bituminous concrete sample was provided by TCT's Construction Materials Department. Four leaching conditions were used for both the bituminous sample and the tire samples (Minnesota Pollution Control Agency, 1990):

- Leach Test #1

  SW-846 Method 1310 (with modification of sample weight and extraction fluid); extraction fluid pH adjusted to approximately 3.5 with acetic acid

- Leach Test #2

  SW-846 Method 1310 (with modification of sample weight); extraction fluid pH maintained at approximately 5 with acetic acid

- Leach Test #3

  Similar technique as above but uses 0.9% sodium chloride solution for extraction fluid; no pH adjustment attempted

- Leach Test #4

  Used a mixture of ammonium hydroxide and ammonium acetate for extraction fluid to maintain a pH of 8.0; no pH adjustment required.

Each leaching condition was used for three samples: new tires composite, old tires composite, and asphalt. The concentrations of 15 metals in the leachate were measured: aluminum, arsenic, barium, calcium, cadmium, chromium, iron, magnesium, mercury, lead, selenium, silver, sulfur, tin, and zinc. In addition, the concentrations of total petroleum hydrocarbons and polynuclear aromatic hydrocarbons (PAHs) were measured. A summary of the results is presented below with detailed results presented in Appendix C.

The results of the metals analysis generally indicated that metals are leached at higher concentrations under low pH conditions (Minnesota Pollution Control Agency, 1990). A summary of the normalized results for barium, cadmium, chromium, iron, lead, selenium, and zinc is given in Tables 2.7 through 2.10. The results were "normalized" to allow direct comparison of the results for each leaching condition for each sample and are expressed in milligrams of constituent of concern per kilogram of tire or parts per million (ppm). In this study, the highest metals concentrations were found at pH 3.5 (Leach Test #1). This behavior is expected for cationic metals, since they tend to sorb to solid material at high pHs. Generally, asphalt samples leached higher concentrations of metals than did scrap tires under all leaching conditions. For some samples and some leaching conditions,

Table 2.7
Minnesota Pollution Control Agency Study
Leach Test #1
pH 3.5
"Normalized" Metals Results
Units: micrograms constituent per kilogram of tire (µg/Kg) and micrograms constituent per liter of leachate (µg/L)

	Ba µg/Kg µg/L	Cd µg/Kg µg/L	Cr µg/Kg µg/L	Fe µg/Kg µg/L	Pb µg/Kg µg/L	Se µg/Kg µg/L	Zn µg/Kg µg/L
New Tires	1080 488	240 110	310 142	763400 346000	920 417	230 106	41000 18600
Old Tires	440 205	270 125	510 235	1081080 500000	ND <47	440 203	50000 23500
Asphalt	16600 734	ND <3	180 8	471510 20850	ND <47	2370 105	3000 135

Note: ND = non-detect

Table 2.8
Minnesota Pollution Control Agency Study
Leach Test #2
pH 5.0
"Normalized" Metals Results

Units: micrograms constituent per kilogram of tire (µg/Kg) and micrograms constituent per liter of leachate (µg/L)

	Ba µg/Kg µg/L	Cd µg/Kg µg/L	Cr µg/Kg µg/L	Fe µg/Kg µg/L	Pb µg/Kg µg/L	Se µg/Kg µg/L	Zn µg/Kg µg/L
New Tires	440	10	ND	87550	ND	ND	18000
	205	7	2	41200	<51	<54	8525
Old Tires	130	ND	ND	49520	ND	ND	37000
	62	<6	<2	23300	<51	<54	17500
Asphalt	6880	ND	ND	31800	ND	ND	1000
	344	<6	<2	1590	<51	<54	63

Note: ND = non-detect

Table 2.9

Minnesota Pollution Control Agency Study

Leach Test #3

pH 7.0

0.9% Sodium Chloride Solution

"Normalized" Metals Results

Units: micrograms constituent per kilogram of tire (µg/Kg) and micrograms constituent per liter of leachate (µg/L)

	Ba **µg/Kg** **µg/L**	**Cd** **µg/Kg** **µg/L**	**Cr** **µg/Kg** **µg/L**	**Fe** **µg/Kg** **µg/L**	**Pb** **µg/Kg** **µg/L**	**Se** **µg/Kg** **µg/L**	**Zn** **µg/Kg** **µg/L**
New Tires	190 48	ND 1950	ND <5	320 80	ND <38	ND <45	3000 824
Old Tires	700 174	ND <5	ND <5	2120 531	ND <38	ND <45	13000 3380
Asphalt	760 38	ND <5	ND <5	400 20	ND <38	ND <45	<1000 24

Note: ND = *non-detect*

Table 2.10
Minnesota Pollution Control Agency Study
Leach Test #4
pH 8.0
"Normalized" Metals Results
Units: micrograms constituent per kilogram of tire (μg/Kg) and micrograms constituent per liter of leachate (μg/L)

	Ba μg/Kg μg/L	Cd μg/Kg μg/L	Cr μg/Kg μg/L	Fe μg/Kg μg/L	Pb μg/Kg μg/L	Se μg/Kg μg/L	Zn μg/Kg μg/L
New Tires	1.06	ND	ND	0.10	ND	ND	NVR
	265	<5	<2	25	<39	<28	<5
Old Tires	0.43	ND	ND	2.87	ND	ND	NVR
	107	<5	<2	718	<39	<28	<5
Asphalt	7.88	ND	ND	0.32	ND	ND	NVR
	394	<5	<2	16	<39	<28	<5

Note: ND = non-detect
NVR = no value reported

arsenic, cadmium, chromium, selenium, and zinc exceeded the Recommended Allowable Limits (RALs) set by the Minnesota Department of Health for drinking water. The highest level of lead was 417 μg/L (Minnesota RAL=20 μg/L), the highest level of cadmium was 125 μg/L (Minnesota RAL=5 μg/L), the highest level of chromium was 235 μg/L (Minnesota RAL=120 μg/L), the highest level of selenium was 203 μg/L (Minnesota RAL=45 μg/L), and the highest level of zinc was 23,500 μg/L (Minnesota RAL=5000 μg/L). Some of the Minnesota RALs are different from the EPA drinking water standards which are: lead 15 μg/L, cadmium 5 μg/L, chromium 100 μg/L, selenium 50 μg/L, and zinc 5000 μg/L. Iron was leached at levels above the secondary maximum contaminant level (SMCL) for all leachate samples, with the highest levels leached at pH 3.5 and the concentration decreasing with increasing pH. The highest level of iron in the tire leachate samples was 500 mg/L (SMCL=0.03 mg/L). The study stated that concerns with iron may be more aesthetic than health related because the drinking water standard for iron is a secondary maximum contaminant level which is based on aesthetics. None of the laboratory leachate samples exceeded the EP Toxicity criteria or the TCLP criteria (see Tables 2.1 and 2.2).

Based on the results of the inorganics analysis, TCT concluded that future monitoring of scrap tires should include analysis for barium, cadmium, chromium, lead, selenium, and zinc. The detection limits for future monitoring of the parameters should be below the RALs for each compound.

The results of the analysis for organics indicate that total petroleum hydrocarbons (TPH) and polynuclear aromatic hydrocarbons (PAHs) are leached at highest concentrations under basic conditions (Leach Test #4, pH = 8.0) (Minnesota Pollution Control Agency, 1990). Asphalt samples leached similar or higher levels than scrap tires under all conditions. The RALs generally were exceeded for List 1 PAHs (carcinogenic) and List 2 PAHs (noncarcinogenic) under all conditions for both tire composite samples and asphalt samples. Based on the results of the organics analysis, TCT concluded that future monitoring of scrap tire sites should include analysis for List 1 and List 2 PAHs.

TCT recommended that use of scrap tires in roadway construction be limited to the unsaturated zone. In addition, the roadway design should limit infiltration of water through the scrap tires and should promote surface water drainage away from the scrap tire subgrade (Minnesota Pollution Control Agency, 1990). Moreover, TCT recommended that scrap tires only be used where pH extremes are not expected, and that additional field studies be performed to evaluate new or existing roadways with tire installations (Minnesota Pollution Control Agency, 1990).

2.3.2 Wisconsin Department of Transportation Study

The University of Wisconsin - Madison performed a study for the Wisconsin Department of Transportation (Edil et al., 1992). The Wisconsin study consisted of two parts: a laboratory leaching study and a field study involving a test embankment. The laboratory leaching tests used a neutral leach (pH 7). The test embankment had lysimeters installed for sampling. The goal of this study was to determine if shredded scrap tires would be classified as hazardous waste. The laboratory portion of this study is discussed below while the field portion is discussed in Section 2.4.2.

To evaluate potential environmental problems, duplicate AFS (American Foundrymen's Society) leaching (neutral leach) (Kunes, 1975; Ham et al., 1978) and EP Toxicity tests were performed on tire chip samples. The resulting data is presented in Appendix D. The shredded tires appeared to leach no base-neutral regulated organics. Most substances that were detected, showed declining concentrations with continued leaching (Edil et al., 1990). However, barium, iron, manganese, and zinc showed increasing concentrations with continued leaching. The AFS leaching data for barium, chromium, iron, manganese, lead, selenium, and zinc are summarized in Table 2.11. Barium was present in the extraction fluid at constant or slightly increasing concentrations (3 AFS elutions were used) of approximately 110 μg/L. Zinc and manganese levels in the extraction fluid increased with continued leaching with the highest levels (630 μg/L and 300 μg/L, respectively) in the third elution. The highest level of iron found (230 μg/L) was also in the third elution. In contrast, the highest level of lead found (15 μg/L) was during the first elution. The highest concentrations of iron and manganese were at or above their applicable drinking water standards while the highest concentrations of barium and zinc were well below their applicable drinking water standards.

Based on the AFS leaching results, Edil et al. (1990) concluded that shredded automobile tire samples show no likelihood of being a hazardous waste. In addition, it was concluded that scrap tires leached very small amounts of substances compared to other wastes and that shredded scrap tires have little or no likelihood of having effects on groundwater.

2.3.3 Scrap Tire Management Council Study

The Radian Corporation (Radian) was contracted by the Rubber Manufacturers Association (RMA) and a subsidiary group, the Scrap Tire Management Council, to assess the levels of TCLP pollutants that are leached from representative cured and uncured products manufactured by RMA members (Radian, 1989). RMA was interested in the extent to which rubber products leach hazardous constituents when placed in landfills. Seven products from tire manufacturers were tested: one truck tire, two light truck tires, and four passenger car tires. Radian also performed a comparison of the results of the

Table 2.11
Wisconsin Department of Transportation Study
Summary of AFS Leaching Results (Metals)
Units: micrograms constituent per liter of leachate (µg/L)

	Ba	Cr	Fe	Mn	Pb	Se	Zn
AFS Elution 1	110	<3	<50	84	15	<5	38
AFS Elution 2	110	<3	<50	89	3	<5	54
AFS Elution 3	110	<3	230	300	<3	<5	360
AFS Dup Elution 1	97	<3	50	82	14	<5	40
AFS Dup Elution 2	97	<3	<50	87	<3	<5	22
AFS Dup Elution 3	120	<3	160	250	<3	<5	630

Note: Dup = duplicate

TCLP analyses to the results of EP Toxicity testing. In this study ground and unground samples were tested. To produce ground samples, the size of the particles were reduced to pass the 9.5-mm (0.375-in.) sieve. The particle size of the unground samples was not given. As required by TCLP testing methods, the samples used in TCLP testing had the particle size reduced to passing the 9.5 mm (0.375-in.) sieve. The samples used for TCLP testing were cured samples (actual tires). The data from this study is presented in Appendix E. Summaries of the TCLP metals and organics results for the seven tire products are included as Tables 2.12 and 2.13, respectively. TCLP regulatory limits were not exceeded by any compound. Most compounds were found at trace levels ranging from ten to 100 times lower than the TCLP regulatory limits. Many TCLP listed chemicals were not detected in cured or uncured samples. The data showed no consistent differences in the levels leached by cured or uncured samples using TCLP extraction procedure or EP Toxicity extraction procedure (Radian, 1989). The comparison of ground to unground samples was made for metals and semivolatile organics. Radian (1989) concluded that the differences in results for ground versus unground samples could

Table 2.12
Scrap Tire Management Council Study
Summary of TCLP Metals Results
Units: μg/L (ppb)

	As	Ba	Cd	Cr	Hg	Pb	Se
Tire Product 1	*	83	*	48	0.2	*	*
Tire Product 2	*	65	*	26	*	16	*
Tire Product 3	*	150	*	12	*	9	*
Tire Product 4	*	*	*	35	*	14	*
Tire Product 5	*	570	*	37	0.4	2	*
Tire Product 6	*	590	*	25	*	2	*
Tire Product 7	*	21	*	47	*	16	*

Note: * = not detected or detected below the method detection limit

Table 2.13
Scrap Tire Management Council Study
Summary of TCLP Organics Results
Units: μg/L (ppb)

	Carbon Disulfide	Methyl Ethyl Ketone	Toluene	Phenol
Tire Product 1	34	*	11	13
Tire Product 2	35	*	7	10
Tire Product 3	67	21	50	*
Tire Product 4	17	*	10	22
Tire Product 5	*	*	190	46
Tire Product 6	*	*	*	45
Tire Product 7	*	*	20	*

Note: * = not detected or detected below the method detection limit be attributed to differences in sample consistency or analysis methods rather than the ground versus unground leaching approach. The cured samples were tire product samples that were already processed to make them ready for use. In this case the rubber was vulcanized, which is the process of treating rubber chemically to give it useful properties such as elasticity, strength, and durability. Compounds that were found at levels below the TCLP regulatory limits for tire products include: carbon disulfide, methyl ethyl ketone, phenol, toluene, 1,1,1-trichloroethane, arsenic, barium, chromium, lead, mercury, and selenium. Chromium was the only compound found in all the tire products tested, however even the highest level (48 µg/L) was well below the TCLP limit (5000 µg/L). Barium and lead were found in six of the seven tire products tested, with the highest levels being 590 µg/L and 15 µg/L, respectively. Mercury was detected in only two of the tire products samples at 0.2 µg/L and 0.4 µg/L. The highest level of carbon disulfide was 67 µg/L: carbon disulfide was detected in four of the seven samples. Methyl ethyl ketone was detected in one tire product sample at 21 µg/L. Phenol was found in five of the seven samples tested with the highest concentration being 46 µg/L. The highest level of toluene measured was 190 µg/L: toluene was detected in six of the seven tire products samples.

2.3.4 Virginia Department of Transportation Final Report on Leachable Metals in Scrap Tires

The Virginia Department of Transportation (VDOT) Materials Division performed a long term study of the leachable metals in scrap tires (Ealding, 1992). The study consisted of two parts: long-term leaching at pHs 4, 7, and 8 and TCLP testing. For the pH 4 extraction, deionized water was used with the addition of acetic acid to maintain the pH between 4 and 5. The pH 7 extraction used a 0.9% sodium chloride solution to mimic the use of road salt. The pH 8 extraction used a 1% ammonium acetate solution adjusted to pH 8 by addition of ammonium hydroxide (Ealding, 1992). Samples were collected from the long term leaching study over the time interval from one hour to one year.

Samples were analyzed for 16 elements: aluminum, arsenic, barium, cadmium, calcium, chromium, copper, iron, lead, magnesium, mercury, nickel, selenium, silver, tin, and zinc. The data from this study is presented in Appendix F.

Metals leached most readily at pH 4, which is consistent with previously published findings (Minnesota Pollution Control Agency, 1990; Ealding, 1992). This data also follows the expected behavior of cationic metals: sorption to the solid phase at high pHs. A summary of the long term leaching test results for pH 4 is presented in Tables 2.14 and 2.15. The metal found at the highest concentration in the extract was iron. Iron reached a saturation concentration of about 30,000 mg/L within two weeks. Zinc was readily leached at pH 4. The zinc concentration reached 150 µg/L after two months. This corresponds to a concentration of 120 µg/L in the porewater volume at scrap tire subgrade (Ealding, 1992). The porewater volume is the volume of water that fills the spaces that remain between the tire chips when the tires are placed as a fill. The Secondary Maximum Contaminant Level (SMCL) for zinc is 5 mg/L. Other metals leached less, resulting in lower concentrations, especially at higher pHs (7 and 8) (Ealding, 1992).

A great deal of carbon black was extracted at higher pH, especially pH 8. In addition some oily material was extracted. This is consistent with the findings of Twin City Testing (1990) that organics are more readily extracted under basic conditions (Minnesota Pollution Control Agency, 1990). Also, some gas generation was observed after two weeks of leaching at pH 4. The gas production may have been due to bacterial activity (Ealding, 1992).

TCLP testing followed EPA Method 1311, with modification: the sample particle size was not reduced to passing the 3/8 inch sieve and a larger mass of tire sample was

Table 2.14
Virginia Department of Transportation Study
Long Term Leaching Test Results for Silver, Aluminum, Barium, Cadmium, and Chromium at pH 4

	Ag	Al	Ba	Cd	Cr
Time	µg/L	µg/L	µg/L	µg/L	µg/L
1 hr	2.3	185	87	1.9	6.3
2 hr	2	321	78	2.6	<4.0
1 day	1.5	23	25	3.5	7.0
2 days	ND	ND	ND	ND	ND
1 week	2.5	746	422	3.5	<4.0
2 weeks	ND	ND	ND	ND	ND
1 month	3.2	177	1262	<1.2	82.4
2 months	ND	ND	ND	ND	ND
6 months	5.2	<24	2083	<1.2	12.6
1 year	10	491	1537	2.1	152

Note: ND = Not Determined

Table 2.15
Virginia Department of Transportation Study
Long Term Leaching Test Results for Copper, Iron, Nickel, Lead, and Zinc at pH 4

	Cu	Fe	Ni	Pb	Zn
Time	µg/L	mg/L	µg/L	µg/L	mg/L
1 hour	109	5.3	<20	<20	13.2
2 hours	188	8.5	<20	<20	18.6
1 day	192	96.1	48.1	<20	25.2
2 days	ND	184.5	ND	ND	15.1
1 week	328	13992	2116	49.2	102.1
2 weeks	ND	31622	ND	ND	112.0
1 month	13	30668	2460	<30	127.4
2 months	ND	30314	ND	ND	153.7
6 months	<12	31344	647	<30	62.5
1 year	159	18788	928	138	124.7

Note: ND = Not Determined

used as particle size reduction was felt impractical in this case. The actual size of the tire chips used was not stated. The resulting volume extraction ratio was 2.84 (rather than the twentyfold ratio specified by the method). This results in a leachate that is approximately seven times more concentrated than usual TCLP extracts. However, the stronger leach may be wholly or partially offset by the use of larger particles than the method calls for. The results of this modified TCLP metals testing are presented in Table 2.16. The concentrations of metals in the leachate are well below the TCLP regulatory limits. The concentrations of cadmium, chromium, and lead in the extract were 1.55 μg/L, 2.8 μg/L, and 19.6 μg/L, respectively. The levels of iron and zinc were 120 mg/L and 10.6 mg/L respectively. These levels of iron, lead, and zinc exceed the drinking water standards for these parameters.

2.3.5 Illinois Department of Energy and Natural Resources Study

In the Illinois Department of Energy and Natural Resources Study, shredded tires were subjected to EP Toxicity testing by DTC Laboratories Inc. (Hutchings, 1990; DTC Laboratories, Inc., 1990). The resulting data is presented in Appendix G. Metals levels were reported as EP TOX and total. Levels of the organic compounds analyzed were below the detection limits in all cases. None of the metals were above the EP TOX limits for the EP TOX tests. However, total metals were also measured, which is not part of the EP Toxicity test. Lead and chromium had total values of 36.55 ppm and 50.79 ppm, which are above the EP TOX limit. No meaningful conclusions could be drawn from the Illinois data (Hutchings, 1990).

Table 2.16

Virginia Department of Transportation Study

TCLP Metals Results

Element	Conc. in extract, µg/L	Conc. in tires, µg/Kg
Ag	<1.0	<2.8
Al	148	420
Cd	1.55	4.4
Cr	2.8	7.9
Cu	83	235
Ni	39.7	113
Pb	19.6	55.6
Sn	<25	<71
	Conc. in Extract, mg/L	**Conc. in tires, mg/Kg**
Ca	1.00	2.84
Fe	120	341
Mg	0.108	0.307
Zn	10.6	30

2.4 FIELD STUDIES

2.4.1 Minnesota Pollution Control Agency Study

The goal of the field sampling program was to collect soil and groundwater samples at existing tire sites and analyze them for parameters identified in the laboratory leaching portion of the study (Minnesota Pollution Control Agency, 1990). Two sites were selected where roadways were constructed over wetland areas using scrap tires. In addition, surface soil samples were collected at existing tire stockpiles.

Soil and groundwater samples were collected at both roadway sites. However, a background groundwater sample to serve as a control could be collected at only one of the roadway sites. Surface soil samples were taken at two existing tire piles where surficial soils were silty sands. The borings were done using a four inch flight auger. The soil samples were collected from auger flights. The groundwater samples were collected from the open boreholes. One groundwater sample was collected from each borehole, then the boring was backfilled with native material.

The data from this study is presented as Appendix C. The data from groundwater sampling is summarized in Table 2.17. The results of the field studies indicated that barium, cadmium, chromium, and lead exceeded the RALs in the groundwater sample collected at the Floodwood Road site (a background sample was collected in which none of the RALs were exceeded). In addition, the samples at the Pine County Site exceeded the RALs for List 1 carcinogenic and List 2 non-carcinogenic PAHs. This data indicated that scrap tires may impact groundwater quality. Based on these results, TCT concluded that additional field studies should be conducted and should include installation of groundwater monitoring wells, with samples repeatedly collected and analyzed for barium, cadmium, chromium, and lead.

Table 2.17

Minnesota Pollution Control Agency Study

Groundwater Sampling Results

Units: mg/L, ppm

	Al	**Ba**	**Ca**	**Cd**	**Cr**	**Fe**	**Mg**	**Pb**
PC-Tire	1.8	<0.01	14.4	<0.003	<0.01	4.4	2.8	<0.02
FL-Tire	180	1.93	1080	0.032	0.35	298	383	0.23
FL-Back	4.3	0.04	36.6	<0.003	<0.01	5.8	6.2	<0.02
RAL	NA	1.5	NA	0.005	0.120	0.3	NA	0.020

Note: PC-Tire = Pine County Road Site sample taken from tire area
FL-Tire = Floodwood Road Site sample taken from tire area
FL-Back = Floodwood Road Site background area
RAL = Recommended Allowable Limit
NA = Not Applicable

2.4.2 Wisconsin Department of Transportation Study

The field study involved collecting samples from a test embankment that was constructed with eight tire-chip-filled-cells, each 6.1 m (20 ft) long. The embankment was 11 m (36 ft) wide at the base, 3.6 m (12 ft) wide at the crest, and had a total thickness of 1.8 m (6 ft). The two lysimeters for sample collection were installed in Sections 2 and 5. The fill material in the two sections were 1.5 m (5 ft) of tire chips topped with a 0.30-m (12-in.) thick conventional soil cap. The tire chips used in Section 2 were from a different source than the tire chips used in Section 5. This study had no control section for sampling an area with no tire chips. Over approximately two years, samples were collected from the two lysimeters ten times. The data from this study is presented in Appendix D.

Many observations were made based on the data from the field study. The interpretation of the data was complicated by several factors: paving of the embankment with asphalt during the study, calcium chloride treatment of the embankment for dust control, suspected improper sampling techniques, flooding of one of the lysimeters by surface water, the base course material may have been treated with salt to prevent freezing, and the embankment and an upstream landfill were treated with fertilizer to help them support vegetation. Many elements that were observed in the lysimeter samples can be leached from soil as well as from tire chips. Unfortunately there was no control section (without tire chips) with a lysimeter to evaluate the contribution of the soils to the concentrations of the contaminants present.

Cationic and anionic compound parameters were observed at high levels. For example, calcium was present at 100 to over 300 mg/L in all samples, magnesium was present at 100 to nearly 400 mg/L in all samples, chloride concentrations were as high as 1400 mg/L, and sulfate concentrations ranged from 100 to 450 mg/L. It is difficult to separate the contribution to these levels by tire chips, soil, or other sources, leading Edil et al. (1992) to conclude that leaching of tire chips may be heavily masked or overwhelmed by leaching of other materials used in the embankment construction. The data for both lysimeters for barium, iron, manganese, lead and zinc are presented as Tables 2.18 and 2.19. Edil et al. (1992) felt that the data indicated that there is little or no likelihood of significant leaching of tire chips for substances that are of specific public health concern such as lead or barium. The lead levels in the samples from the East Lysimeter equaled or exceeded the EPA primary drinking water standard of 15 μg/L for two sampling events. In addition, leaching potential for manganese and zinc was indicated, but no expected levels were given. The highest level of manganese found in the lysimeter samples was 3200 μg/L, while the highest level of zinc observed was 750 μg/L. The secondary drinking water standards for manganese and zinc are 50 μg/L and 5000 μg/L, respectively.

Table 2.18

Wisconsin Department of Transportation Study

Test Embankment - West Lysimeter

	Ba	**Fe**	**Mn**	**Pb**	**Zn**
Date	ppb	ppm	ppb	ppb	ppb
4/11/90	240	0.05	170	<3	19
5/9/90	240	<0.05	200	<3	12
6/6/90	230	0.24	220	<3	17
7/5/90	210	0.57	350	<3	ND
8/3/90	360	0.26	2500	<3	780
9/4/90	470	4	2100	<3	830
12/14/90	690	0.25	1900	<3	1100
3/28/90	430	0.96	1200	5	1500
10/10/90	430	0.13	45	<3	1500
6/1/90	160	0.56	2600	<3	2100

Note: ND = non-detect

Table 2.19

Wisconsin Department of Transportation Study

Test Embankment - East Lysimeter

	Ba	**Fe**	**Mn**	**Pb**	**Zn**
Date	ppb	ppm	ppb	ppb	ppb
4/11/90	220	1.3	230	9	84
5/9/90	210	<0.05	270	<3	46
6/6/90	240	0.12	300	5	44
7/5/90	190	0.54	1200	4	540
8/3/90	270	5.3	1700	15	560
9/4/90	310	0.36	2300	6	120
12/14/90	NVR	NVR	NVR	NVR	NVR
3/28/90	350	0.7	3200	22	560
10/10/90	190	0.15	3200	<3	84
6/1/90	570	1.6	1300	<3	33

Note: NVR = no value reported

Manganese and zinc may also leach from soil. By comparing the tire leach data with the lysimeter data Edil et al. (1992) concluded that the high concentrations of cationic and anionic compound constituents are probably due to another source. The leach test data indicated that tire chips may have contributed organic compounds to the lysimeter samples, but are not likely to be responsible for the constant presence of the levels of BOD and COD observed (Edil et al., 1992).

2.4.3 The Tire Pond

The Tire Pond is operated by Hamden Tire Salvage in Hamden, Connecticut for the disposal of whole tires. The tire pond is a 32 acre body of water that was previously a quarry. About fifteen million tires have been added to the Pond which is now half full (McPhee, 1993). Although the problems of mosquitoes and other vermin and fire hazards are eliminated, the tire pond has become a controversial scrap tire disposal alternative because the tires and the energy that they represent are permanently lost (McPhee, 1993). The State of Connecticut has required testing of the surface water in the tire pond and testing of the groundwater. Tire Pond sampling data is presented as Appendix H. This data is also included in the State of Vermont Department of Environmental Conservation's Report on the Use of Shredded Scrap Tires in On-Site Sewage Disposal Systems (Envirologic, 1990). The samples collected were tested for metals, pesticides, herbicides, volatile organics, inorganics, and PCBs by Environmental Consulting Laboratory, New Haven, Connecticut (1987). The results of the chemical analyses showed that most compounds tested were below detection limits. Compounds that were detected but were below regulatory limits (where applicable) include: ammonia-N, nitrate-N, nitrite-N, sulfate, nickel, zinc, trans-1,2-dichloroethylene, 1,2-dichloropropane, trichloroethylene, tetrachloroethylene, toluene, mixed xylenes, and benzene. A summary of the highest levels of the organic compounds found is presented in Table 2.20. Iron was the only compound found in concentrations that exceeded drinking water standards. Table 2.21 presents a summary of the iron, nickel, and zinc data for five sampling events for the tire pond surface water and three groundwater wells adjacent to the tire pond. This data indicates that scrap tires may affect surface water and/or groundwater.

Table 2.20

Tire Pond

Summary of the Highest Levels of Organics Found

Units: ppb

Compound	**Level, ppb**	**Location**
Trichloroethylene	343	Groundwater
Toluene	18	Pond Water
Mixed Xylenes	36	Pond Water
Tetrachloroethylene	9	Groundwater
Benzene	below MDL	Groundwater
trans-1,2-dichloroethylene	51	Groundwater
1,2-dichloropropane	2	Groundwater

Table 2.21

Tire Pond Metals Data

Units: ppm

	GW 1	GW 2	GW 3	Pond
Sampling 1				
Fe	0.14	2.04	32.73	0.26
Ni	0.010	0.009	<0.005	<0.005
Zn	0.27	0.04	0.10	0.03
Sampling 2				
Fe	<0.05	5.32	29.26	0.38
Ni	<0.005	<0.005	<0.005	<0.005
Zn	0.04	<0.02	0.03	<0.02
Sampling 3				
Fe	1.60	11.8	55.2	0.195
Ni	<0.005	0.155	<0.005	<0.005
Zn	0.062	0.102	0.024	0.020
Sampling 4				
Fe	0.197	22.0	16.8	0.052
Ni	<0.040	0.673	<0.040	<0.040
Zn	0.038	2.88	0.022	<0.020
Sampling 5				
Fe	19.14	<0.05	0.38	1.83
Ni	<0.005	<0.005	<0.005	<0.005
Zn	0.04	<0.02	0.03	<0.02

Note: GW = groundwater sampling well
Pond = surface water sample from the tire pond

2.5 BIOLOGICAL AND TOXICITY STUDIES

2.5.1 Minnesota Pollution Control Agency Biological Surveys

The Minnesota Pollution Control Agency Study (1990) biological surveys were intended to serve as a qualitative indicator of environmental impacts from the use of scrap tires at existing sites. Two study areas with scrap tire fill were chosen: a minimum maintenance road and a gravel road. At the minimum maintenance road site, a general vegetation survey was conducted by lowering a pick and recording the first vegetation type encountered at twenty-nine randomly placed points. The breakdown of the vegetation encountered was: 52% grasses, 21% forbs, and 27% litter (Minnesota Pollution Control Agency, 1990). TCT felt that an acceptable control area could not be found at this site because of variation in the vegetation at the sample site. However, another tire area along the same road was visually inspected and no major differences between tire areas and non-tire areas were observed at the second site.

At the gravel road site a similar general vegetation survey was conducted. For a total of forty randomly placed points at the scrap tire area the vegetation composition was 60% grasses, 15% forbs, 2% shrubs, and 8% litter. For a total of twenty-four points randomly placed at the control area, the vegetation composition was 67% grasses, 8% forbs, 4% shrubs, and 21% litter. Differences in the overall vegetation composition at this site were not observed (Minnesota Pollution Control Agency, 1990).

The results of the biological survey indicated no observable difference in either of the study areas when compared to the control areas. Based on these results, TCT concluded that future biological surveys would likely indicate no observable differences at tire sites when compared to background sites (Minnesota Pollution Control Agency, 1990).

2.5.2 Tire Water Toxicity

In a study by Abernethy (1994), tire contaminated water caused 100% mortality in Oncorhynchus mykiss (rainbow trout) fry in static acute lethality tests usually within 48 hours. Three other species were tested but showed no lethality: Daphnia magna, Ceriodaphnia dubia, and Pimephales promelas (fathead minnows). The study data is presented in Appendix I. The tire contaminated water was prepared by submersing a passenger tire for 10 to 14 days in 300 liters of dechlorinated tap water under continuous and vigorous aeration. To reduce the toxicity and to gather information about the toxicant, samples of tire water were subjected to aeration, addition of acid, addition of base, addition of anti-oxidant, addition of activated carbon, and addition of a metal chelating agent. Activated carbon completely removed the toxicity, while none of the other measures had any effect on the toxicity except storing the sample under light for seven days which reduced the toxicity slightly (Abernethy, 1994).

Of the 143 compounds targeted, only zinc was found. The levels of zinc found were 23 and 25 μg/L). The presence of zinc is consistent with the chemical makeup of tires since zinc oxides are used in the rubber and the bead and tread wire is often zinc coated (Fishbein, 1991; Abernethy, 1994). According to the MSDS for zinc (MDL Information Systems, Inc., 1994), patients ingesting zinc at 10 times the recommended daily allowance for months and years have not shown any adverse reactions. Ingestion of approximately 85.7 mg/Kg/day for 2 days caused lethargy, lightheadedness, staggering, and difficulty in writing clearly. Two people who ingested 40 mg/L in drinking water for several months experienced lack of concentration, drowsiness, mental and physical fatigue, pain in the arms and legs, headache, stiffness, muscle pains, loss of appetite, nausea, weight loss, and lassitude. A decrease in the HDL cholesterol level resulted from 90 mg/l in the diet for five weeks. Pancreatic abnormalities have also been seen.

Other non-target compounds were detected using gas chromatography mass spectroscopy (GC/MS). Up to 62 organic contaminants were detected in individual samples, most of which could not be identified, but some could be placed into chemical classes. Most of these compounds were arylamines or phenols. This is consistent because these chemicals are used in the rubber processing industry (Fishbein, 1991). Four organic compounds were found in all of the tire water samples: aniline, 4-(1-methyl-1-phenylethyl)-phenol; benzothiazole; 4-(2-benzothiazolythio)-morpholine. The toxicant in this study could not be confirmed. The toxicant is water soluble, relatively persistent, and nonvolatile and is thought to be some rubber processing chemical or combination of chemicals dissolving from the rubber into the water (Abernethy, 1994). Due to the nature of the toxicant, Abernethy (1994) concluded that there is significant potential for aquatic contamination from tire structures.

In a study by Nelson et al. (1994), tire contaminated water was acutely toxic to Ceriodaphnia dubia but was not to Pimephales promelas. The study data is presented in Appendix J. The tire leachate was prepared by soaking 29 plugs cut from tires in 16 liters of Lake Mead, Nevada water for 31 days under gentle aeration. The resulting "loading" was 181 grams of tire material per liter of water. Toxicity reduction tests using sodium thiosulfate, EDTA, and solid phase extraction (SPE) indicated cationic metal toxicity. None of the organic analytes tested for were detected (the detection limit was 1 µg/L). Zinc was found to be present at potentially toxic levels: the Lake Mead dilution water contained 8.7 µg/L zinc while the tire leachate samples contained 751 µg/L and 755 µg/L zinc (Nelson et al., 1994). Cadmium, copper, and lead were also present at levels significantly above background. Cadmium was present in the dilution water at 0.2 µg/L and in the tire leachate samples at 0.6 µg/L. The copper concentration in the dilution water was < 5.0 µg/L while the concentrations in the tire leachate were 6.7 µg/L and 5.7

μg/L. The concentration of lead in the dilution water was <1.0 μg/L and in the tire leachate water the lead level was 6.7 μg/L in both samples. Further testing indicated that zinc was the main toxicant (Nelson, 1994).

2.6 EVALUATION OF PREVIOUS STUDIES

The purpose of this section is to compare and evaluate the results of the studies discussed in Chapter 2. Tables 2.22 through 2.24 present a summary of the metal concentrations from the laboratory leaching studies reviewed above. Tables 2.25 and 2.26 present a summary of the metal concentrations from the field studies reviewed. The results summarized here are presented in two sets of units. For comparison of results from study to study the concentrations are presented in micrograms of the constituent of concern per kilogram of tire sample used (μg/Kg). For comparison to regulatory limits, the results are presented in micrograms of constituent of concern per liter of extraction fluid used (μg/L).

2.6.1 Evaluation of Laboratory Studies

The laboratory leaching test results indicate that the metals of concern are: aluminum, barium, cadmium, chromium, iron, manganese, mercury, lead, selenium, and zinc. As seen in Tables 2.22 and 2.23, tires have shown potential to leach these metals on a μg/Kg basis. Although the concentrations of the metals of concern listed in Tables 2.22 and 2.24 are below the TCLP regulatory limits, they do raise concerns that groundwater quality may be degraded by using tire chips as fill material. Metals leach at highest concentrations under low pH conditions (Minnesota Pollution Control Agency, 1990; Ealding, 1992). The results of the studies reviewed consistently show that tire chips are not classified as a hazardous waste. None of the metals studied exceeded the TCLP regulatory limits in the laboratory leachates. The highest levels of organics are leached under basic conditions

(Minnesota Pollution Control Agency, 1990; Ealding, 1992). Observed leaching of polynuclear aromatic hydrocarbons and suspected toxicity due to organics in the studies reviewed warrants further research on organics leaching from tire chips. Although scrap tires are not a hazardous waste, the data summarized here indicate that scrap tires have the potential to adversely affect groundwater quality. This warrants further laboratory study.

Table 2.22
Summary of Metals Results for Laboratory Leaching Studies
Pollutants with Primary Drinking Water Standards

	As μg/Kg (ppb)	**Ba** μg/Kg (ppb)	**Cd** μg/Kg (ppb)	**Cr** μg/Kg (ppb)	**Cu** μg/Kg (ppm)	**Hg** μg/Kg (ppb)	**Ni** μg/Kg (ppb)	**Pb** μg/Kg (ppb)	**Se** μg/Kg (ppb)
Virginia DOT TCLP Conc in Tires	NA	NA	4.4	7.9	235	NA	113	55.6	NA
Virginia DOT (long term) pH 4 Max Conc	<25	2083	3.5	152	328	<1	2460	138	<30
Minnesota Old Tires pH 3.5 Normalized Conc	ND	440	270	510	NA	ND	NA	ND	440
Minnesota Old Tires, pH 5 Normalized Conc	ND	130	ND	ND	NA	ND	NA	ND	ND
	As μg/L (ppb)	**Ba** μg/L (ppb)	**Cd** μg/L (ppb)	**Cr** μg/L (ppb)	**Cu** μg/L (ppm)	**Hg** μg/L (ppb)	**Ni** μg/L (ppb)	**Pb** μg/L (ppb)	**Se** μg/L (ppb)
TCLP Regulatory Limit	5000	100000	1000	5000	-	200	-	5000	1000
Virginia DOT TCLP Conc in extract	NA	NA	1.55	2.8	83	NA	39.7	19.6	NA
Wisconsin AFS Elution 3 (neutral)	<10	110	NA	<3	<20	NA	NA	<3	<5
Scrap Tire Mngmnt TCLP Max Conc	2	590	ND	48	NA	0.4	NA	16	ND

Notes: NA = not available, that is not measured or not reported for that study
ND = non-detect

Table 2.23

Summary of Metals Results for Laboratory Leaching Studies

Pollutants with Secondary Drinking Water Standards

"Normalized" Concentration in Tire Material

	Ag µg/Kg (ppb)	**Al** µg/Kg (ppb)	**Fe** mg/Kg (ppm)	**Mn** µg/Kg (ppb)	**Zn** mg/Kg (ppm)
Virginia DOT TCLP Conc in Tires	<2.8	420	341	NA	30
Virginia DOT (long term) pH 4 Max Conc	10	746	31622	NA	153.7
Minnesota Old Tires pH 3.5 Normalized Conc	ND	2020	1081	NA	50
Minnesota Old Tires, pH 5 Normalized Conc	ND	750	49.52	NA	37

Notes: NA = not available, that is not measured or not reported for that study

ND = non-detect

Table 2.24
Summary of Metals Results for Laboratory Leaching Studies
Pollutants with Secondary Drinking Water Standards
Concentration in Extract

	Ag µg/L (ppb)	**Al** µg/L (ppb)	**Fe** mg/L (ppm)	**Mn** µg/L (ppb)	**Zn** mg/L (ppm)
SMCL	100[a]	50-200[a]	0.3[a]	50[a]	5[a]
TCLP Regulatory Limit	5000	-	-	-	-
Virginia DOT TCLP Conc in extract	<1.0	148	120	NA	10.6
Wisconsin AFS Elution 3 (neutral)	NA	NA	0.23	300	0.36
Scrap Tire Mngmnt TCLP Max Conc	ND	NA	NA	NA	NA

Notes: NA = not available, that is not measured or not reported for that study

ND = non-detect

[a] Viessman and Hammer, 1985

Table 2.25

Summary of Results for Field Studies

Pollutants with Primary Drinking Water Standards

	As µg/L	**Ba** µg/L	**Cd** µg/L	**Cr** µg/L	**Cu** µg/L	**Hg** µg/L	**Ni** µg/L	**Pb** µg/L	**Se** µg/L
MCL	50[a]	2000[b]	5[b]	100[b]	1300[c]	2[b]	100[b]	15[c]	50[b]
Minnesota FL Groundwater	<100	1930	32	350	NA	<1	NA	230	<100
Minnesota PC Groundwater	<100	<10	<3	<10	NA	<1	NA	<20	<100
Wisconsin East Lysimeter Max Conc	NA	570	NA	NA	NA	NA	NA	22	NA
Wisconsin West Lysimeter Max Conc	NA	690	NA	NA	NA	NA	NA	5	NA
Tire Pond Surface Water Max Conc	NA	NA	<2	NA	<25	NA	<40	NA	NA

Notes: NA = not available, not measured or not recorded for that study
ND = non-detect
[a] Federal Register, July 1, 1993; 40 CFR Ch. 1, section 141.11
[b] Federal Register, July 1, 1993; 40 CFR Ch. 1, section 141.62
[c] Federal Register, July 1, 1993; 40 CFR Ch. 1, section 141.80

Table 2.26
Summary of Results for Field Studies
Other Parameters

	Al µg/L	**Ca** mg/L	**Fe** mg/L	**Mg** mg/L	**Mn** µg/L	**Zn** µg/L	**SO_4^{2-}** mg/L
SMCL	50-200[a]	-	0.3[a]	-	50[a]	5000[a]	250[a]
Minnesota FL Groundwater	180000	1080	298	383	NA	870	NA
Minnesota PC Groundwater	1800	14.4	4.4	2.8	NA	<10	NA
Wisconsin East Lysimeter Max Conc	NA	340	5.3	390	3200	560	450
Wisconsin West Lysimeter Max Conc	NA	300	4	320	2600	750	150
Tire Pond Surface Water Max Conc	NA	NA	1.83	NA	NA	30	17

Notes: NA = not available, not measured or not recorded for that study
ND = non-detect

[a] Viessman and Hammer, 1985.

2.6.2 Evaluation of Field Studies

The results of the field studies reviewed above indicate that the metals of concern are: aluminum, barium, cadmium, chromium, iron, lead, manganese, and zinc. Organic compounds were detected in the Pond water and the groundwater during monitoring at the Tire Pond and polynuclear aromatic hydrocarbons were found in groundwater samples taken as part of the Minnesota Study. Iron levels consistently exceeded the SMCL of 0.3 mg/L for all the field data reviewed; the highest concentration observed being 298 mg/L. Levels of manganese above the SMCL of 50 μg/L were observed in the Wisconsin Study test embankment for all but one sample, with the highest concentration being 3200 μg/L. In addition, aluminum exceeded the SMCL at both field sites investigated in the Minnesota Study. The primary drinking water standards of 5 μg/L and 100 μg/L for cadmium and chromium, respectively, were exceeded at the Floodwood Road site in the Minnesota Study. The MCL for lead (15 μg/L) was exceeded at the Floodwood Road site and in the Wisconsin Study test embankment. These levels are high enough to warrant further field study, especially considering the lack of control samples for both field studies. None of the studies reviewed above have data for tire chips used in field applications below the groundwater table.

2.6.3 Health and Aesthetics

Serious health problems are associated with exposure to some metals found in the laboratory and field studies cited in the previous sections. However, it is not clear from these studies if the levels would be high enough under field conditions to be of concern. Cadmium and lead are classified as probable human carcinogens, chromium VI is a known human carcinogen, and the carcinogenicities of barium and selenium have not been classified due to lack of evidence (Tate and Arnold, 1990). Chronic exposure to barium may contribute to hypertension, chronic exposure to cadmium causes renal failure, and lead exposure is associated with a plethora of patho-physiological effects including anemia, kidney damage, impaired reproductive function, impaired cognitive performance, and elevation of blood pressure (Tate and Arnold, 1990). Chromium VI is toxic and produces liver and kidney damage, internal hemorrhage, and respiratory disorders. In addition, subchronic and chronic effects of chromium VI include dermatitis and skin ulceration (Tate and Arnold, 1990). Dermatitis, hair loss, abnormal nail formation, and psychological disturbances have all been attributed to chronically high selenium intakes (Tate and Arnold, 1990).

In addition to the health effects discussed above, some of these metals pose aesthetic problems with drinking water. Iron and manganese ions are sources of color in water. Taste and odor problems are caused by iron, manganese, and zinc. The taste thresholds for these three metals are listed in Table 2.27. Staining of laundry and household fixtures can occur with water having iron and manganese in solution (Tate and Arnold, 1990). Iron, manganese, and zinc are essential to human nutrition at low doses. However, in excess, zinc has been reported to cause muscular weakness and pain, irritability, and nausea: the zinc levels associated with these symptoms was 40 mg/L over a long period (Tate and Arnold, 1990). The SMCL of 5 mg/L for zinc is based upon taste.

Table 2.27

Taste Thresholds for Iron, Manganese, and Zinc

(Adapted from Tate and Arnold, 1990)

Metal	Taste Threshold (mg/L)
Fe	0.04 - 0.1
Mn	4 - 30
Zn	4 - 9

CHAPTER 3

METHODS

3.1 INTRODUCTION

A description of the detailed sample collection, handling, and storage techniques used for the three phases of this project will be provided in this chapter. The discussion of the sampling program will be broken into four parts: volatile organic compounds, semivolatile organic compounds, metals, and other tests. In addition, the sample analysis techniques and methods and where the analyses were done will be discussed. Finally, the details of the methods used to set up and carry out the laboratory leaching tests, the laboratory simulation of ground conditions, and the small scale field trials will be described.

3.2 SAMPLE COLLECTION, HANDLING, AND STORAGE

3.2.1 Volatile Organics Samples

The sample containers used for collecting samples to be analyzed for volatile organics were clear 40 mL borosilicate glass vials with polypropylene closures and Teflon faced silicone septa. The samples were preserved by adding 4 drops of hydrochloric acid (HCl) to each vial before collecting the samples. Ultrex II ultrapure hydrochloric acid (HCl) was used. Hydrochloric acid (HCl) was the only preservative required because none of the samples were chlorinated. The samples were stored in coolers upon collection and at 4°C in the laboratory until they were shipped. Coolers and blue ice were used to ship all samples. The maximum hold time for volatile organic samples is seven days. The maximum time that any organic samples were held in our laboratory before shipping was one day.

3.2.2 Semivolatile Organics Samples

Samples to be analyzed for semivolatile organics analysis were collected in 1 L amber borosilicate glass bottles with polypropylene closures with Teflon liners. No sample preservation is required for semivolatiles samples. The samples were stored in coolers upon collection and at 4°C in the laboratory until shipping. Coolers and blue ice were used to ship all samples. The maximum hold time for semivolatiles samples is seven days. The maximum time that any semivolatile samples were held in our laboratory before shipping was one day.

3.2.3 Metals Samples

Samples to be analyzed for metals were collected in 1 L or 0.5 L high-density polyethylene (HDPE) bottles with HDPE closures. All metals samples were stored in coolers upon collection and kept at 4°C in the laboratory until analysis or further preparation for analysis. Samples for all metals except mercury were preserved with 1.5 mL nitric acid (HNO_3) per liter of sample. Ultrex II ultrapure nitric acid (HNO_3) was used. Samples to be analyzed for mercury were preserved with 2 mL 20% potassium dichromate ($K_2Cr_2O_7$) solution (prepared in 1+1 nitric acid) per liter of sample. Samples to be analyzed for dissolved metals were filtered within 2 hours of collection, upon returning to the laboratory. The filters used were Corning disposable sterile filters with 0.45 μm cellulose acetate filters. The maximum hold time for metals samples is 6 months, with the exception of mercury which has a maximum hold time of 28 days.

3.2.4 Other Samples

Samples collected to be analyzed for other parameters were collected in 1 or 0.5 L HDPE bottles with HDPE closures. All samples were stored in coolers upon collection and kept at 4°C in the laboratory until analysis. In addition to refrigeration, samples for COD analysis were acidified by adding 2 mL nitric acid (HNO_3) per liter of sample. Samples for alkalinity, BOD, chloride, and sulfate analysis required no preservation other than refrigeration. The maximum hold time before analysis for BOD samples was 48 hours. The maximum hold times before analysis for COD and alkalinity were 7 days and 14 days, respectively. The maximum hold time before analysis for chloride and sulfate samples was 28 days.

3.3 ANALYTICAL TECHNIQUES

3.3.1 Analysis at Plant, Soil, and Environmental Sciences Laboratory

The University of Maine Department of Plant, Soil, and Environmental Sciences Analytical Laboratory analyzed samples for the following metals: aluminum, barium, calcium, chromium, copper, iron, magnesium, manganese, mercury, silver, sodium, and zinc. All of these metals, except for mercury, were measured in both dissolved and total forms. EPA Method 7471 Mercury in Solid or Semisolid Waste (Manual Cold-Vapor Technique) (EPA, 1987) was used for the sample preparation technique for total mercury. The sample preparation technique outlined in EPA Method 200.7 (Inductively Coupled Plasma - Atomic Emission Spectrometric Method for Trace Element Analysis) (EPA, 1991) was used for all other metals listed above. The samples were analyzed according to manufacturers instructions for the instrument used. Mercury was measured using a Thermo Jarrell Ash Atomic Absorption Spectrometer Model Scan-1 with an Atomic Vapor Accessory Model 880. Silver was measured using a Thermo Jarrell Ash Atomic Absorption Spectrometer Model Scan-1. All other metals listed above were measured using a Thermo Jarrell Ash Model 975 Plasma Atomcomp Inductively Coupled Plasma Emission Spectrometer.

3.3.2 Analysis at Environmental Chemistry Laboratory

The University of Maine Environmental Chemistry Laboratory analyzed samples for the following metals: arsenic, cadmium, and lead. Both dissolved and total forms of these metals were measured. Sample preparation followed that outlined in EPA Method 200.9 (Determination of Trace Elements by Stabilized Temperature Graphite Furnace Atomic Absorption Spectrometry) (EPA, 1991). The analytical methods used were: EPA Method 7060 Arsenic (Atomic Absorption, Furnace Technique); EPA Method 7131 Cadmium (Atomic Absorption, Furnace Technique); EPA Method 7421 Lead (Atomic Absorption, Furnace Technique); and EPA Method 7740 Selenium (Atomic Absorption, Furnace Technique) (EPA, 1987).

In addition to metals, total organic carbon (TOC), chloride, and sulfate were measured at the Environmental Chemistry Laboratory. The method used for TOC was EPA Method 415.1 (Organic Carbon, Total) (EPA, 1993). The method used for chloride and sulfate was EPA Method 300.0 (Determination of Inorganic Anions by Ion Chromatography) (EPA, 1983).

3.3.3 Analysis at Environmental Research Institute

Organics analysis for this project was done at the Environmental Research Institute (ERI), University of Connecticut in Storrs, Connecticut. The analytical methods used for determining organics concentrations were: EPA Method 8260 (Determination of Volatile Organics by purge-and-trap capillary column GC/MS) and EPA Method 8270 (Determination of Semivolatile Organics by capillary column GC/MS). In addition, TCLP testing and subsequent analysis was done at ERI. EPA Method 1311 (EPA, 1991) is the Toxicity Characteristic Leaching Procedure (TCLP). The analytical methods used for metals determination in the TCLP extracts were: EPA Method 3010 (Acid Digestion of Aqueous Samples and Extracts); EPA Method 6010 (Inductively Coupled Plasma Atomic Emission Spectroscopy); EPA Method 7060 Arsenic (Atomic Absorption, Furnace Technique); EPA Method 7421 Lead (Atomic Absorption, Furnace Technique); EPA Method 7740 Selenium (Atomic Absorption, Furnace Technique); and EPA Method 7470 Mercury in Liquid Waste (Manual Cold -Vapor Technique) (EPA, 1987).

3.3.4 Analysis at Civil and Environmental Engineering Department and in the Field

Sample pH and conductivity were measured and recorded in the field upon sample collection. Portable pH probes and conductivity meters were used.

Chemical oxygen demand (COD) was measured using HACH prepared COD tubes (HACH Chemical Company, 1980). Two milliliters of acid preserved refrigerated sample were added to each vial and then the vials were heated in a COD reactor for 2 hours. A Bausch and Lomb Spec 20 with COD attachment was used to measure the COD. The method used for determining BOD was that outlined in Standard Methods for the Examination of Water and Wastewater (APHA, AWWA, WPCF, 1989). Raw influent waste from the Orono Municipal Waste Treatment Plant was used to seed the samples. Alkalinity was measured using the method given in Standard Methods (APHA, AWWA, WPCF, 1989).

3.4 LABORATORY LEACHING TESTS

Toxicity Characteristic Leaching Procedure (TCLP) (EPA Method 1311) is used to determine if a waste is a hazardous waste. TCLP is meant to determine if a waste is a significant hazard to human health due to leaching of toxic compounds. TCLP represents the worst case scenario of acid rain falling on a landfill, percolating through the waste, and exiting as leachate. The compounds regulated under TCLP include pesticides, herbicides, metals, semivolatile organics, and volatile organics. Leaching of volatile organics takes place in a zero headspace extractor (ZHE), while leaching of semivolatile organics, pesticides, and metals takes place in a containment jar. Pesticides and herbicides were not looked at in this study because leaching of pesticides and herbicides is not a concern with scrap tires. The TCLP testing and subsequent analysis was done by Environmental Research Institute (ERI) at the University of Connecticut in Storrs, Connecticut. Four samples were subjected to TCLP testing and subsequent analysis for this study. Two samples were mixed steel and glass belted chips from Pine State Recycling in Nobleboro, Maine. The other two samples were glass belted chips from F&B Enterprises in New Bedford, Massachusetts. One sample of each type of chip was washed. The washing procedure was to rinse the tire chips (before particle size reduction) under warm water for approximately 10 minutes. During the rinsing, surface debris, dirt, and oil were removed either by hand or with a laboratory glassware brush. Only loose and easily removed material was washed or brushed from the surface. No detergent was used. The other two samples (one of each type of chip) were tested unwashed. The purpose of testing washed and unwashed samples was to determine if the leached contaminants could be due to dirt and debris on the surface of the tire chips rather than to the tire chips themselves.

TCLP requires particle size reduction to passing the 9.5 mm (0.375 in.) sieve. A representative sample of each of the four types of tire chips was selected. The tire chips were super-cooled by placing them in a shipping dewar that had been charged with liquid nitrogen. The tire chips were not in contact with the liquid nitrogen at any point during this process. The chips were left in the dewar for several minutes. After being cooled the tire chips were placed in a plastic bucket. A modified Proctor compaction hammer was dropped on the chips to shatter them into particles. The resulting particles were collected from the bucket. Particles that still did not pass the 9.5 mm (0.375 in.) sieve would be cooled again and the process repeated. Some of the chips required that the exposed belts be snipped with wire cutters to separate small particles of tire chip after the initial smashing with the compaction hammer. The material resulting from the size reduction process were subjected to TCLP testing. This included both bits of rubber and bits of belts. A total of 200 grams of each type of tire chip sample was prepared. The samples were stored in glass jars and were shipped to ERI for analysis.

3.5 LABORATORY SIMULATION OF GROUND CONDITIONS

3.5.1 Set-up

The laboratory simulation of ground conditions was a reactor study. The reactors were 20 L (5 gal) PYREX glass bottles that were sealed with rubber stoppers and stored in the dark at ambient temperature (15 °C to 20 °C) for approximately ten months. A total of eight reactors were set up. The tire chips used in the reactor study were mixed steel and glass belted chips from Pine State Recycling in Nobleboro, Maine. The maximum tire chip size used in the reactors was approximately 7.5 cm by 7.5 cm (3 in. by 3 in.). Distilled water was added to the reactors. Two reactors contained only tire chips and water: one washed sample and one unwashed sample. The washing method was the same as that used for the TCLP study. Three reactors were set up with soil and water only. The three soil types were clay, till, and peat. The soil samples used were bulk samples collected from each of the three field sites used for this project. The final three reactors contained mixtures of soil, unwashed tire chips, and water. One reactor was set up using tire chips and each of the three soil types: clay, till, and peat. The purpose of this set-up was to allow direct comparison of the metals, semivolatile organics, and volatile organics found in the jars with soil and water only, to the same parameters in the jars with mixtures of soil, tire chips, and water. No pH adjustment was made in the reactors.

When setting up the reactors, the goal was to maintain the same soil to water ratio in each of the soil/water jars as in the corresponding soil/tire chip/water jar. Also, the tire chip to water ratio in the tire chip/water jars and the soil/tire chip/water jars was the same. The solid material was added to the reactors first and the water was added after the solid materials were placed. The soil and tire chips were placed in the mixed reactors in alternating layers. The bottom layer was tire chips. Three layers of tire chips and three layers of soil were used in each reactor. The reactors were filled and sealed on April 13, 1994. Table 3.1 summarizes the contents of each jar.

Table 3.1
Contents of Reactors

Reactor Description	Soil (grams)	Tire Chips (grams)	Water (Liters)	Soil/Water (grams/Liter)	Tire Chips/Water (grams/Liter)
Peat + Water	3055.0	0	19.6	156	0
Peat + Water + Tire Chips	2250.0	6001.1	14.8	152	405
Till + Water	13744.8	0	16.5	833	0
Till + Water + Tire Chips	10500.1	6000.0	12.6	833	476
Clay + Water	13350.1	0	15.0	890	0
Clay + Water + Tire Chips	10500.0	5999.6	11.8	890	508
Washed Tire Chips	0	7877.1	15.5	0	508
Unwashed Tire Chips	0	7876.7	15.7	0	502

3.5.2 Sampling Methods

The reactors were sampled on February 22, 1995. Samples were collected to be analyzed for volatile organic compounds, semivolatile organic compounds, and metals. The sample volume collected from each reactor was: 2 L for semivolatiles, 2.5 L for metals, and three 40 ml vials for volatiles. In addition, approximately 500 grams of soil was collected from each reactor that contained soil. The soils samples were stored in separate sealed plastic bags.

The first step in sampling was to siphon the required water samples from the reactors. After the water samples were collected the siphoning was continued to remove as much water as possible without disturbing the solid contents of the reactors. Next the reactors containing only soil were tilted or laid on their sides and soil samples were collected using a scoop. Samples of the soil were taken randomly at different depths in the reactor and from different locations over the cross-section of the reactor.

After the water was removed from the reactors containing soil and tire chips, each reactor was placed in a large bucket and the reactor was broken so that soil samples could be collected. The broken glass was removed from the top of the sample and soil samples were collected from each layer of soil in the reactor. After sampling randomly over the cross-section of each layer of soil, the tire chips under that layer of soil were removed to expose the next layer of soil. The waste from the reactors was separated into glass, soil, and tire chips for disposal.

The soils samples collected were vigorously mixed in porcelain dishes to ensure homogeneity. A portion of each soil type sample was used to determine the water content. The water content of the soil samples is needed so that the metal concentrations found during the subsequent analysis of digestates can be reported on a dry weight of soil basis. The soils samples were subjected to digestion (in triplicate). The digestates were analyzed for metals. The till samples were treated differently from the clay and peat samples because the till samples contained a coarse fraction, while the others contained only fines. The entire till samples was dried and then sieved. The sample was separated into two portions: that retained on the No. 4 sieve and that passing the No. 4 sieve. The sample of material passing the No. 4 sieve was used for further analysis (that is digestion and metals determination). This method was used for the till samples due to sample size restrictions used for digestion. The mass of the sample used in the digestion (EPA Method 3050) (EPA, 1987), is 1 g to 2 g. Since the till sample had single particles that would exceed the mass required for the sample to be digested, it was necessary to divide the sample in some way. Most sorption takes place on the small particles, due to high surface area to volume ratio; therefore, it was reasonable to digest a sample of only the fine fraction of the sample.

3.6 SMALL SCALE FIELD TRIALS

3.6.1 Site Selection

Three sites were chosen for the small scale field trials. One trial was conducted in each of three Maine soil types: glacial marine clay (locally known as Presumpscot Formation), glacial till, and fibrous peat. The search for the sites was initially limited to University property. However, a suitable peat site could not be found on University of Maine property; therefore, a site was chosen on private property. The two criteria used in the site search were soil type and topography. United States Department of Agriculture Soil Survey maps for Penobscot County, Maine were used to make a preliminary identification of the desired soil types. Copies of the relevant soils maps are included as

Figures 3.1 and 3.2. The legend of symbols for the USDA Soil Survey Maps is included as Appendix K. United States Geological Survey 7.5 minute quadrangle maps with 20 ft contour intervals were used to ascertain general topography. Copies of the pertinent USGS topographical maps are included as Figures 3.3 and 3.4. Using these maps, possible sites were chosen and visited. Hand auger borings or test pits were made at potential sites to confirm the desired soil type and position of the groundwater table. The desired conditions were high groundwater table for as much of the year as possible at sites that could be reasonably accessed with the equipment required to install the tire chips and monitoring wells. The clay and till sites are on University of Maine property in the Dwight B. DeMeritt Forest (University Forest) in Old Town, Maine, while the peat site is in Bangor, Maine on property owned by Doug Schmidt. The University Forest manager approved our application for use of University Forest land for research purposes: a copy of the application is included as Appendix L. Verbal permission was received from the private land owner, Doug Schmidt, to perform research on his land. The verbal agreement was followed with a letter stating our intended use of his land: a copy of the letter is included as Appendix M.

3.6.2 Site Description

The clay site is located in the University Forest, Old Town, Maine. The site is located approximately 180 m (200 yds) south of the intersection of Sewall and Logan Roads. These are gravel surfaced forest roads that are cabled off so that they are not accessible by vehicle to the public. The positioning of the clay site is shown on Figures 3.1 and 3.3. The subsurface conditions at the clay site are 0.2 m (0.8 ft) of topsoil, underlain by 1.0 m (3.4 ft) of moist gray silty fine sand, which is underlain by very moist gray silty clay with a trace of fine sand. The depth of the hand auger boring made at the site was 2.7 m (8.8 ft). The boring log for the clay site is included as Figure 3.5. The

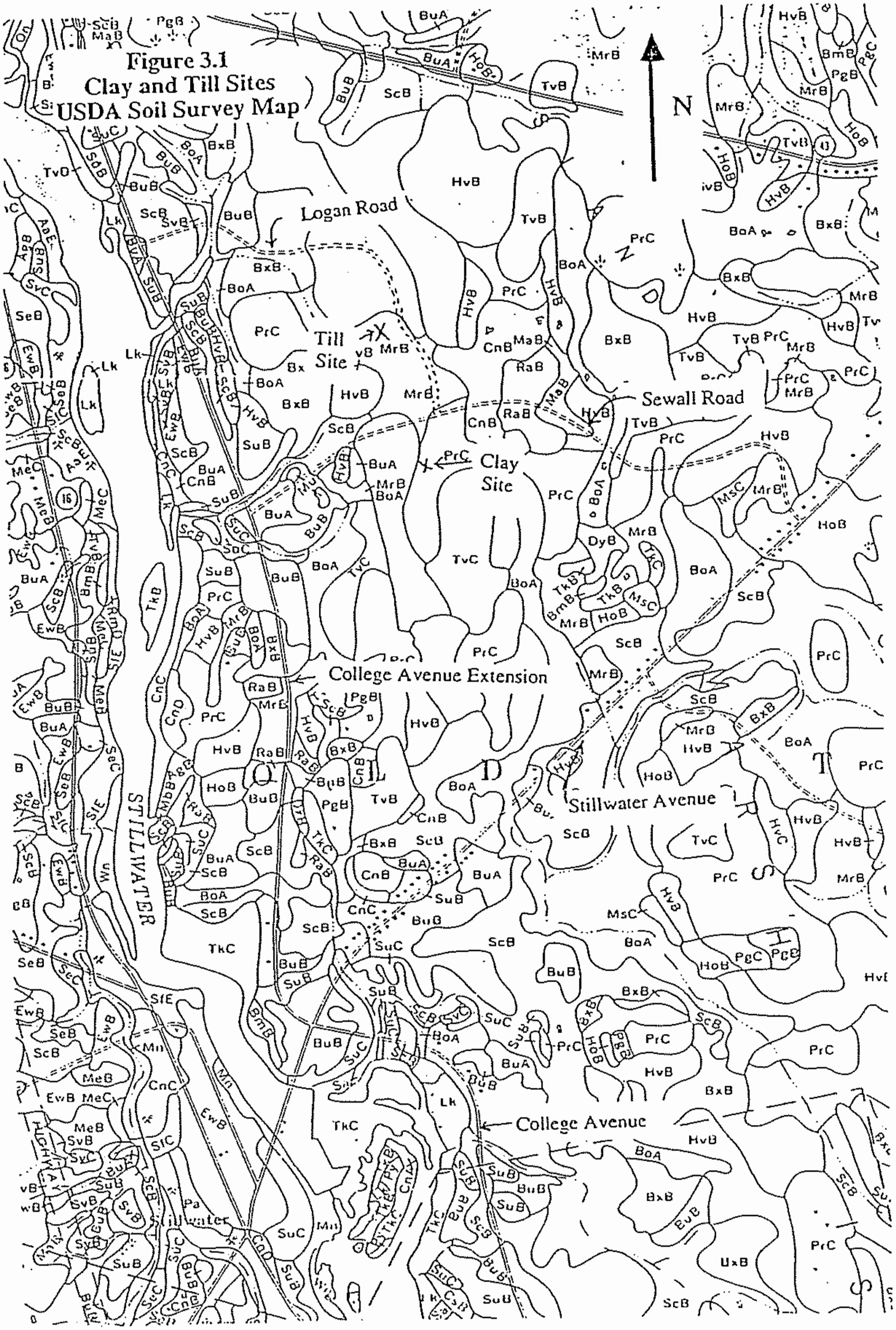


Figure 3.1
Clay and Till Sites
USDA Soil Survey Map

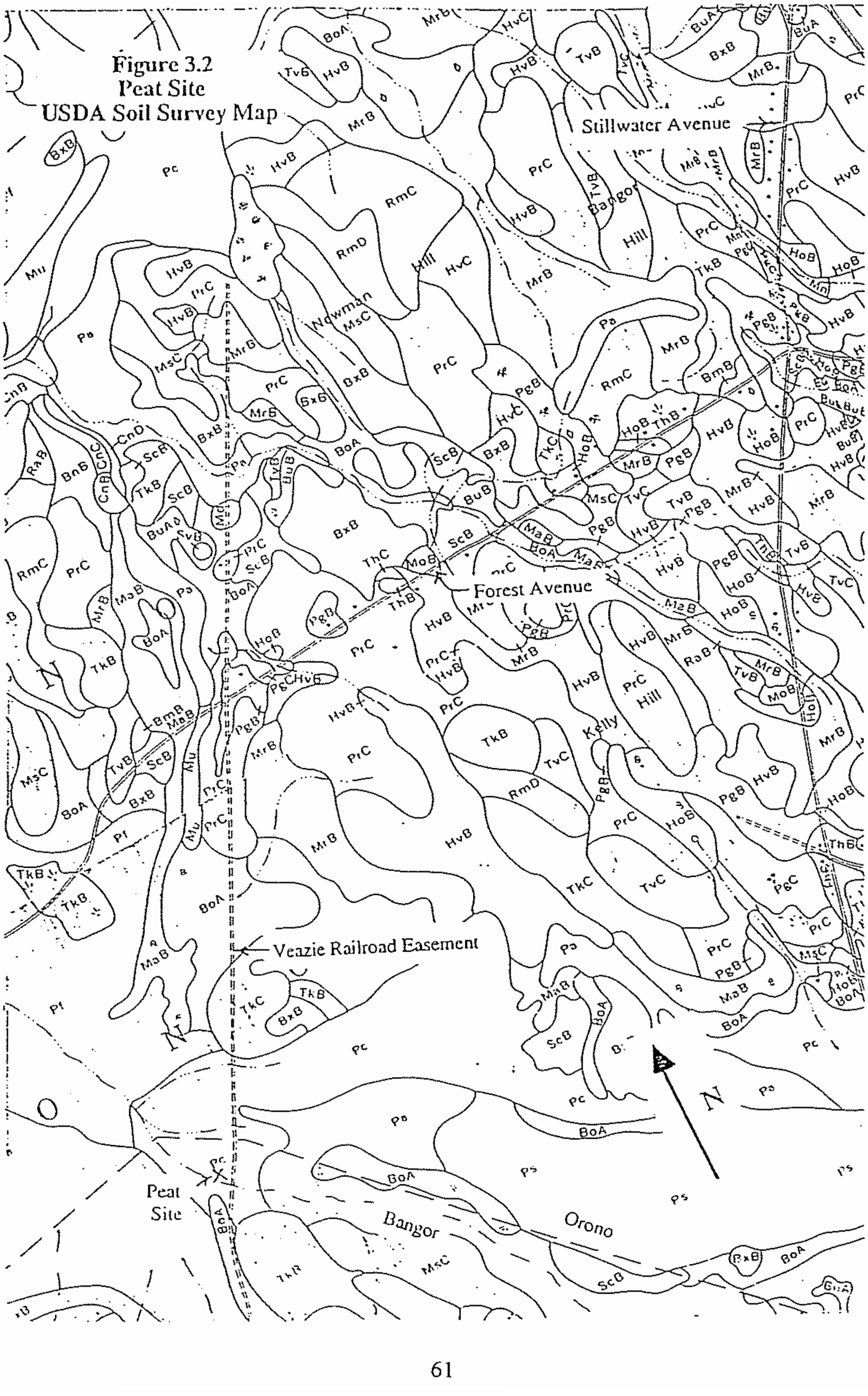


Figure 3.2
Peat Site
USDA Soil Survey Map

Figure 3.3
Clay and Till Sites
USGS Topographical Map

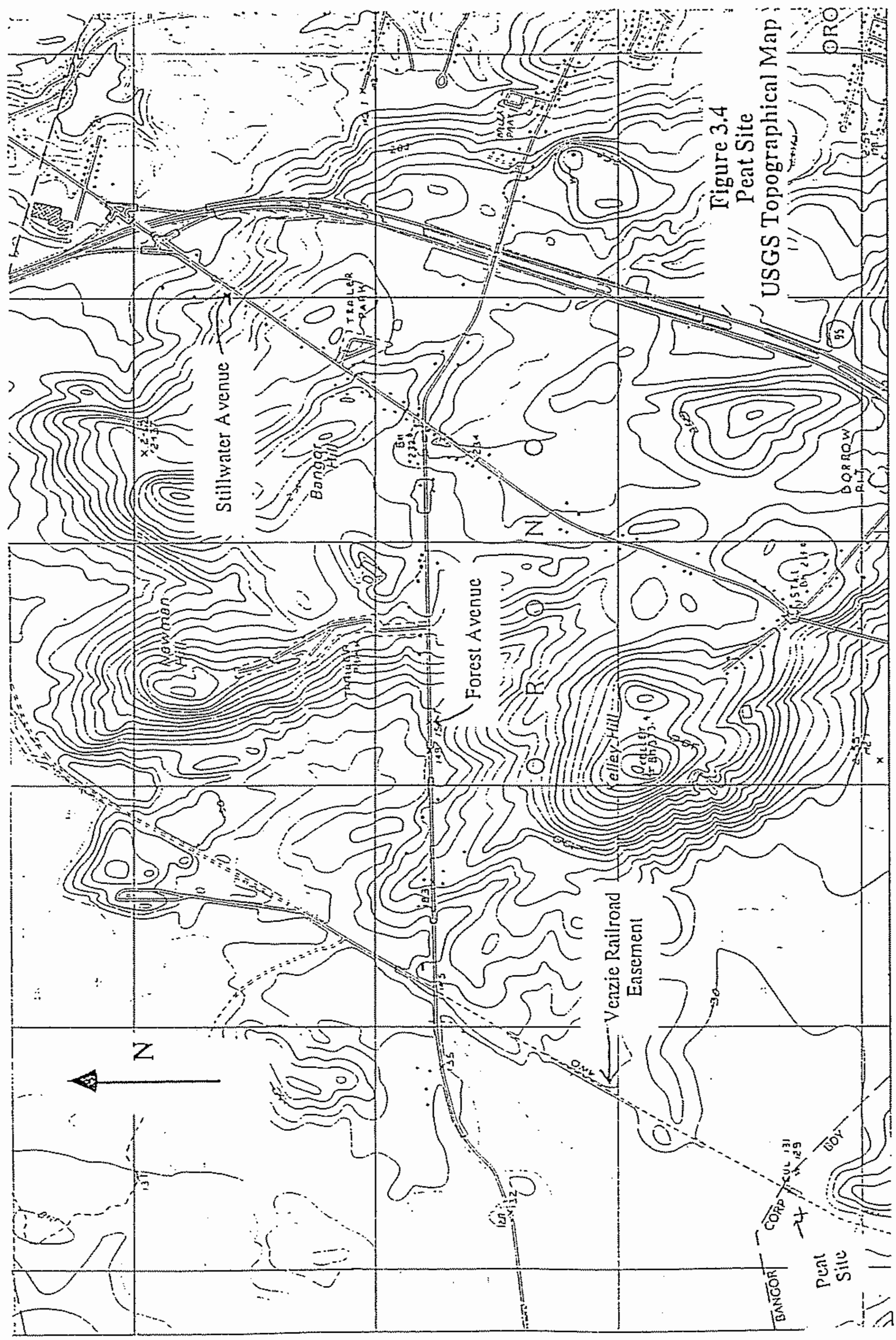
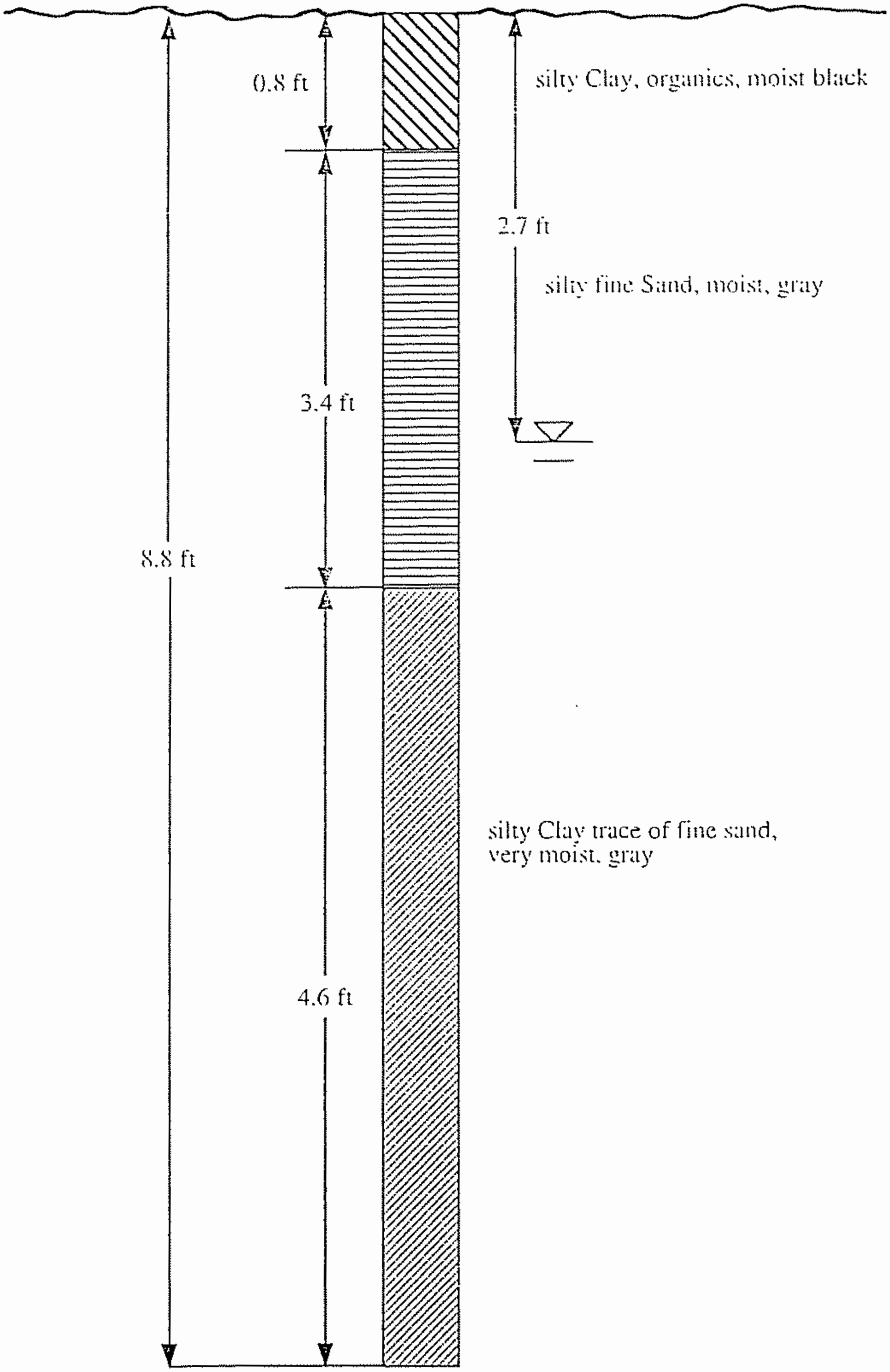


Figure 3.4
Peat Site
USGS Topographical Map

Figure 3.5
Boring Log
Clay Site
August 2, 1993



groundwater table varied from approximately 0.2 m (0.5 ft) to approximately 0.9 m (3 ft) below the ground surface from July 1993 to November 1993.

The till site is also located in the University Forest, Old Town, Maine. The site is approximately 230 m (250 yds) west of the Logan Road. The positioning of the till site is shown on Figures 3.1 and 3.3. The subsurface conditions at the till site are 0.2 m (0.5 ft) of topsoil underlain by approximately 0.7 m (2.2 ft) of silty clay, which is underlain by clayey sand with some gravel and some cobbles. The depth of the test pit at the till site was 2 m (6.7 ft). The boring log for the till site is included as Figure 3.6. The groundwater table varied from approximately 0.2 m (0.5 ft) to approximately 1.7 m (5.5 ft) below the ground surface from July 1993 to November 1993.

The peat site is located in Bangor, Maine adjacent to the Veazie Railroad Easement. The Easement intersects Forest Avenue approximately 2.4 km (1.5 miles) west of the intersection of Stillwater Avenue and Forest Avenue. The site is located approximately 1.9 km (1.2 miles) southwest of the intersection of Forest Avenue and the Easement. The site is approximately 18 m (20 yds) northwest of the Easement. The positioning of the site is shown on Figures 3.2 and 3.4. The subsurface conditions at the peat site are 4 m (13.2 ft) of black fibrous peat underlain by gray silty clay. The depth of the hand auger boring at the peat site was 4.4 m (14.4 ft). A copy of the boring log for the peat site is included as Figure 3.7. The groundwater table varied from 0.2 m (0.5 ft) to 0.3 m (1.0 ft) below the ground surface from July 1993 to November 1993.

3.6.3 Preliminary Site Data

A hand auger was used to install piezometers at the clay and peat sites. Hand augering was not possible at the till site. The preliminary wells (piezometers) were used

Figure 3.6
Boring Log
Till Site
August 18, 1993

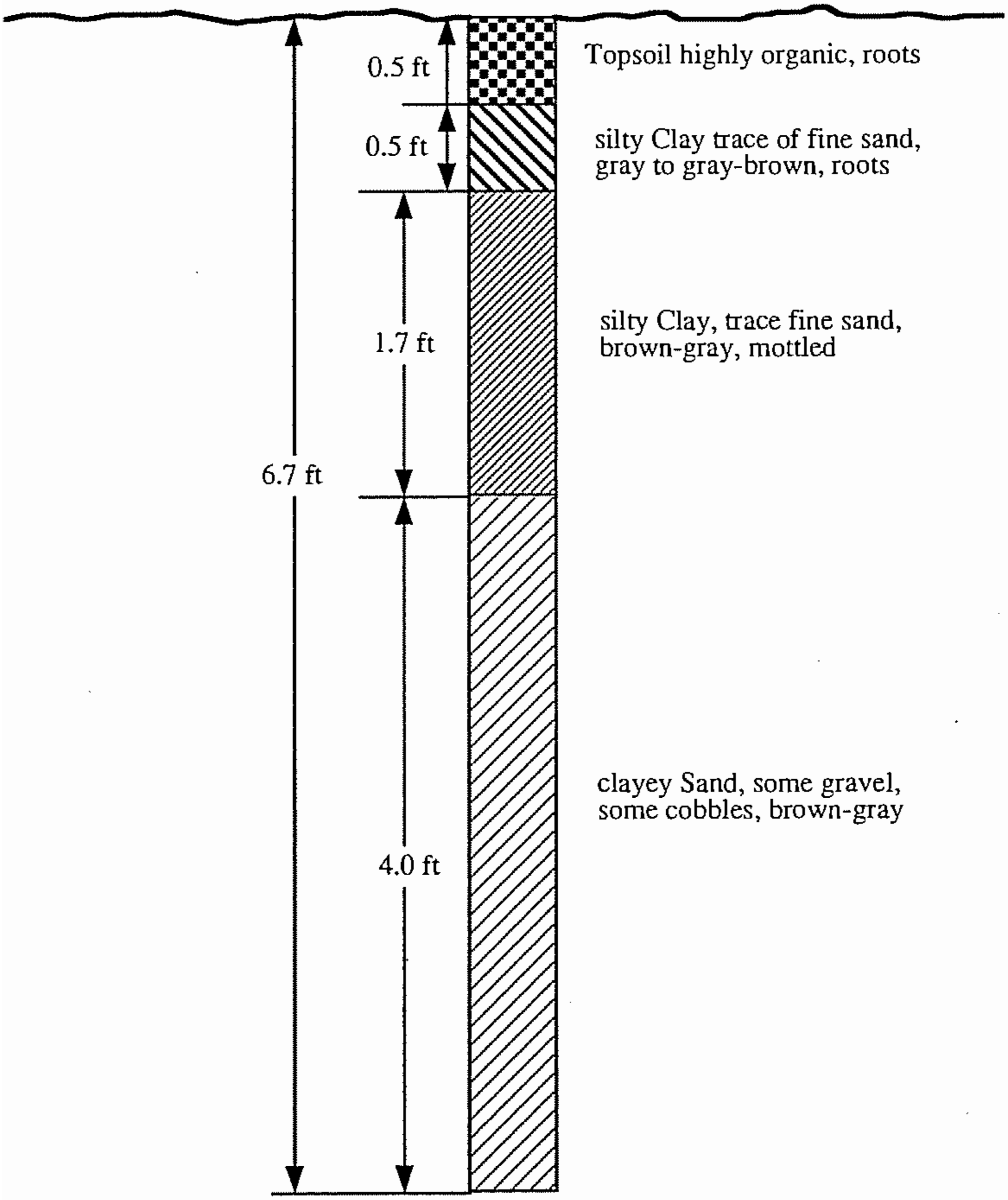
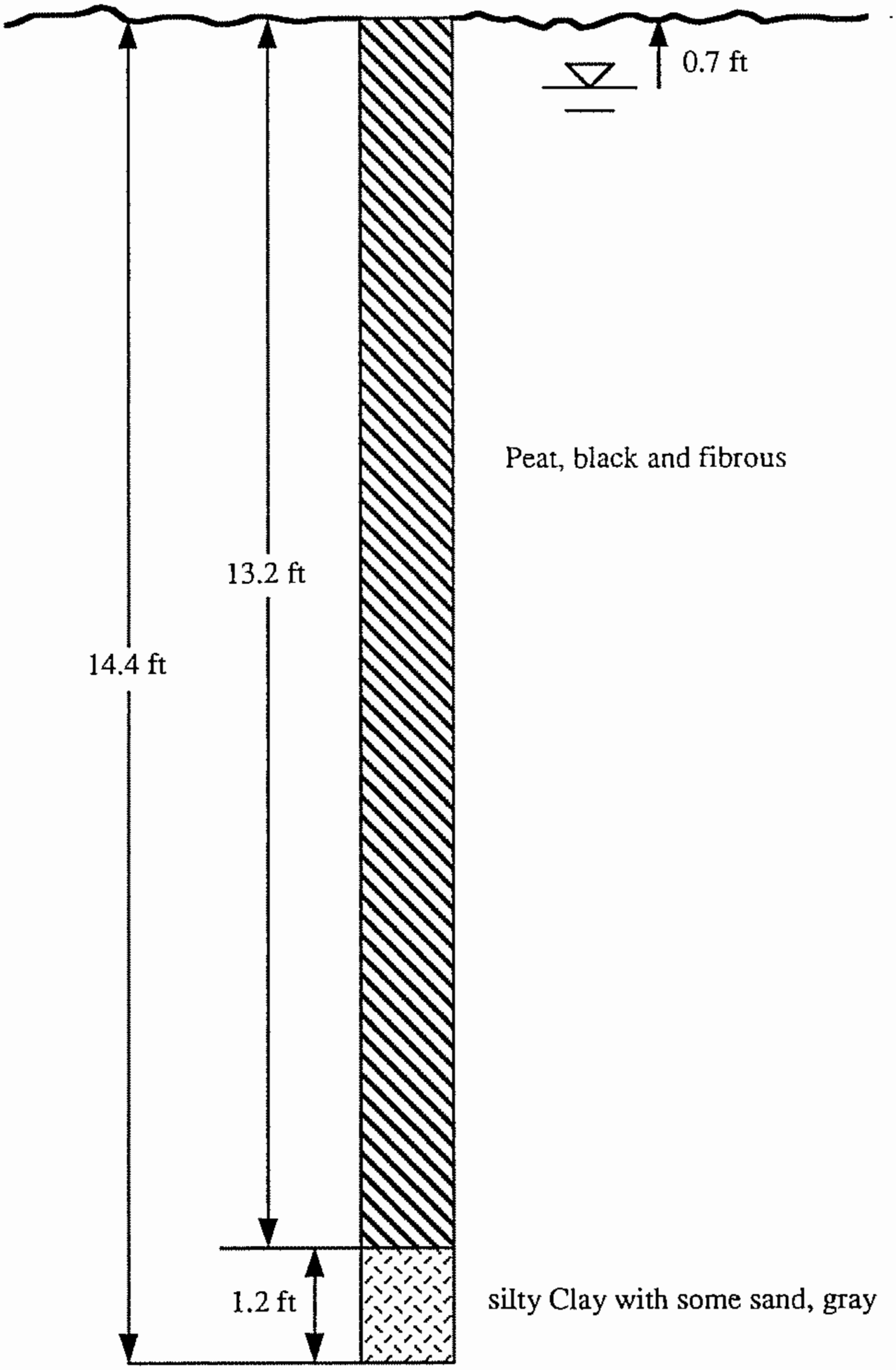


Figure 3.7
Boring Log
Peat Site
July 23, 1993



to determine the elevation of the groundwater table at the sites. Each site was surveyed to define the topography that would be surrounding the trench and the groundwater monitoring wells. The topographic site maps generated from survey data are included as Figures 3.8 through 3.10. The groundwater elevation data was used with the survey data to determine the desired positioning of the trenches and the groundwater monitoring wells. The trenches were positioned perpendicular to the inferred direction of groundwater flow, with monitoring wells within each trench, upgradient, and downgradient of each trench. A schematic of this arrangement is presented as Figure 3.11.

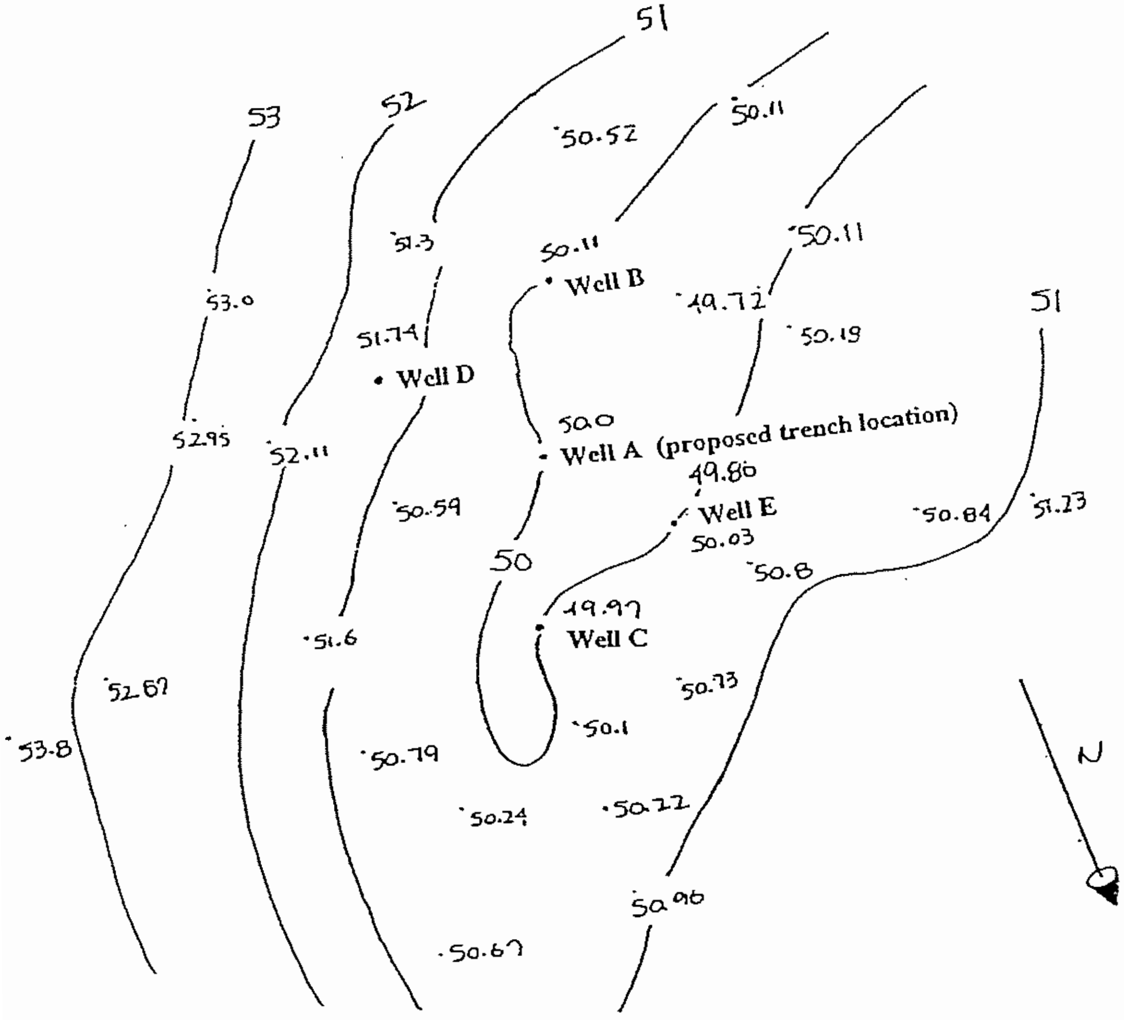
3.6.4 Soils Data

The grain size distribution for a bulk sample of soil from the clay site is presented as Figure 3.12. The Unified Soil Classification System (USCS) classification for the clay was CL. The plastic limit was 16.5 and the liquid limit was 25.0. The field moisture of the bulk samples was approximately 21%. The grain size distribution for a bulk sample of soil from the till site is included as Figure 3.13 (the analysis was done twice therefore there are two curves on the graph). The field moisture of the bulk samples was approximately 10%. The soil at the till site is a sand, with a USCS classification of SM or SC.

3.6.5 Tire Chip Installation

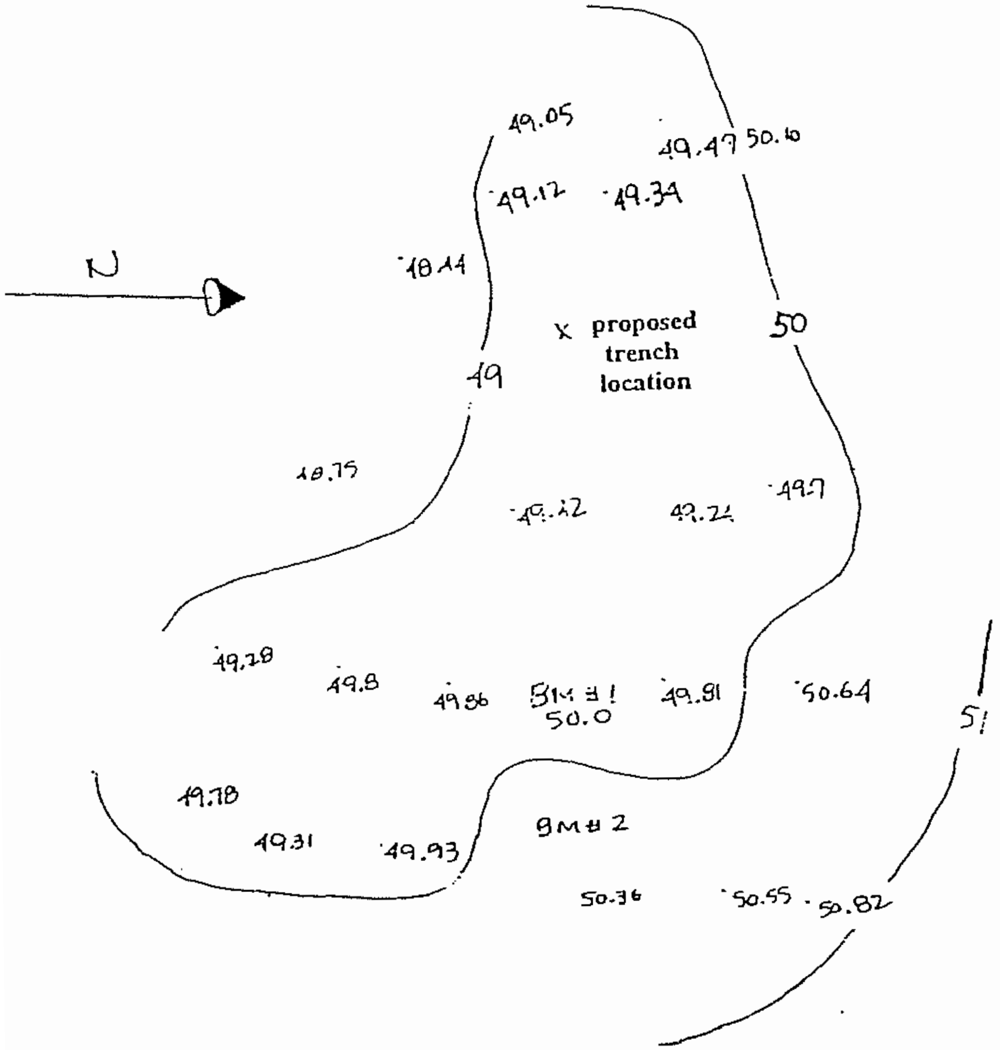
Approximately 1.5 tons of tire chips were installed at each of the field sites. The tire chips were mixed steel and glass belted chips donated by Pine State Recycling in Nobleboro, Maine. The chips were transported to the field sites using a skid pulled by a small farm tractor or skidder.

Figure 3.8
Local Topography from Survey Notes
Clay Site



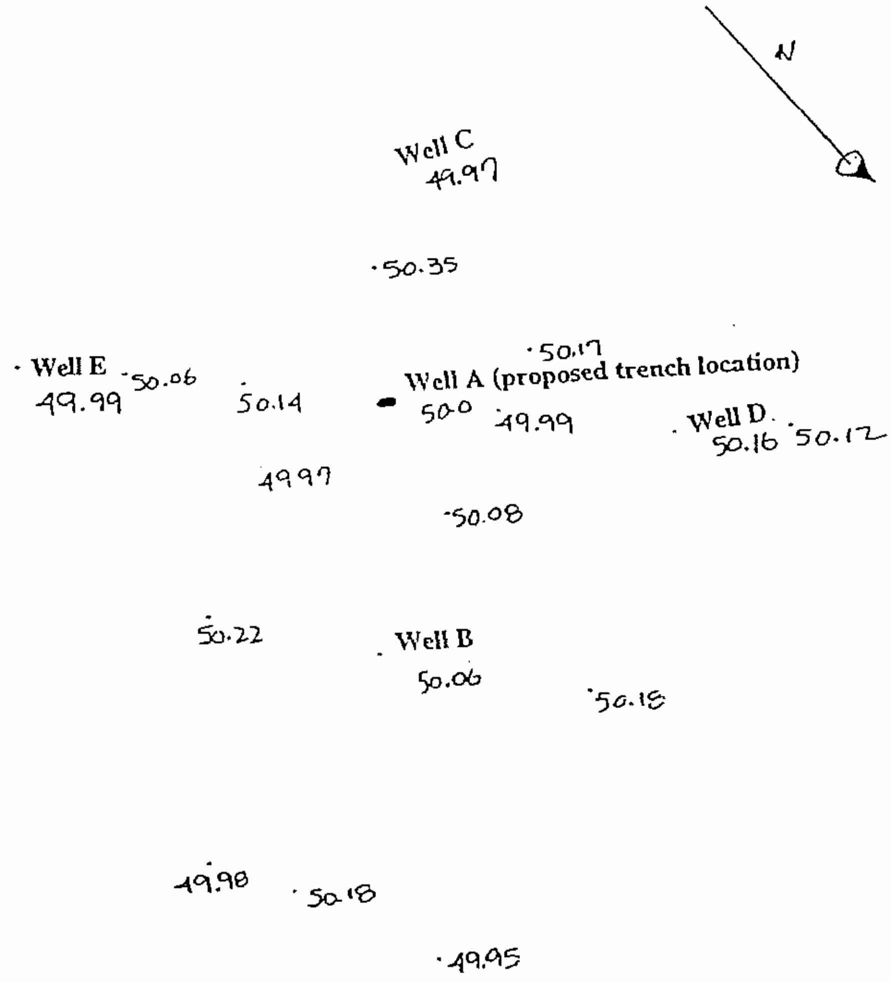
Scale: 1" = 30'

Figure 3.9
Local Topography from Survey Notes
Till Site



Scale: 1" = 30'

Figure 3.10
Local Topography from Survey Notes
Peat Site



Note: Elevation changes too small to allow contours to be drawn.

Scale: 1" = 20'

Figure 3.11
Plan View of Trench and Wells

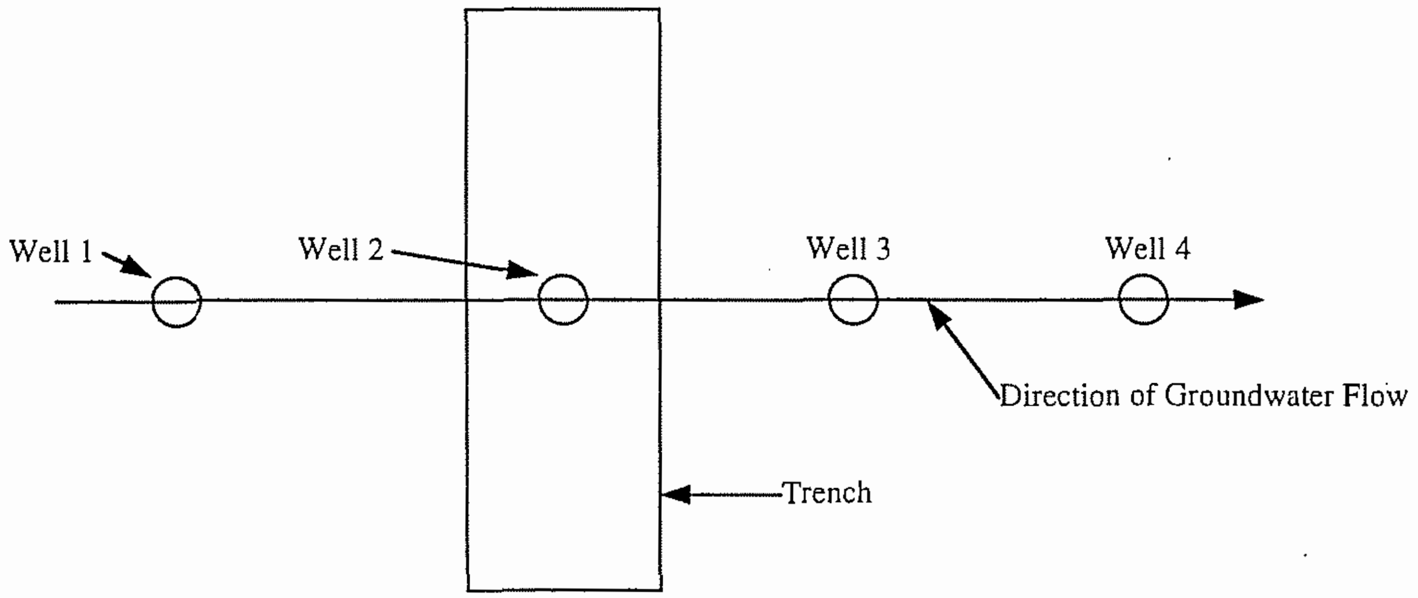


Figure 3.12
Grain Size Distribution
Clay Sample

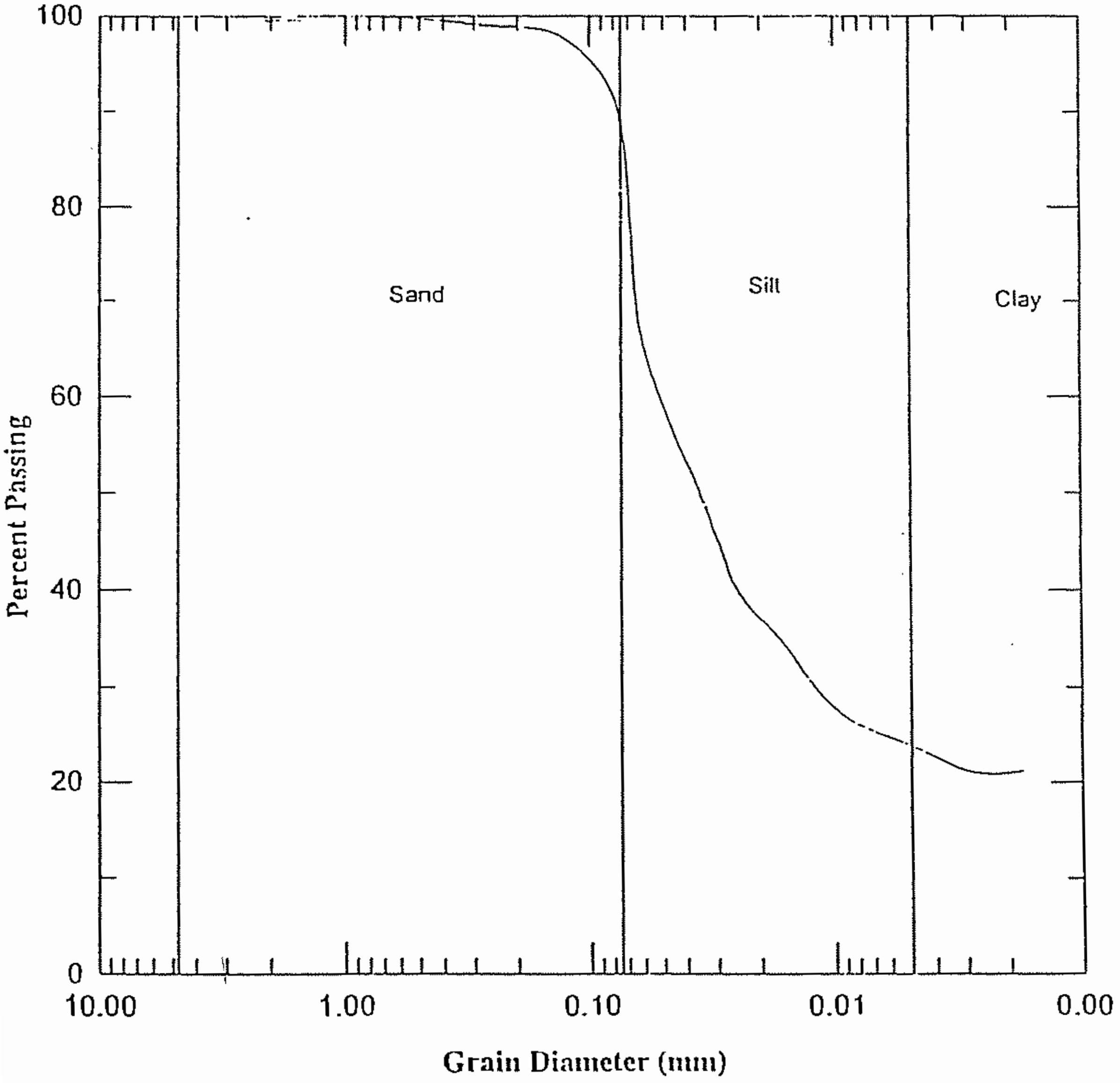
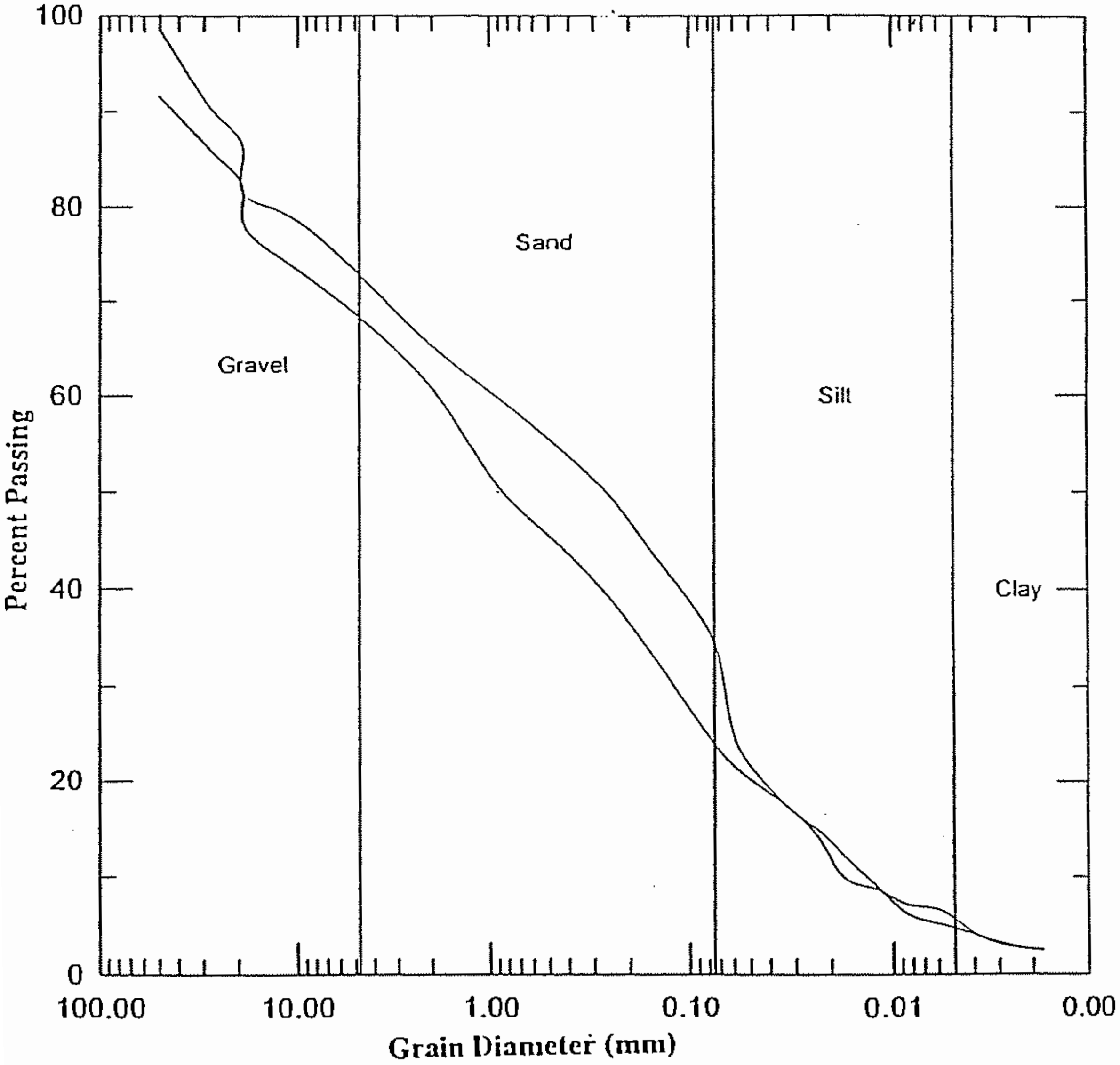


Figure 3.13
Grain Size Distribution
Till Sample



A trench approximately 3 m (10 ft) long, 1.8 m (6 ft) deep, and 0.6 m (2 ft) wide was dug with a small backhoe at each site for tire chip placement. The trenches were dug perpendicular to the inferred direction of groundwater flow. A non-woven geotextile (SD Teratex) pocket was placed in each trench to surround the tire chips and aid in their removal at the end of the study. Approximately 1.5 m (5 ft) of tire chips were placed in each trench, the geotextile was folded over the top and the remaining foot was backfilled with native material. The purpose of this arrangement was to keep the tire chips below the groundwater table for as much of the year as possible. A schematic of the trench and geotextile placement is presented as Figure 3.14. Monitoring wells were installed at each site: one well within the trench, one control well upgradient of the trench, and two or more wells downgradient of the trench. A plan view of the trench and wells at each site is presented in Figure 3.15. Table 3.2 summarizes the dates of the field installations for this study.

Table 3.2

Dates of Field Installations

Site	Tire Chips Installed	Monitoring Wells Installed
Till	12/17/93	2/3/94
Clay	12/31/93	3/11/94
Peat	1/6/94	3/16/94 and 3/25/94

3.6.5.1 Clay Site

Since the clay site is quite wet and had considerable standing water at the time of the tire chip installation, it was necessary to place a small berm alongside the trench to create a staging area for the spoils removed by the backhoe. The berm was constructed with hay bales and geotextile, which helped keep the excavated soil in a position where it can easily be used for backfill upon removal of the tire chips. The actual dimensions of the trench at the clay site were 1.8 m (6 ft) deep, 4.1 m (13.5 ft) long, and approximately 0.6

Figure 3.14
Section View of Trench

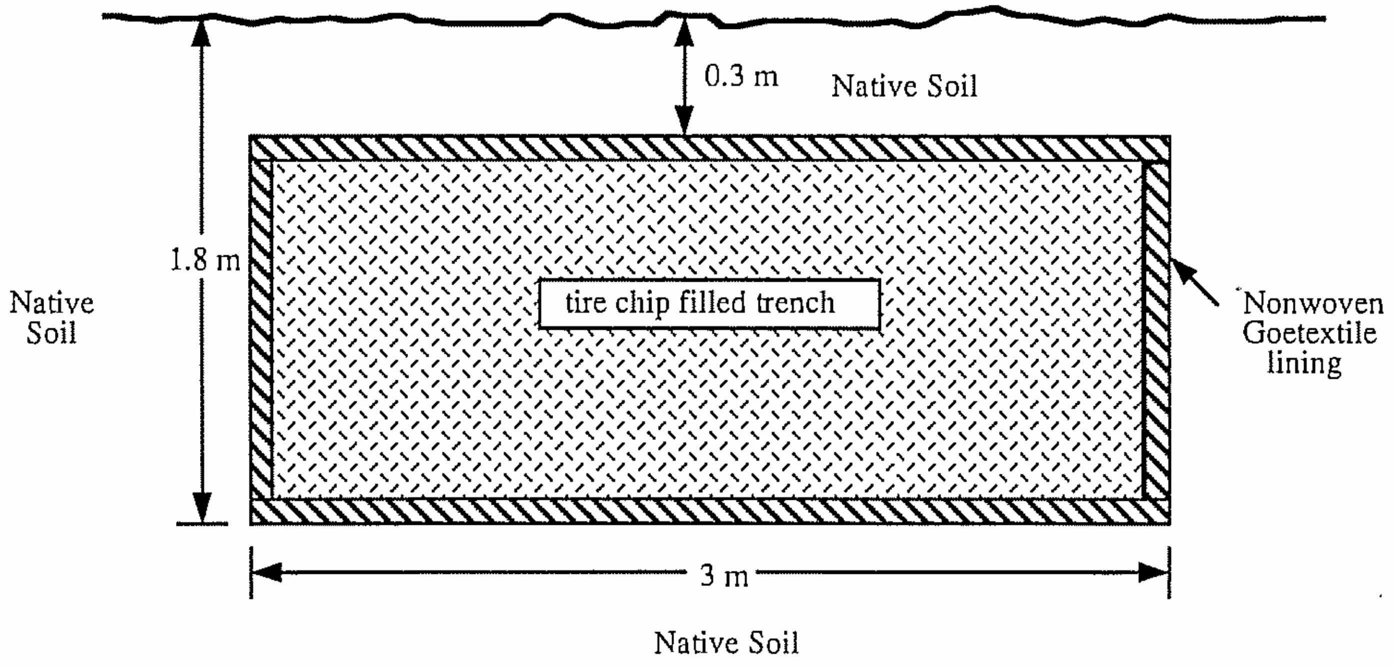
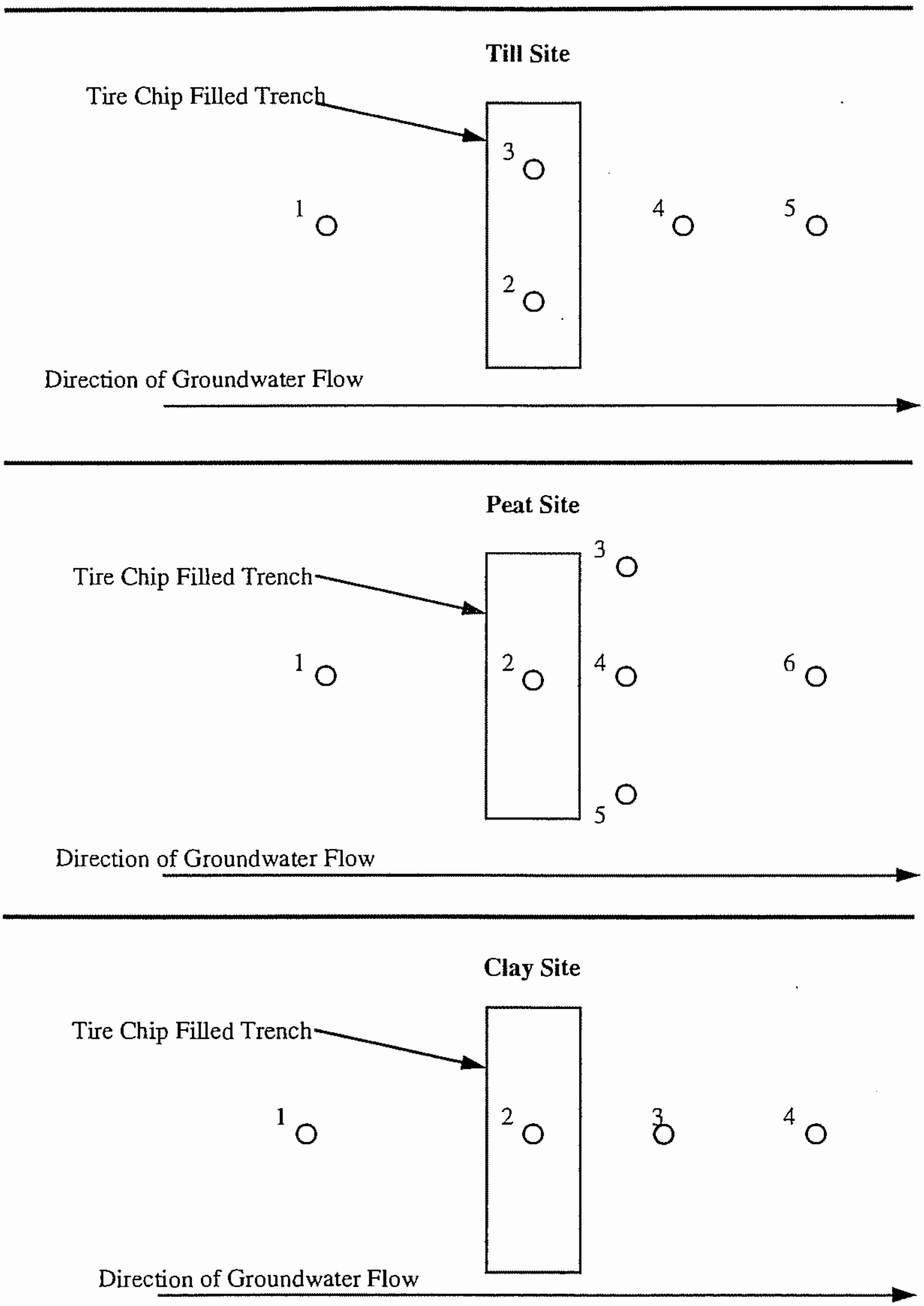


Figure 3.15

Schematic of Well Layout at Each Site



m (2 ft) wide at the bottom. The width of the trench varied somewhat as it flared out at the ground surface and there was a bulge in one side of the trench. The width at the ends of the trench (at the ground surface) was approximately 0.8 m (2.5 ft) and at the widest point (also at the ground surface) the trench was 1.2 m (4 ft) wide. The monitoring well within the trench was placed at approximately the widest point which was 1.4 m (4.5 ft) from one end of the trench. A plan view of the trench as-installed is included as Figure 3.16.

3.6.5.2 Till Site

At the till site, significant groundwater flow into the trench caused caving of the sidewalls during excavation. This caused the shape of the trench to be somewhat irregular. A plan view of the trench as-installed is presented in Figure 3.17. The depth of the trench before the caving started was 1.8 m (6 ft). After the caving, the depth varied from 1.8 m (6 ft) to 1.1 m (3.5 ft). The widths of the trench at the ends were 0.9 m (3 ft) and 0.5 m (1.7 ft). At the widest point after caving the trench was 1.8 m (6 ft) wide. The trench was 4.6 m (15 ft) long. One monitoring well was installed in the trench at the time of the tire chip installation (in the end away from the caving) and a second well was drilled in the opposite end of the trench at the same time the upgradient and downgradient wells were installed by Maine Test Borings, Inc., Brewer, Maine.

3.6.5.3 Peat Site

A plan view of the trench as-installed at the peat site is included as Figure 3.18. The width of trench varied from 0.8 m (2.6 ft) to 0.7 m (2.3 ft). The depth of the trench varied from 1.2 m (4 ft) to 1.7 m (5.5 ft). The peat site trench had fairly uniform dimensions and no problems due to caving were encountered. The trench filled with groundwater very rapidly. One monitoring well was installed in the tire chip trench at the time of installation of the tire chips. Since the peat site was very flat, it was difficult infer the direction of groundwater flow. This required that more monitoring wells be installed

Figure 3.16
Sketch of Clay Site Trench
As-Installed
(Plan View)

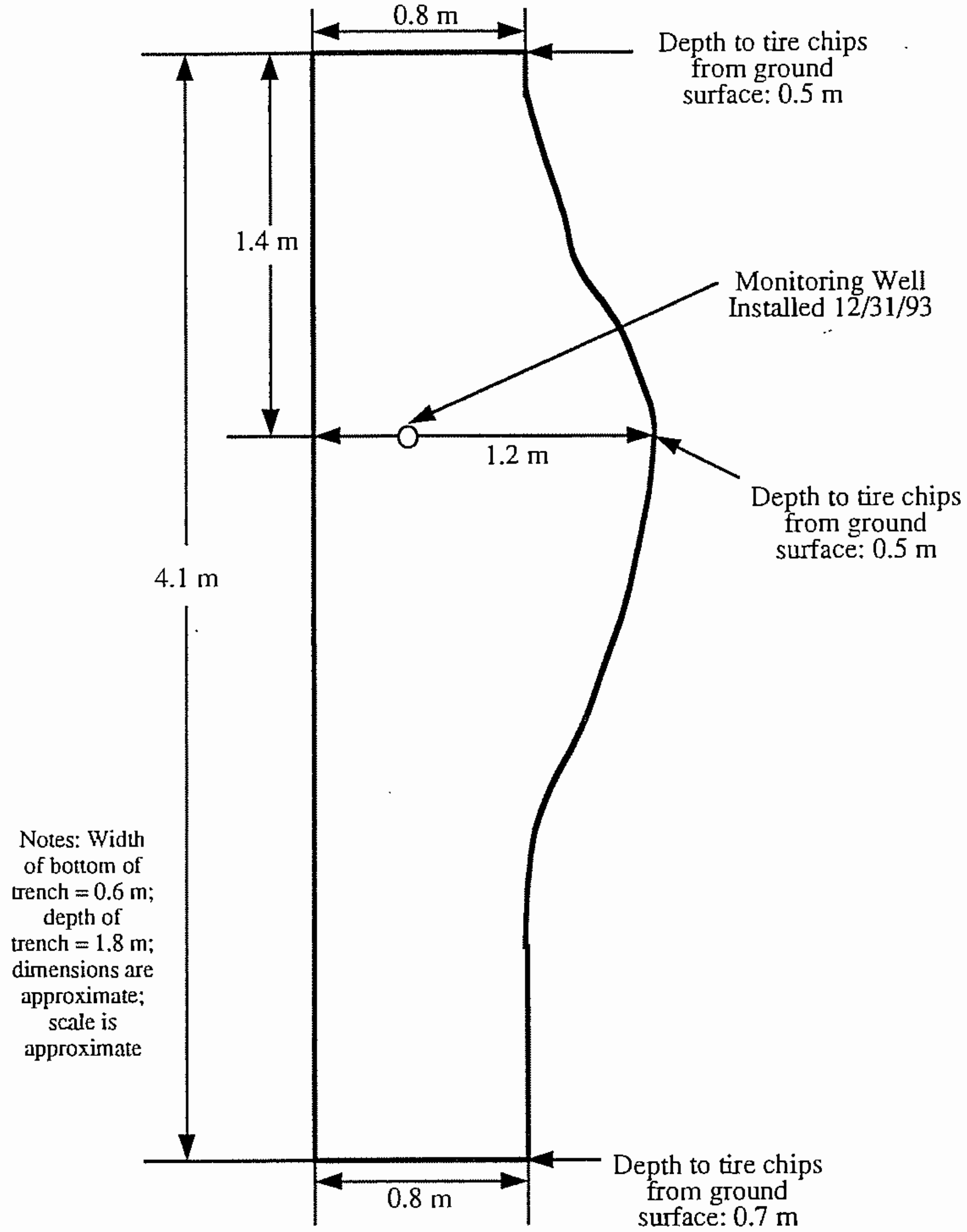


Figure 3.17
Sketch of Till Site Trench
As-Installed
(Plan View)

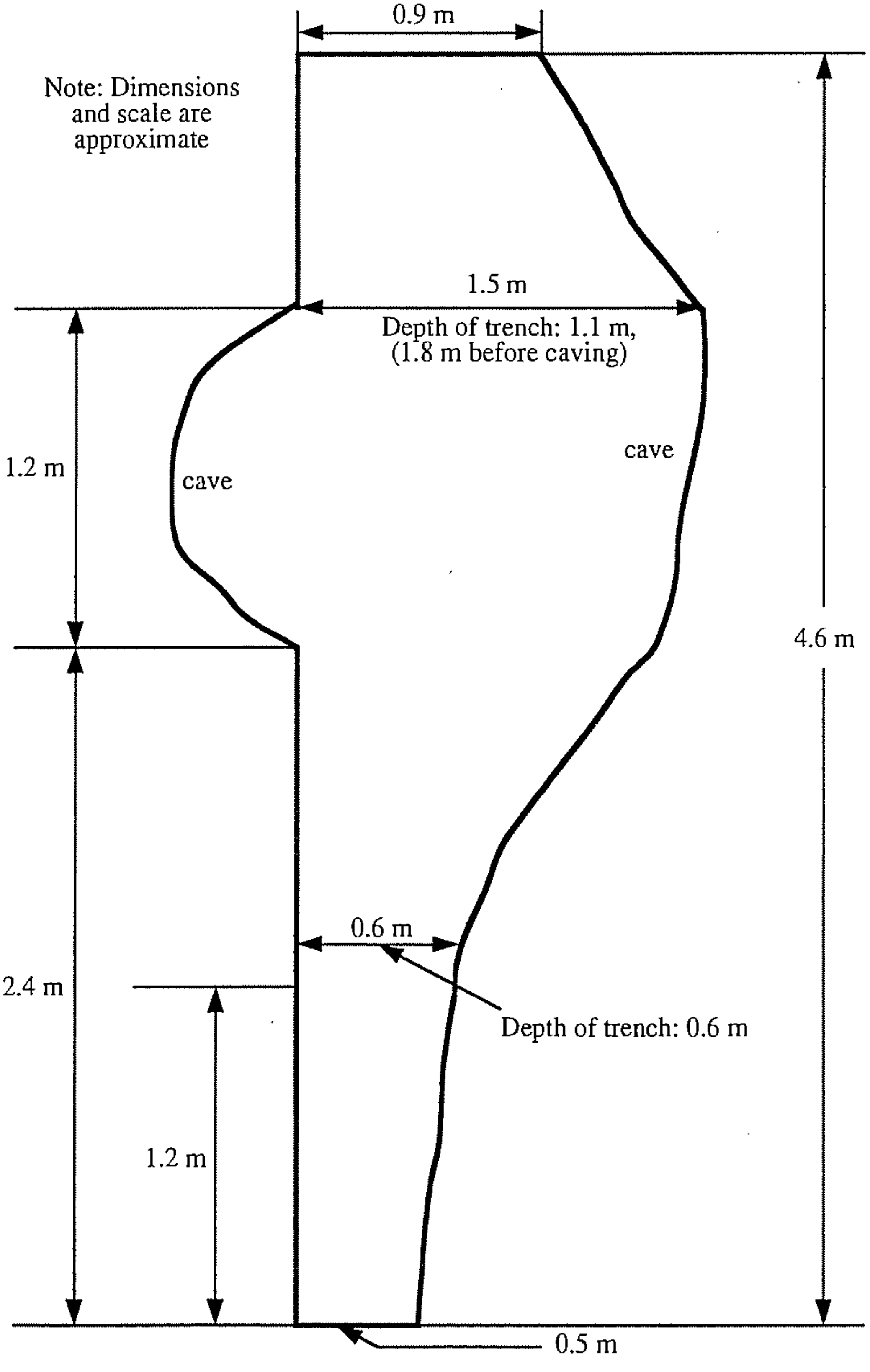
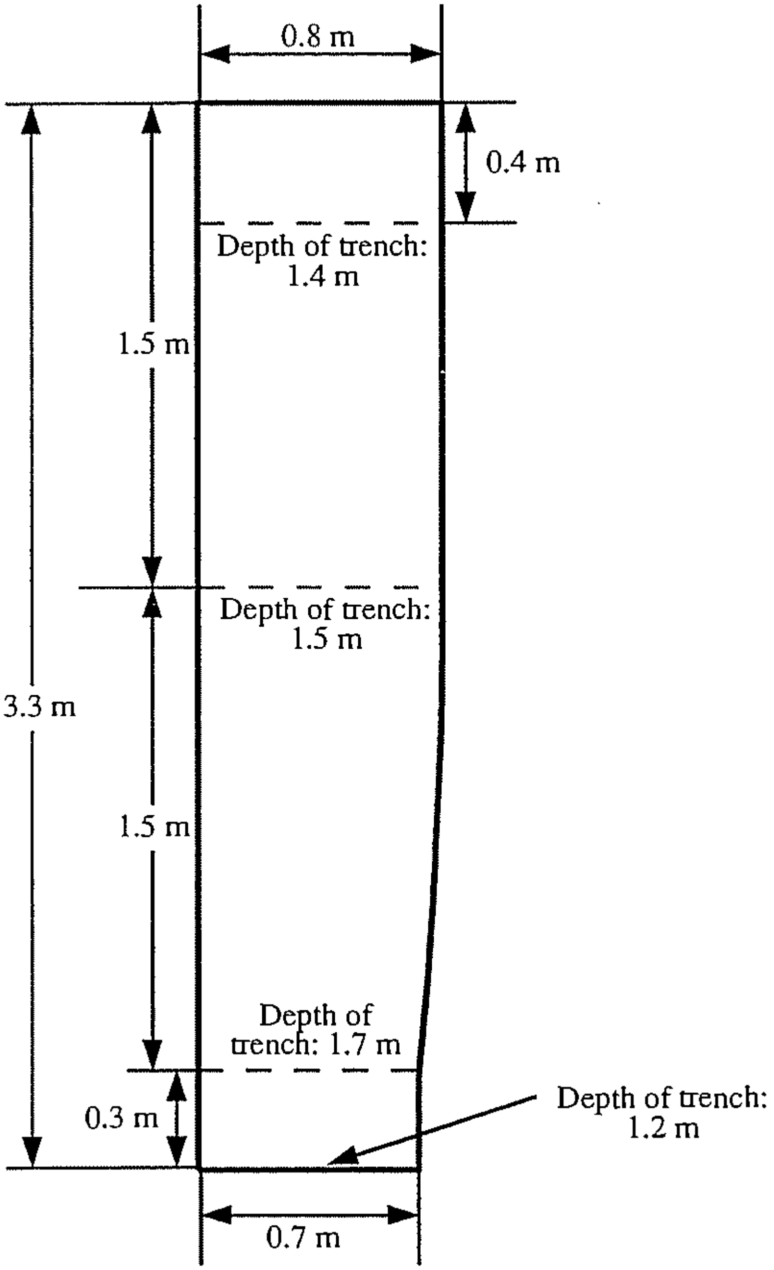


Figure 3.18
Sketch of Peat Site Trench
As-Installed
(Plan View)



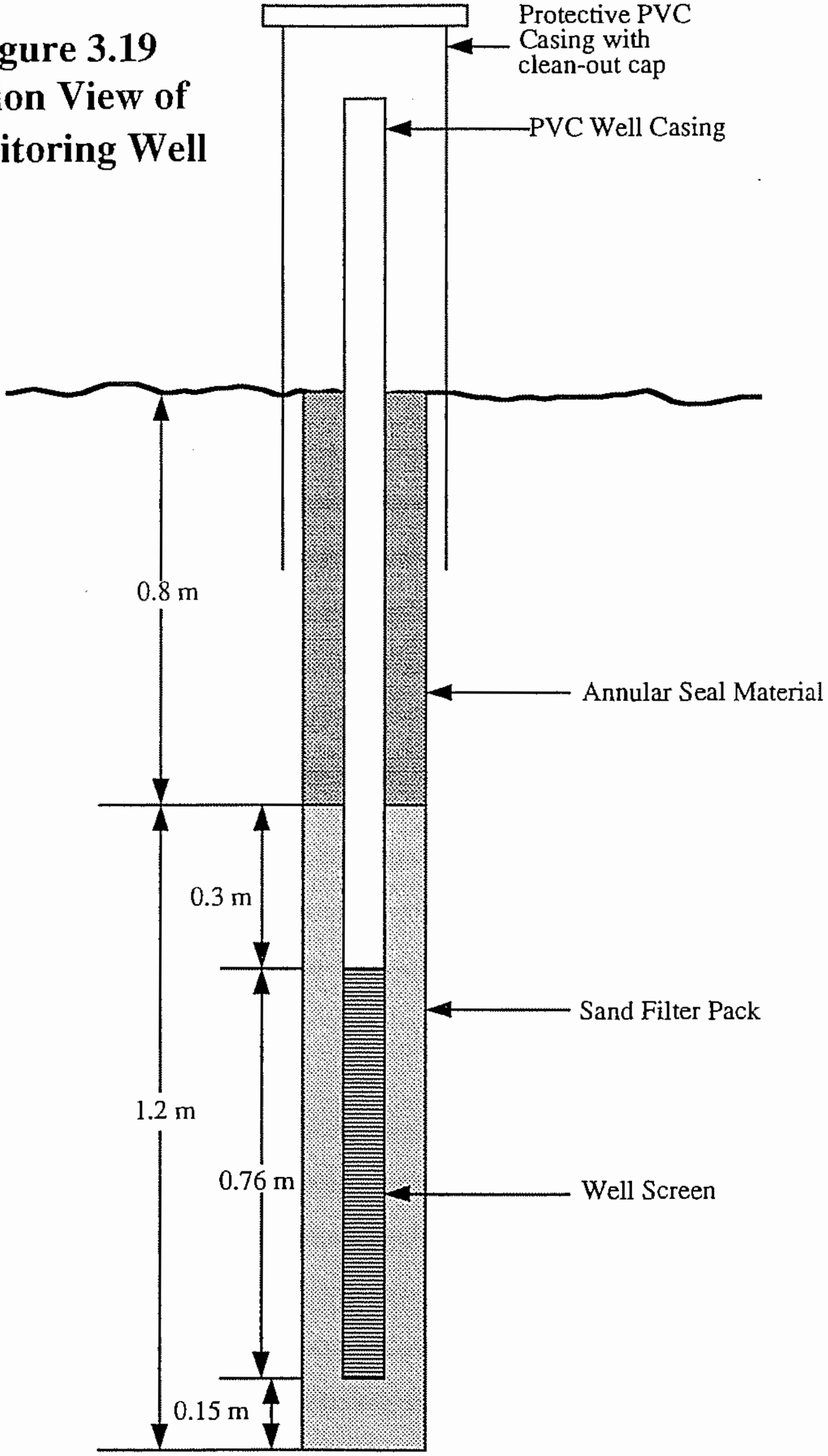
Note: Dimensions and scale are approximate downgradient of the tire chips to be sure that wells were in position to intercept any leachate plume that developed. Three monitoring wells were placed in a horizontal line parallel to the trench, and an additional well was placed further downgradient, approximately in-line with the well in the center of the trench.

3.6.6 Well Installation

The monitoring wells at the clay and peat sites were installed by hand using a 15 cm (6 in.) diameter bucket auger. The wells at the till site were drilled by Maine Test Borings, Inc. of Brewer, Maine. The drilled wells had a diameter of 10 cm (4 in.). A schematic of a typical monitoring well is presented as Figure 3.19. The casing used for the monitoring wells was 5 cm (2 in.) PVC pipe manufactured by Monoflex. To minimize vandalism and possible contamination, a section of 4 inch PVC pipe with clean-out type cap was used as a protective casing around the portion of the 5 cm (2 in.) pipe that extended above the ground surface. The bottom 0.76 m (2.5 ft) of each well was screened, using slotted pipe screen with opening size 0.010 inch (Monoflex). The end of the well screen was covered with a slotted PVC cap.

For the wells placed in soil, clean uniform silica sand (50 grit) was used as a filter pack. Gravity emplacement (free-fall) was used to place the artificial filter packs. The depths of the well holes were such that the bottom of the well screen would coincide with the approximate bottom of the tire chip installation. Before placing the well casing, 15 cm (6 in.) of sand was placed in the bottom of the well. After placing the well casing, the filter pack was placed surrounding the well screen and extending 0.3 m (1 ft) above the top of the screen. The annular space above the filter pack and extending to the ground surface was sealed. Bentonite chips were used to seal the wells at the peat site. The bentonite chips were placed by gravity, with tamping to eliminate bridging and clumping

Figure 3.19 Section View of Monitoring Well



of the chips. Powdered bentonite (approximately 10%) and cement (approximately 90%) grout slurry was used for the annular seals at the clay and till sites. Since the groundwater table was near the ground surface at both sites, a tremie pipe was used to place the grout seals. Bentonite chips were appropriate for the peat site because the water table is at the ground surface or within 0.3 m (12 in.) of the ground surface throughout the year. At the clay and till sites the water table could be below the seal during the drier portions of the year. For this situation a grout slurry is appropriate since it is less susceptible to cracking when it dries.

The wells within the tire chip trenches were placed directly into the tire chip matrix. The bottom 0.76 m (2.5 ft) of the wells were screened as with the other wells. No filter packs were needed since there were very little fines in the tire chips, and the turbidity of the samples from the trenches was expected to be low.

3.6.7 Well Development

The wells were developed during May and June of 1994. The monitoring wells were developed by bailer. Separate decontaminated HDPE bailers and nylon lines were used for each well. Surging action was created each time the bailer was introduced or removed from the well.

The goal of well development was to remove the fines from the filter pack. Since the surrounding soil formations for all of these wells contained substantial amounts of fines, well development was difficult. Some of the wells did not show any improvement in sample clarity upon bailing. In addition, the till and clay formations in which the tire chips were placed are low yield formations. Thus, the wells at these sites were often very slow to recharge, requiring that the development efforts continue over several days. Ideally, the development by bailer would continue until the water removed from the well was clear. Since the fines content of the surrounding formations was so high, it was impractical and impossible to obtain clear water from the wells. Development was continued until no noticeable improvement of water clarity was observed.

The volume of water removed from each well was measured in well volumes. The volume of each well was calculated by measuring the depth of groundwater in the well and knowing the inside diameter of the well casing. There was marked improvement in the clarity of the water from the upgradient well at the clay site (well C1) after 50 well volumes were removed. The 50 volumes were removed in one day. The water from the well within the trench (well C2) was comparatively clear: eight well volumes were bailed from this well. The down gradient wells at the clay site showed little improvement in visual quality after two days of bailing. A total of 50 and 17 well volumes were removed from the first and second downgradient wells (wells C3 and C4) respectively during the two days. At the till site, 50 well volumes were removed from each of the wells within the trench (wells T2 and T3), with significant turbidity in the drilled well (well T2) within the trench. The turbidity in this well within the trench was probably due to drilling too deeply into the underlying soil formation. A total of 14 well volumes were removed from the upgradient well (well T1) over five days. A total of 14 and 10 well volumes were bailed from the first and second downgradient wells (wells T4 and T5) respectively over four days. The second downgradient well (well T5) showed the most improvement in water quality after bailing.

3.6.8 Monitoring Plan

The monitoring wells installed at the three field sites were sampled quarterly. Metals samples were collected in early June 1994, late September 1994, mid-November

1994, and late April 1995. Organics samples were collected in mid-August 1994, mid-November 1994, and late April 1995.

3.6.9 Sampling Methods

Field samples were collected using an HDPE bailer and nylon line dedicated for each well. The bailers were left hanging in the wells (at the top) between sampling events. Before sample collection, it is recommended that three well volumes be bailed from the each well to ensure that the samples collected are a fresh inflow of groundwater. Three well volumes were bailed from all the wells at the peat site and the wells within the trenches at the till and clay sites before samples were collected. For the other wells at the till and clay sites the wells recharged very slowly; therefore, one well volume was bailed or the well was bailed dry before samples were collected. The sample collection, handling, and storage methods used were discussed in Section 3.2 above.

CHAPTER 4

TCLP STUDY OF TIRE CHIP LEACHABILITY

4.1 INTRODUCTION

For the laboratory leaching portion of this study four tire chip samples were subjected to the toxicity characteristic leaching procedure (TCLP). The four samples were: washed mixed steel and glass belted chips, unwashed mixed steel and glass belted chips, washed glass belted chips, and unwashed glass belted chips. The washing procedure is discussed in Section 3.4. TCLP was used to characterize the leaching potential of tire chips and to determine whether scrap tires are a hazardous waste. The results of the TCLP testing will be discussed in two parts: metals and organics.

TCLP (EPA Method 1311) is designed to determine the mobility of both organic and inorganic compounds present in liquid, solid, and multiphasic wastes (EPA, 1990). In this study, the waste (tire chips) was 100% solid. When using TCLP, leaching of metals, semivolatile organic compounds, pesticides, and herbicides takes place in an extraction vessel. A 100 gram sample is added to the extraction vessel and the appropriate amount of extraction fluid is added, then the extraction vessel is rotated on a tumbler at 30±2 revolutions per minute (rpm) for 18±2 hours. The leaching of volatile organic compounds takes place in a zero headspace extractor (ZHE), which is also rotated on a rotary tumbler at 30±2 revolutions per minute (rpm) for 18±2 hours. The purpose of the ZHE is to allow the leaching and subsequent separation of the waste and the extraction fluid without exposing the contents to air. The extraction fluid used is 0.1 M acetate buffer at pH 4.9 for acidic wastes and at pH 2.9 for alkaline wastes. The ratio of the extraction fluid to the solid phase of the waste is 20:1. After tumbling, the extraction fluid is filtered and further analyzed for contaminants of concern. For this study, the analytes were metals and semivolatile organic compounds and volatile organic compounds.

TCLP requires particle size reduction of the solid phase of the waste to passing the 9.5 mm (0.375 in.) sieve. The solid portion of the waste must be crushed, ground, or cut to meet the above criteria. When volatile organic compounds are of interest the waste and the particle size reduction equipment should be refrigerated, if possible, to 4 °C prior to size reduction. The exposure of the waste to the atmosphere should be minimized to avoid the loss of volatiles. The particle size reduction method used for the tire chips was to super cool them and then break them into smaller bits using a modified Proctor compaction hammer. The size reduction process was difficult due to the belts within the tires. Exposed belts that held bits of rubber were snipped with wire cutters. The size reduction process used is further detailed in Section 3.4.

The required chemical analyses and regulatory levels for TCLP are listed in Tables 2.1 (metals) and 2.2 (organics). Of the organic compounds listed in Table 2.2, methyl ethyl ketone, pyridine, and m-cresol were not tested for in the TCLP extracts in this study due to a miscommunication with ERI.

4.2 METALS RESULTS

The metals regulated under the toxicity characteristic (EPA Method 1311) are: arsenic, barium, cadmium, chromium, lead, mercury, selenium, and silver. The results for the TCLP metals for the four samples are summarized in Table 4.1. The results include the concentration of each metal in the TCLP extract and the concentration expressed as μg of contaminant per Kg of tire chips. The results are converted from concentration in μg/L in the extract to μg of contaminant per kilogram of waste (in this case, tire chip sample) by multiplying the concentration (μg/L) by the volume of extract (L) and then

Table 4.1

Toxicity Characteristic Leaching Procedure (TCLP)
Metals Results
Samples: Unwashed Mixed Chips, Washed Mixed Chips, Unwashed Fiberglass Belted Chips, Washed Glass Belted Chips
Note: Mixed Chips include Steel and Glass Belted Chips,
ND=Not Detected
Units: ug/L (ppb)

Unwashed Mixed Sample	**Concentration in Extract (ug/L)**	**Total Theoretical Leaching Potential (ug)**	**Normalized Concentration From Tires (ug/Kg)**	**TCLP Regulatory Limit (ug/L)**
Arsenic	ND	ND	ND	5000
Barium	149	298	2980	100000
Cadmium	107	214	2140	1000
Chromium	84	168	1680	5000
Lead	34	68	680	5000
Mercury	ND	ND	ND	200
Selenium	ND	ND	ND	1000
Silver	ND	ND	ND	5000
Washed Mixed Sample				
Arsenic	ND	ND	ND	5000
Barium	185	370	3700	100000
Cadmium	114	228	2280	1000
Chromium	82	164	1640	5000
Lead	32	64	640	5000
Mercury	ND	ND	ND	200
Selenium	ND	ND	ND	1000
Silver	ND	ND	ND	5000
Unwashed Fiberglass Sample				
Arsenic	ND	ND	ND	5000
Barium	357	714	7140	100000
Cadmium	20	40	400	1000
Chromium	34	68	680	5000
Lead	216	432	4320	5000
Mercury	ND	ND	ND	200
Selenium	ND	ND	ND	1000
Silver	ND	ND	ND	5000
Washed Fiberglass Sample				
Arsenic	ND	ND	ND	5000
Barium	259	518	5180	100000
Cadmium	15	30	300	1000
Chromium	36	72	720	5000
Lead	111	222	2220	5000
Mercury	ND	ND	ND	200
Selenium	ND	ND	ND	1000
Silver	ND	ND	ND	5000

dividing by the mass of tire chip sample (Kg). To convert this data, these operations reduce to multiplying the concentration in the extraction fluid by 20, which is also the ratio of the extraction fluid to the solid phase of the waste. Expressing the concentration in the form of µg of contaminant per Kg of tire chips allows comparison of the results from these TCLP tests to results from other studies that used a different test procedure. Arsenic, mercury, selenium, and silver were not detected in the leachates of any of the four samples tested. Although barium, cadmium, chromium, and lead were detected in all four samples, the concentrations were well below the TCLP regulatory limits. Lead and barium levels were higher in the leachates of the glass belted chip samples, while cadmium and chromium levels were higher in the leachates of the mixed chip samples. Since only one sample of each type was tested it was not possible to determine if these differences are due to the presence of steel belts in the mixed sample or other differences in the chemical makeup of the samples.

The process of washing the tire chips had relatively little effect on the concentrations of metals. The major exception was lead in the glass belted chip samples. In this case, lead was only about half (2220 µg/Kg vs. 4320 µg/Kg) in the washed samples. However, in the mixed chip samples, lead was virtually the same (640 µg/Kg vs. 680 µg/Kg) for both washed and unwashed samples. Conflicting results were obtained with barium, which was 38% lower in the washed glass belted sample, but was 20% higher in the washed mixed chip sample when compared to the respective unwashed samples.

These results indicate that tires have the potential to leach barium, cadmium, chromium, and lead. It is recommended that field and laboratory studies include analysis for these four metals.

4.3 ORGANIC RESULTS

The organic results are quantified as both the concentration in the TCLP extract and the concentration from the tire chips, as with the metals results. The only organic compound regulated by TCLP detected in the extracts was 1,2-dichloroethane. As shown in Table 4.2, 1,2-dichloroethane was detected in the unwashed mixed chips (140 µg/Kg), unwashed glass belted chips (140 µg/Kg), and washed glass belted chips (54 µg/Kg). 1,2-Dichloroethane was not detected in the washed mixed chip sample. The regulatory limit for 1,2-dichloroethane in the TCLP extract is 500 µg/L. The highest level of 1,2-dichloroethane found in extracts from the four tire chip samples was 7 µg/L. The organic compounds regulated by TCLP but not detected in the extracts along with their regulatory limits are listed in Table 4.3.

In addition to the organics regulated by TCLP, the samples were tested for other volatile organic compounds. The only additional volatile organic compound detected was dichloromethane, which was found in all four samples (Table 4.4). The concentrations of dichloromethane found in the TCLP extracts ranged from 4 µg/L to 10 µg/L, which corresponds to concentrations from the tire chips of 69 µg/Kg to 195 µg/Kg, respectively. Those additional volatile compounds not detected in the TCLP extracts are listed in Table 4.5.

Semivolatile organics not regulated by TCLP but detected in the extracts are listed with their concentrations expressed as µg per L of extract and µg per Kg of tire chips in Table 4.6. Aniline was detected in the unwashed mixed chips sample extract (19.4 µg/L) and in the washed glass belted chip sample extract (9.1 µg/L). Other semivolatile organic compounds that were tentatively identified were 1-(2-butoxyethoxy)-ethanol; benzonthiazole; 1H-isoindole-1,3(2H)-dione; 2(3H)-benzothiazolone; 4-(2-

Table 4.2
Toxicity Characteristic Leaching Procedure (TCLP) Volatile Organics Results
TCLP Volatile Organic Compounds Detected
1,2-Dichloroethane
Detection Limit = 2.5 ug/L

Sample	**TCLP Regulatory Limit (ug/L)**	**Concentration in Extract (ug/L)**	**Normalized Concentration from Tires (ug/Kg)**
Unwashed Mixed Chips	500	7	140
Washed Mixed Chips	500	ND	ND
Unwashed Glass Chips	500	7	140
Washed Glass Chips	500	3	54

Table 4.3
Toxicity Characteristic Leaching Procedure (TCLP) Organic Compounds Not Detected

Note: *=Quantitation Limit
NA=Not Applicable

Compound	TCLP Regulatory Limit (ug/L)	Drinking Water Standard (ug/L)
Benzene	500	5
Carbon Tetrachloride	500	5
Chlorobenzene	100000	100
Chloroform	6000	NA
o-Cresol	200000	NA
p-Cresol	200000	NA
1,4-Dichlorobenzene	7500	NA
1,1-Dichloroethylene	700	7
2,4-Dinitrotoluene	130*	NA
Hexachlorobenzene	130*	1
Hexachloro-1,3-butadiene	500	NA
Hexachloroethane	3000	NA
Nitrobenzene	2000	NA
Pentachlorophenol	100000	1
Tetrachloroethylene	700	5
Trichloroethylene	500	5
2,4,5-Trichlorophenol	400000	NA
2,4,6-Trichlorophenol	2000	NA
Vinyl Chloride	200	2

Table 4.4
Toxicity Characteristic Leaching Procedure (TCLP)
Volatile Organics Results
Compounds Detected but Not Regulated by TCLP

Compound	**Sample**	**Concentration in Extract (ug/L)**	**Normalized Concentration in Tires (ug/Kg)**
Dichloromethane	Unwashed Mixed Chips	6.0	120
Dichloromethane	Washed Mixed Chips	10.0	195
Dichloromethane	Unwashed Fiberglass Chips	5.0	95
Dichloromethane	Washed Fiberglass Chips	4.0	69

Table 4.5
Toxicity Characteristic Leaching Procedure (TCLP)
Volatile Organics Results
Compounds Not Detected Not Regulated by TCLP
For All TCLP Samples

Compound	MDL (ug/L)	Compound	MDL (ug/L)
Dichlorodifluoromethane	5.0	Ethylbenzene	2.5
Chloromethane	5.0	m-Xylene+p-Xylene	2.5
Bromomethane	5.0	o-Xylene	2.5
Chloroethane	5.0	Styrene(ethyl-benzene)	5.0
Trichlorofluoromethane	5.0	Bromoform	2.5
(E)-1,2-Dichloroethene	2.5	iso-Propylbenzene	2.5
(Z)-1,2-Dichloroethene	2.5	1,1,2,2-Tetrachloroethane	2.5
1,1-Dichloroethane	2.5	1,2,3-Trichloropropane	2.5
MTBE	2.5	Bromobenzene	2.5
2,2-Dichloropropane	2.5	n-Propylbenzene	2.5
Bromochloromethane	2.5	2-Chlorotoluene	2.5
1,1,1-Trichloroethane	2.5	1,3,5-Trimethylbenzene	2.5
1,1-Dichloropropene	2.5	4-Chlorotoluene	2.5
1,2-Dichloropropane	2.5	tert-Butylbenzene	2.5
Dibromomethane	2.5	1,2,4-Trimethylbenzene	2.5
Bromodichloromethane	5.0	sec-Butylbenzene	2.5
(Z)-1,3-Dichloropropene	2.5	4-iso-Propyltoluene	2.5
Toluene	2.5	1,3-Dichlorobenzene	5.0
(E)-1,3-Dichloropropene	2.5	n-Butylbenzene	5.0
1,1,2-Trichloroethane	2.5	1,2-Dichlorobenzene	2.5
1,3-Dichloropropane	2.5	1,2-Dibromo-3-chloropropane	5.0
Dibromochloromethane	2.5	1,2,4-Trichlorobenzene	5.0
1,2-Dibromoethane	2.5	Naphthalene	2.5
1,1,1,2-Tetrachloroethane	2.5	1,2,3-Trichlorobenzene	2.5

Table 4.6
Toxicity Characteristic Leaching Procedure (TCLP) Semivolatile Organics Compounds Detected but Not Regulated by TCLP

Notes: *=Tentatively Identified, **=Estimated Concentration (ug/L/ug/Kg), ND=Not Detected

Compound	Unwashed Mixed Chips**	Washed Mixed Chips**	Unwashed Glass Belted Chips**	Washed Glass Belted Chips**
1-(2-Butoxyethoxy)-ethanol*	143 / 2860	ND / ND	ND / ND	40 / 800
Benzothiazole*	286 / 5720	214 / 4280	286 / 5720	200 / 4000
1H-Isoindole-1,3(2H)-dione*	286 / 5720	ND / ND	ND / ND	50 / 1000
2(3H)-Benzothiazolone*	143 / 2860	143 / 2860	286 / 5720	100 / 2000
2,5-Cyclohexadiene-1,4-dione*	ND / ND	ND / ND	114 / 2280	ND / ND
4-(2-Benzothiazolythio)-morpholine*	ND / ND	ND / ND	143 / 2860	100 / 2000

benzothiazolylthio)-morpholine; and 2,5-cyclohexadiene-1,4-dione. The estimated concentrations for these compounds were higher than the concentrations of aniline. The highest estimated concentration was 286 µg/L for benzothiazole, 1H-isoindole-1,3(2H)-dione, and 2(3H)-benzothiazolone. The compound 4-(2-benzothiazolythio)-morpholine is a main ingredient in a commercial blend used as a delayed-action accelerator in rubber processing (Taylor and Son, 1982). According to Abernethy (1994), 2,5-cyclohexadiene-1,4-dione is likely an oxidation product of aniline or hydroquinone. Therefore, it seems reasonable to expect leaching of these compounds when using tire chips as construction materials. Table 4.7 lists the additional semivolatile organic compounds not detected in the TCLP extracts for the four tire chip samples. None of the TCLP regulatory limits were exceeded for organic compounds.

4.4 COMPARISON TO PREVIOUS STUDIES

4.4.1 Metals

Two previous studies in which TCLP testing for metals was done are the Scrap Tire Management Council Study by Radian Corporation (1989) (see Table 2.11) and the Virginia Department of Transportation Study by Ealding (1992) (see Table 2.15). The Scrap Tire Management Council Study tested for arsenic, barium, cadmium, chromium, lead, mercury, selenium, and silver. The Virginia DOT Study tested for the TCLP metals cadmium, chromium, lead, and silver. Additional metals tested in that study were aluminum, calcium, copper, iron, magnesium, nickel, tin, and zinc. None of the TCLP metals tested in those studies exceeded the TCLP regulatory limits, which is consistent with the findings of the University of Maine Study.

Lead, chromium, and barium were found consistently in the extracts in the University of Maine Study and in the Radian Study. The lead levels in the University of Maine Study varied from 32 µg/L to 216 µg/L, in the Radian Study from 2 µg/L to 16

Table 4.7
Toxicity Characteristic Leaching Procedure (TCLP)
Semivolatile Organics
Compounds Not Detected Not Regulated by TCLP
Note: MRL=Method Reporting Limit (ug/L)

Compound	MRL (ug/L)	Compound	MRL (ug/L)
2-Chlorophenol	7	3-Nitroaniline	36
bis(2-Chloroethyl)ether	7	2,4-Dinitrophenol	36
phenol	7	Dibenzofuran	36
1,3-Dichlorobenzene	7	2,4-Dinitrotoluene	7
1,4-Dichlorobenzene	7	4-Nitrophenol	36
1,2-Dichlorobenzene	7	Fluorene	7
bis(2-Chloroisopropyl)ether or 2,2'	7	4-Chlorophenyl phenyl ether	7
2-Methylphenol or o-Cresol	7	Diethyl phthalate	14
Hexachloroethane	7	4-Nitroaniline	36
n-Nitrosode-n-propylamine	7	4,6-Dinitro-2-methylphenol	14
4-Methylphenol or p-Cresol	14	n-Nitrosodiphenylamine	7
Nitrobenzene	7	4-Bromophenyl phenyl ether	7
Isophorone	14	Hexachlorobenzene	7
2-Nitrophenol	7	4-Aminobiphenyl	7
2,4-Dimethylphenol	7	Pentachlorophenol	36
a,a-Dimethylphenethylamine	7	Phenanthrene	7
bis(2-Chloroethoxy)methane	7	Anthracene	7
2,4-Dichlorophenol	7	Carbazole	7
1,2,4-Trichlorobenzene	7	di-n-Butyl phthalate	7
Naphthalene	7	Fluoranthene	7
4-Chloroaniline	14	Pyrene	7
Hexachlorobutadiene	7	Butyl benzyl phthalate	7
2-Methylnaphthalene	7	benzo(a)Anthracene	7
4-chloro-3-Methylphenol	7	Chrysene	7
Hexachlorocyclopentadiene	7	3,3'-Dichlorobenzidine	14
2,4,6-Trichlorophenol	7	bis(2-Ethylhexyl)phthalate	14
2,4,5-Trichlorophenol	7	di-n-Octyl phthalate	14
2-Chloronaphthalene	7	benzo(b)Fluoranthene	7
Safrole	7	benzo(k)Fluoranthene	7
2-Nitroaniline	36	benzo(a)Pyrene	7
Acenaphthylene	7	indeno(123-cd)Pyrene	7
Dimethyl phthalate	14	dibenzo(a,h)Anthracene	7
2,6-Dinitrotoluene	7	benzo(ghi)Perylene	7
Acenaphthene	7		

µg/L, and was found at 19.6 µg/L in the Virginia Study. Chromium levels in the Radian Study varied from 12 µg/L to 48 µg/L, in the University of Maine Study from 34 µg/L to 84 µg/L, and was detected at 2.8 µg/L in the Virginia Study. The barium levels found in the Radian Study varied from 21 µg/L to 590 µg/L, while the barium levels in the University of Maine Study varied from 149 µg/L to 357 µg/L. Cadmium levels in the extracts in the University of Maine Study varied from 15 µg/L to 114 µg/L and was present at 1.55 µg/L in the extract in the Virginia Study, however, cadmium was not detected in the Radian Study. Mercury was detected in two of the Radian Study tire products, but was not detected in any of the samples in the University of Maine study. Silver, arsenic, and selenium were not detected in any of the tire product extracts in the Radian Study, which is consistent with the findings of the Maine Study. Silver was also not found in the Virginia DOT Study. The additional metals tested for in the Virginia Study aluminum, calcium, copper, iron, magnesium, nickel, tin, and zinc were found at concentrations of 148 µg/L, 1.00 mg/L, 83 µg/L, 120 mg/L, 0.108 mg/L, 39.7 µg/L, <25 µg/L, and 10.6 mg/L, respectively.

The results of these studies consistently show that scrap tires do not exceed TCLP regulatory limits for metals. Although the levels of the metals are below TCLP regulatory limits, the studies indicate that the TCLP metals of concern with tire leaching are: barium, cadmium, chromium, and lead.

4.4.2 Organics

The Radian Study also included analysis for organic compounds. The compounds detected below the TCLP regulatory limits in the Radian Study were carbon disulfide, methyl ethyl ketone, toluene, 1,1,1-trichloroethane, and phenol. None of these compounds were found in this study. The only TCLP organic compound found below the TCLP regulatory limit for this study was 1,2-dichloroethane and its concentrations were well below the TCLP regulatory limit (500 µg/L). Aniline was also detected in two of the four samples studied in this project, but aniline is not regulated by TCLP. Several other semivolatile organics were tentatively identified in the extracts. Of the identified or tentatively identified semivolatile organic compounds, aniline; benzothiazole; 2(3H)-benzothiazolone; 4-(2-benzothiazolylthio)-morpholine; and 2,5-cyclohexadiene-1,4-dione were also identified in a toxicity study by Abernethy (1994). Aniline and 2,5-cyclohexadiene-1,4-dione are used as antidegradants in the rubber industry, while benzothiazoles are used as accelerators (Fishbein, 1991).

The results of these studies show that tires do not exceed the TCLP regulatory limits for organic compounds. However, they do indicate that tire chips have the potential to leach organic compounds.

4.5 SUMMARY

In this study and in the studies reviewed, none of the TCLP regulatory limits were exceeded for metals or organics; therefore, tire chips are not classified as a hazardous waste based on the toxicity characteristic. The TCLP testing does however indicate leaching potential for some organic compounds and some metals. The metals of concern with scrap tire leaching indicated in the TCLP portion of this study were barium, cadmium, chromium, and lead. These metals were also cited as likely metals of concern in previous studies, and in addition, one study also indicated leaching potential for mercury. Leaching potential of organic compounds used as accelerators (benzothiazoles) and antidegradants (aniline and 2,5-cyclohexadiene-1,4-dione) in the rubber processing industry was also indicated by the TCLP portion of this study. In addition, dichloromethane, 1-(2-butoxyethoxy)-ethanol, and 1H-isoindole-1,3(2H)-dione were detected in the TCLP portion of this study.

CHAPTER 5

LONG TERM LABORATORY STUDY OF TIRE CHIP LEACHABILITY

5.1 INTRODUCTION

The long term study of tire leachability was a batch reactor study in which field conditions were simulated in the laboratory. The reactors used were 20 L (5 gal) glass Pyrex bottles. The reactors were sealed with rubber stoppers and held at ambient temperature (15°C to 20°C) in the dark for approximately ten months. Eight reactors were set up: three control reactors that contained soil and distilled water; three mixed reactors that contained soil, tire chips, and distilled water; and two reactors that contained tire chips and distilled water. Three types of soil were used in the batch reactor study: glacial marine clay (locally known as Presumpscot Formation), glacial till, and fibrous peat. The soil samples were bulk samples collected from the three field sites used in this project. The tire chips had a maximum nominal size of 75 mm (3 in.), and were made from a mixture of steel and glass belted tires. The chips were donated by Pine State Recycling in Nobleboro, Maine. The purpose of this experiment was to allow direct comparison of the metals, semivolatile organics, and volatile organics found in the jars with soil and distilled water only to the corresponding jars with mixtures of soil, tire chips, and distilled water. The procedure used when setting up the reactors and a summary of the contents of each reactor are included in Section 3.5.1.

During the ten month storage period, the reactors were not mixed or disturbed. The reactors that contained tire chips and distilled water and the reactors that contained mixtures of soil, tire chips, and distilled water produced gas. Some of the reactors, particularly the reactor that contained peat, tire chips, and distilled water, produced sufficient gas to dislodge the rubber stopper from the top of the reactor. The gas production was probably due to microbial activity. In addition to gas production, the reactors that contained tire chips also formed an orange residue around the neck of the reactor bottles. This residue was absent in the control (soil and distilled water only) reactors. The sampling methods used to collect water and soil samples from the reactors are discussed in Section 3.5.2.

Both dissolved and total metals were measured in the reactor water samples. Dissolved metals are those metals measured after the sample has been passed through a 0.45 μm filter. The sample is acidified after the filtration. Samples to be analyzed for total recoverable metals are not filtered and are subjected to rigorous digestion. Total metals include all metals that are organically or inorganically bound both in dissolved and particulate form. In the reactor study, total metals will include metals that are associated with particulate matter in the samples. The source of these metals may be the tire chips or the soil particles.

The mass of soil and tire chips and the volume of distilled water added to each reactor were known, so by comparing to the control reactors containing only soil and water, the tire chip contribution to the concentrations of metals in the mixed reactors could be estimated. The contributions of the soil and the tire chips could be expressed as μg of contaminant per Kg of material (either soil or tire chips). To convert the concentration in the water to concentration from the soil (or tire chips), the concentration (in μg/L) was multiplied by the volume of water (in liters) added to the reactor and then divided by the mass of soil (in Kg) (or mass of tire chips in Kg) added to the reactor. The results expressed in μg of contaminant per Kg of tire chips (or soil) could then be compared to the results of other laboratory leaching studies.

5.2 METALS RESULTS

5.2.1 Soil Samples

For the reactor study, soil samples from each of the reactors that contained soil were digested in triplicate according to EPA Method 3050 (EPA, 1987). The soil digests results for metals with primary drinking water standards are presented as Table 5.1. The soil digest results for metals with secondary drinking water standards and metals without drinking water standards are presented as Table 5.2. The results in Tables 5.1 and 5.2 are presented as the average and standard deviation of the three concentrations for each metal tested for each reactor. Since soil samples were digested in triplicate it is possible to use statistical analysis to determine whether the data for the samples from the reactors that contained tire chips came from the same population as the data for the samples from the control reactors (soil only). Since the sample size was three, this analysis must be used with caution. A larger sample size is preferred.

The first step in the analysis was to test each set of three data points (three digests per reactor) for normality. The Shapiro-Wilk Test was used to test for normality (Shapiro and Wilk, 1965). The null hypothesis was that the data is normally distributed. A 95% confidence interval was used. Any sets of data (n=3) that had two values that were the same were not from a normal distribution. Several of the data sets failed the Shapiro-Wilk test, meaning that the null hypothesis was rejected, and the data was not from a normal distribution. The data sets that were not normally distributed were 1)till: sodium, copper, and cadmium 2) till and tire chips: aluminum and 3) clay: copper. For these samples the Wilcoxon-Mann-Whitney Rank Sum Test (Smith, 1988) was used to test the null hypothesis that the data sets for the reactors containing tire chips and soil came from the same distribution as the data from the corresponding control reactor. The null hypothesis was accepted for each of these test cases. This indicates that there was no statistically

Table 5.1
Laboratory Simulation of Ground Conditions
Reactor Study
Soil Digests Samples (in triplicate)
Results Presented as Average and Standard Deviation
Total Metals with Primary Drinking Water Standards
Note:* indicates approximate average and standard deviation for samples with concentrations below the method detection limit

	As (mg/Kg)	Ba (mg/Kg)	Cd (ug/Kg)	Cr (mg/Kg)	Cu (mg/Kg)	Pb (mg/Kg)
Clay						
Average Concentration	13.8	49.43	<513*	36.47	40.6	8.9
Standard Deviation	1.757	2.669	<101.65*	0.666	23.3	0.6245
Clay and Tire Chips						
Average Concentration	16.97	46.9	<504*	33.37	21.93	7.583
Standard Deviation	7.975	10.39	<146.37*	2.219	1.626	0.9866
Till						
Average Concentration	7.87	27.3	<395*	25.2	13.77	5.173
Standard Deviation	1.49	1.916	<91.82*	1.082	0.2309	0.625
Till and Tire Chips						
Average Concentration	7.383	26.23	<395.67*	23.6	15.13	4.883
Standard Deviation	0.5181	1.504	<66.154*	0.9165	0.8327	0.2
Peat						
Average Concentration	<5.47*	33.57	<1823.3*	<0.892	6.233	2.063
Standard Deviation	<0.9617*	2.926	<318.96*	<0.1065	1.42	0.1701
Peat and Tire Chips						
Average Concentration	<7.95*	40.53	<2646.7*	5.743	21.83	11.19
Standard Deviation	<1.534*	1.06	<512.48*	0.792	0.8083	1.22

Table 5.2
Laboratory Simulation of Ground Conditions
Reactor Study
Soil Digests Samples (in triplicate)
Results Presented as Average and Standard Deviation
Total Metals with Secondary Drinking Water Standards or with no Standard
Note: * indictaes approximate average and standard deviation for samples with concentrations below the method detection limit

	Ag (mg/Kg)	**Al (mg/Kg)**	**Ca (mg/Kg)**	**Fe (mg/Kg)**	**Mg (mg/Kg)**	**Mn (mg/Kg)**	**Na (mg/Kg)**	**Zn (mg/Kg)**
Clay								
Average Concentration	1.07	18433	2736.7	17567	4846.7	175.67	351.67	56.733
Standard Deviation	0.6956	404.15	20.817	3442.9	72.342	4.7258	27.647	8.6431
Clay and Tire Chips								
Average Concentration	1.01	16900	2676.7	18733	4466.7	188.67	352.67	60.067
Standard Deviation	0.8848	1637.1	255.02	2606.2	115.04	5.6862	31.086	1.3614
Till								
Average Concentration	0.6033	11023	2350	14400	4510	315	342.33	35.867
Standard Deviation	0.3	1140.5	280	1600	219.32	18.52	10.97	0.6429
Till and Tire Chips								
Average Concentration	<0.3317*	10600	2223.3	14067	4406.7	355.33	301	42.9
Standard Deviation	<0.056*	173.21	86.217	1955.3	356.42	32.532	10.44	3.3422
Peat								
Average Concentration	5.01	3380	16600	3010	1643.3	149.33	445.33	37.933
Standard Deviation	2.827	330.45	1216.6	286.88	119.3	13.317	110.96	9.9299
Peat and Tire Chips								
Average Concentration	<2.463*	3623.3	15500	36467	1556.7	302.67	587	395
Standard Deviation	<0.435*	72.342	793.73	4209.9	45.092	13.051	75.505	15.524

significant difference in the concentrations from the reactors with tire chips when compared to the control reactors for 1) aluminum, cadmium, copper, and sodium for the till samples and 2) copper for the clay samples.

The remainder of the data sets were normally distributed. The t-statistic (Smith, 1988) was used to test the null hypothesis that the data from the mixed reactors came from the same population as the data from the control reactors (i.e. the mean of the three results for the control reactor would equal the mean of the three results for the corresponding mixed reactor for each of the three soil types for each of the metals tested). The assumptions made when using the student t test are that the data is normally distributed and that the population standard deviations are equal. The rejection criteria was set at a 95% confidence interval. The null hypothesis (H_0) was that $\mu_c = \mu_{tc}$ where μ_c is the mean of the control (soil and distilled water only) and μ_{tc} is the mean of the mixed sample with soil, tire chips, and distilled water (i.e. the data is from the same population). The alternate hypothesis (H_a) was that $\mu_c < \mu_{tc}$ (i.e. the control mean is less than the mean of the mixed samples with tire chips and therefore tire chips may have an effect on the metal concentrations). The pooled sample variance and the t-statistic for each set of reactors for each metal are presented in Table 5.3. The pooled sample variance is the combined variance estimate of the samples. The individual variances are combined in proportion to their degrees of freedom. Also noted in Table 5.3 for each case is reject or not reject the null hypothesis.

5.2.1.1 Metals with Primary Drinking Water Standards

The data analysis described above showed that barium, chromium, copper, and lead sorbed to the soil were increased in the mixed reactor containing peat, tire chips, and distilled water when compared to the control reactor that contained peat and distilled water. Copper was the only metal with a primary drinking water standard that was sorbed

Table 5.3
Laboratory Simulation of Ground Conditions
Reactor Study
Soil Digests Samples (in triplicate)
Results for Student t Test
95% Confidence Interval
t95 = -2.132
Notes: NA=Not Applicable, Rej=Reject the null hypothesis, No rej=Cannot reject the null hypothesis

	As	Ba	Cd	Cr	Cu	Pb	Ag	Al	Ca	Fe	Mg	Mn	Na	Zn
Clay														
Sp^2	33.345	57.607	NA	2.683	272.74	0.6817	633331	1E+06	25533	9E+06	9233.3	27.333	865.33	38.278
t	-0.6716	0.4091	NA	2.317	1.384	1.9531	0.0923	1.575	0.4599	-0.4682	4.843	-3.0454	-0.0416	-0.8578
	No Rej	No Rej	NA	No Rej	No Rej	No Rej	No Rej	No Rej	No Rej	No Rej	No Rej	Rej	No Rej	No Rej
Till														
Sp^2	1.244	2.967	NA	1.005	0.3733	0.2153	46569	665317	42917	3E+06	87567	700.67	114.67	5.7917
t	0.5344	0.7584	NA	1.955	-2.739	0.7654	1.541	0.6356	0.7488	0.2285	0.4277	-1.866	4.727	-3.579
	No Rej	No Rej	NA	No Rej	Rej	No Rej	No Rej	No Rej	No Rej	No Rej	No Rej	No Rej	No Rej	Rej
Peat														
Sp^2	NA	4.843	NA	0.3194	1.335	1.335	4E+06	57217	1E+06	9E+06	8133.3	173.83	9006.7	169.8
t	NA	-3.877	NA	-10.514	-16.537	-16.537	1.542	-1.246	1.312	-13.733	1.177	-14.243	-1.828	-35.56
	NA	Rej	NA	Rej	Rej	Rej	No Rej	No Rej	No Rej	Rej	No Rej	Rej	No Rej	Rej

to the soil in higher concentrations in the mixed till, tire chips, and distilled water reactor samples when compared to the samples from the control reactor containing till and distilled water. In the clay there was no statistically significant increase in metals with primary standards that were sorbed to the soil. This indicates higher mobility of metals in clay due to less sorption to the soil particles. These results indicate that in peat, and to a lesser extent in till, the tire chips were leaching metals with primary standards that were sorbing to the soils under the conditions in the reactors. The metals were leached from the tire chips and then sorbed to the soil particles, therefore increasing the metal concentrations seen in the digestates of the soil samples.

The control reactor sample digest data indicated that several metals with primary drinking water standards could leach from the soils. At the clay and till sites arsenic, barium, chromium, copper, and lead were found in the soil. The peat samples contained barium, copper, and lead.

5.2.1.2 Metals with Secondary Drinking Water Standards or with No Standard

The data analysis described above showed that iron, manganese, and zinc were significantly higher in the soil samples from some of the mixed soil and tire chip reactors than in the soil samples from the corresponding control reactors. Iron, manganese, and zinc sorbed to the soil were significantly higher in the samples from the mixed peat, tire chips, and distilled water reactor than in the samples from the control reactor that contained peat and distilled water. The manganese concentration was also greater in the mixed clay reactor samples and the zinc concentration was increased in the mixed till reactor samples, when compared to the corresponding control reactor samples.

Analysis of the control reactor digestates indicated that all of the metals with secondary standards were naturally present in all three soil types. The metals tested were aluminum, calcium, iron, magnesium, manganese, silver, sodium, and zinc.

5.2.2 Water Samples

The reactor samples were analyzed for eight metals that have primary drinking water standards. The measured concentrations are summarized in Table 5.4. In addition, the reactor water samples were analyzed for five metals with secondary drinking water standards and three metals with no standard. These results are summarized in Table 5.5.

5.2.2.1 Metals with Primary Drinking Water Standards

Dissolved chromium was detected in three of the eight reactor water samples. The highest level of dissolved chromium found was 14 μg/L (till and tire chips sample), which is approximately 14% of the primary drinking water standard for chromium (100 μg/L). In each of the control reactors (soil and distilled water only), dissolved chromium was below the method detection limit (2 μg/L), while in the mixed reactors (containing soil, tire chips, and distilled water) chromium levels ranged from 2 μg/L to 14 μg/L. Dissolved chromium was not detected in the samples from either of the reactors that contained only tire chips and distilled water. The concentration of chromium from the tire chips ranged from <4 μg/Kg to 29 μg/Kg.

Total chromium was detected in all eight of the reactor samples. Total chromium levels were five to 13 times higher in the samples from the reactors that contained soil and tire chips than the samples from the reactors that contained only soil. The highest chromium level found was 67 μg/L in the sample from the mixed clay and tire chips reactor, the total chromium concentration in the corresponding control reactor (clay and distilled water only) was 12 μg/L. The concentration of total chromium from the tire

Table 5.4
Laboratory Simulation of Ground Conditions
Reactor Study
Water Samples
Metals with Primary Drinking Water Standards

Units: ug/L (ppb)
Notes: NA = Not Available, PDWS = Primary Drinking Water Standard (ug/L)

	As	Ba	Cd	Cr	Cu	Hg	Pb
	Diss/Total	Diss/Total	Diss/Total	Diss/Total	Diss/Total	Diss/Total	Diss/Total
PDWS	50	2000	5	100	1300	2	15
Detection Limit	15	1	5	2	4	0.0001	15
Sample							
Clay	<15 / <15	<1 / 24	<5 / <5	<2 / 12	<4 / 15	<0.0001 / NA	<15 / <15
Clay and Tire Chips	18.9 / 38.4	<1 / 72	<5 / <5	8 / 67	<4 / 32	<0.0001 / NA	<15 / <15
Peat	<15 / <15	3 / 10	<5 / <5	<2 / <2	<4 / <4	<0.0001 / NA	<15 / <15
Peat and Tire Chips	<15 / <15	31 / 94	<5 / <5	2 / 27	<4 / 14	<0.0001 / NA	<15 / <15
Till	<15 / <15	<1 / 19	<5 / <5	<2 / 6	<4 / 5	<0.0001 / NA	<15 / <15
Till and Tire Chips	<15 / <15	2 / 30	<5 / <5	14 / 40	<4 / <4	<0.0001 / NA	<15 / <15
Unwashed Tire Chips	<15 / <15	111 / 228	<5 / <5	<2 / 2	<4 / <4	<0.0001 / NA	<15 / <15
Washed Tire Chips	<15 / <15	57 / 121	<5 / <5	<2 / 2	<4 / <4	<0.0001 / NA	<15 / <15

Table 5.5
Laboratory Simulation of Ground Conditions
Reactor Study
Water Samples
Metals with Secondary Drinking Water Standards or with no Standard
Units: ug/L (ppb)
Notes: NA=Not Applicable, SDWS=Secondary Drinking Water Standard

	Ag	Al	Ca	Fe	Mg	Mn	Na	Zn
	Diss/Total	Diss/Total	Diss/Total	Diss/Total	Diss/Total	Diss/Total	Diss/Total	Diss/Total
SDWS	100	50-200	NA	300	NA	50	NA	5000
Detection Limit	5	150	100	100	100	2	500	3
Sample								
Clay	<5 / <5	254 / 6960	5610 / 11100	72 / 6350	1270 / 3550	<2 / 31	2700 / 4560	<3 / <3
Clay and Tire Chips	<5 / <5	165 / 23600	105000 / 215000	12700 / 75500	19200 / 46600	2410 / 4960	9420 / 18800	15 / 544
Peat	<5 / <5	358 / 838	10000 / 19900	779 / 1660	2640 / 5490	94 / 189	5110 / 9760	<3 / <3
Peat and Tire Chips	<5 / <5	144 / 933	55800 / 117000	43000 / 113000	15600 / 33100	1030 / 2100	11800 / 22900	18 / 427
Till	<5 / <5	446 / 4920	2920 / 5550	301 / 6050	1350 / 4320	3 / 87	2570 / 4890	<3 / <3
Till and Tire Chips	<5 / <5	112 / 3850	77700 / 160000	10600 / 67700	23800 / 50800	9120 / 15500	10200 / 20700	<3 / 52
Unwashed Tire Chips	<5 / <5	91 / 339	26200 / 52700	36600 / 103000	2270 / 4640	437 / 868	7500 / 15700	6 / 112
Washed Tire Chips	<5 / <5	172 / 195	15400 / 31000	52700 / 113000	1790 / 3630	783 / 1570	7040 / 13600	15 / 176

chips ranged from 4 μg/Kg in the samples from the reactors containing only tire chips, to 108 μg/Kg in the mixed tire chips and clay reactor sample.

Table 5.6 compares the concentrations of metals found in the reactor water samples to the total theoretical leaching potential of the metals from the soils and the tire chips. The theoretical leaching potential from tires was determined using the results of the TCLP study (Chapter 4). The concentrations of metals in μg/Kg of tire chip were used knowing the mass of tire chips added to each reactor to determine the total theoretical mass of a particular metal that could have come from the tire chips. The soils digest data were used in a similar manner to determine the total theoretical leaching potential from the soils.

Chromium is a trace component of steel tire cord and bead wire (Dunlop Tire Corporation, 1990). Though the concentrations of chromium in the reactors that contained only tire chips were below the detection limit, the chromium data show that under the environmental conditions where the tire chips are in contact with the soils, chromium is increased. For the till and clay reactors the source of the chromium cannot be identified because, as seen in Table 5.6, the theoretical total leaching potential from both the soil and the tire chips is greater than the concentration of chromium that was actually present. However, there is no leaching potential for chromium from the peat, based on the soil digest data. Hence the increase in chromium in the peat reactor must be due to the tire chips. Based on these data it can be concluded that, under some conditions, tire chips will leach low levels of chromium. In addition, the environmental conditions created by placing tire chips in contact with soil and water may cause increases in chromium due to release from the soil matrix.

Table 5.6
Laboratory Simulation of Ground Conditions
Reactor Study
Water Samples
Metals with Primary Drinking Water Standards
Notes: x=Concentration From Tire Chips, y=Mass From Tire Chips, NA=Not Applicable

	Concentration in Water Diss/Total (ug/L)	Actual Concentration From Soil Diss/Total (ug/Kg)	Actual Concentration From Soil Diss/Total (ug)	Actual Concentration From Tire Chips Diss/Total (ug/Kg)	Actual Concentration From Tire Chips Diss/Total (ug)	Theoretical Potential Concentration From Soil (ug)	Theoretical Potential Concentration From Tire Chips (ug)
Arsenic							
Clay	<15 / <15	<16.8 / <16.8	<225 / <225			184000	
Clay and Tire Chips	18.9 / 38.4			3.9<x<18.9 / 42.5<x<75.6	23.4<y<113 / 255<y<454	145000	0
Peat	<15 / <15	NA / NA	NA / NA			102000	
Peat and Tire Chips	<15 / <15			NA / NA	NA / NA	75500	0
Till	<15 / <15	NA / NA	NA / NA			375000	
Till and Tire Chips	<15 / <15			NA / NA	NA / NA	287000	0
Unwashed Tire Chips	<15 / <15	NA / NA	NA / NA	NA / NA	NA / NA	NA	0
Copper							
Clay	<4 / 15	NA / 17	<60 / 225			542000	
Clay and Tire Chips	<4 / 32			NA / 33	NA / 198	426000	NA
Peat	<4 / <4	NA / 26	<47.2 / 378			19000	
Peat and Tire Chips	<4 / 14			NA / 25<x<35	NA / 150<y<210	14000	NA
Till	<4 / 5	NA / 6	<66 / 82.5			189000	
Till and Tire Chips	<4 / <4			NA / NA	NA / NA	144000	NA
Unwashed Tire Chips	<4 / <4	NA / NA	NA / NA	NA / <8	NA / <63	NA	NA

Table 5.6 Continued
Laboratory Simulation of Ground Conditions
Reactor Study
Water Samples
Metals with Primary Drinking Water Standards
Notes: x=Concentration From Tire Chips, y=Mass From Tire Chips

	Concentration in Water Diss/Total (ug/L)	Actual Concentration From Soil Diss/Total (ug/Kg)	Actual Concentration From Soil Diss/Total (ug)	Actual Concentration From Tire Chips Diss/Total (ug/Kg)	Actual Concentration From Tire Chips Diss/Total (ug)	Theoretical Potential Concentration From Soil (ug)	Theoretical Potential Concentration From Tire Chips (ug)
Barium							
Clay	<1 / 24	<1.1 / 27	<15 / 360			660000	
Clay and Tire Chips	<1 / 72			NA / 94	NA / 564	519000	17879
Peat	3 / 10	20 / 64	59 / 196			102000	
Peat and Tire Chips	31 / 94			69 / 207	414 / 1242	75500	17880
Till	<1 / 19	<1.2 / 23	<16.5 / <314			375000	
Till and Tire Chips	2 / 30			2<x<4 / 23	12<y<24 / 138	287000	17883
Unwashed Tire Chips	111 / 228	NA / NA	NA / NA	111 / 228	874 / 1796	NA	23470
Chromium							
Clay	<2 / 12	<2.2 / 13	<30 / 180			487000	
Clay and Tire Chips	8 / 67			12<x<16 / 108	72<y<96 / 648	383000	10079
Peat	<2 / <2	<13 / <13	<39 / <39			NA	
Peat and Tire Chips	2 / 27			0<x<5 / 62<x<67	0<y<30 / 372<y<402	NA	10080
Till	<2 / 6	<2.4 / 7	<33 / 99			346000	
Till and Tire Chips	14 / 40			25<x<29 / 71	150<y<174 / 426	265000	10081
Unwashed Tire Chips	<2 / 2	NA / NA	NA / NA	<4 / 4	<31.5 / 31.5	NA	13230

Barium was detected in five of the eight reactor water samples. The highest dissolved barium level (57 μg/L) was found in the unwashed mixed tire chip reactor sample, with that level being less than 6% of the primary drinking water standard of 2000 μg/L for barium. Dissolved barium was not detected in either of the reactors that contained clay, but was detected in both samples from the reactors that contained peat (3 μg/L for peat alone and 31 μg/L for peat and tire chips), and in the sample from the reactor that contained till and tire chips (2 μg/L). The concentration of barium expressed in terms of mass of tire chips ranged from <2 μg/Kg (clay and tire chip sample) to 221 μg/Kg (unwashed mixed tire chip sample).

Total barium levels were 1.5 to 9 times higher in all the mixed soil and tire chip reactors samples than in the corresponding control reactor (soil and distilled water only) samples. The highest level of total barium found was 228 μg/L. The concentration of total barium from the tire chips ranged from 23 μg/Kg for the till and tire chip reactor samples to 454 μg/Kg for the unwashed tire chips reactor sample.

The TCLP testing indicated leaching potential for barium from tire chips (Table 4.1). The analysis of the samples from the reactors that contained only tire chips supports the TCLP data. Barium was increased also in each of the three soil types. As seen in Table 5.6, the theoretical leaching potential from both tire chips and the soils is great enough to account for the increases in barium. Under the conditions created in the reactors, barium is released from the soils or the tire chips or both, but the source cannot be identified based on this data. There is potential for barium levels to increase under conditions where tire chips are placed in contact with soil and water. Barium levels could also be expected to increase where tire chips are in contact with water in the absence of soil.

Dissolved arsenic was less than the method detection limit for all samples tested, while total arsenic was less then the method detection limit of 15 µg/L for the samples from all the reactors except the mixed reactor containing clay, tire chips, and distilled water. The level of arsenic in that reactor water sample was 38.4 µg/L, with the primary drinking water standard for arsenic being 50 µg/L. This would result in an apparent concentration of arsenic from the tires of 67.3 µg/Kg. However, the results of the TCLP testing showed that there was no potential for leaching of arsenic from tires (Table 4.1). In this case, it appears that environmental conditions were created in the clay and tire chip reactor that favored release of arsenic from the soil. It is not likely that the tire chips are the source of the increase in arsenic.

Dissolved copper was below the method detection limit (4 µg/L) for all samples tested. The levels of total copper were higher in the mixed reactors that contained clay and tire chips and peat and tire chips than each of the corresponding control reactors (soil and distilled water only). The highest level of total copper found was 32 µg/L. The primary drinking water standard for copper is 1300 µg/L. The concentration of total copper from the tire chips ranged from 8 µg/Kg in the samples from the reactors containing only tire chips and distilled water, to 33 µg/Kg in the mixed tire chips and clay reactor sample.

Leaching of copper is not part of the TCLP test, therefore leaching potential data for copper from tire chips is not available. As seen in Table 5.6, the theoretical leaching potential from the soil samples is high enough to account for the increases in total copper. Neither dissolved copper or total copper were detected in the samples from the reactors that contained only tire chips. Copper is a trace constituent in steel tire cord and beadwire (Dunlop Tire Corporation, 1990). This reactor study shows that conditions can be created that favor increases in total copper. However, the source of the copper cannot be identified as the soil or the tire chips.

Dissolved lead, mercury, and copper levels were below the method detection limits of 5 µg/L, 0.0001 µg/L, 5 µg/L, respectively for the samples from all the reactors. Total lead and total cadmium levels were below the method detection limits of 5 µg/L for the samples from all the reactors.

5.2.2.2 Metals with Secondary Drinking Water Standards or with No Standard

The dissolved iron levels in the mixed reactors (soil, tire chips, and distilled water) samples were 35 to 76 times higher than the dissolved iron levels in the corresponding reactors that contained only soil and distilled water. All samples had dissolved iron levels above the secondary drinking water standard of 300 µg/L, except for the sample from the reactor that contained only clay. The highest level of dissolved iron was 52,700 µg/L, which was in the sample from the reactor that contained only washed mixed tire chips and distilled water. The concentrations of dissolved iron expressed in terms of mass of tire chips ranged from 21,600 µg/Kg in the till and tire chips reactor sample to 104,000 µg/Kg for the washed tire chips sample and the peat and tire chips reactor samples.

Total iron in the mixed soil and tire chip reactors was approximately 11 to 68 times higher than the total iron concentration in the corresponding control reactor (soil and distilled water only) sample. The maximum concentration of total iron from the tire chips was 274,000 µg/Kg. The concentrations in terms of mass of tire chips in the samples from the reactors that contained only tire chips were 205,000 µg/Kg and 222,000 µg/Kg.

Increased iron concentrations can be expected when steel belted tire chips are in contact with water or with water and soil. Since iron is not one of the TCLP metals, the theoretical leaching potential for iron could not be computed. However, the samples from the reactors that contained only tire chips had high levels of dissolved and total iron. As seen in Table 5.7, the theoretical leaching potential for iron from the soil is significant. In each case, for the three different soil types, the iron concentration is higher when tire chips are included in the reactor. Iron levels much higher than the secondary drinking water standard can be expected when using tire chips below the groundwater table.

Levels of dissolved manganese in the mixed soil and tire chips reactor samples were much higher than the levels of dissolved manganese in the corresponding control reactors (soil and distilled water only). The secondary drinking water standard for manganese is 50 μg/L. The secondary drinking water standard was exceeded by all of the samples from the mixed soil and tire chip reactors and by the samples from the reactors that contained only tire chips. The only control reactor sample that exceeded the drinking water standard was the peat reactor. The highest dissolved manganese level was 9120 μg/L (clay and tire chips mixed reactors). Dissolved manganese was approximately 10 times higher in the mixed peat reactor than in the reactor with only peat, while it was approximately 1000 times higher in the mixed clay reactor than in the reactor with only clay and was approximately 3000 times higher in the mixed till reactor sample than in the reactor with only till. The concentration of dissolved manganese expressed in terms of mass of tire chips from the reactors that contained only tire chips were 870 μg/Kg and 1540 μg/Kg. The levels of manganese in the mixed reactors were higher than the additive expected effects from the soil and tire chip contributions when considered separately. The expected level could be approximated by adding the concentrations from the tires alone to the concentration from the soil alone. The highest manganese concentration from the tire chips found was 19,200 μg/Kg.

Table 5.7
Laboratory Simulation of Ground Conditions
Reactor Study
Water Samples
Metals with Secondary Drinking Water Standards or with no Standard

Notes: x=Concentration From Tire Chips, y=Mass From Tire Chips, NA=Not Applicable

	Concentration in Water Diss/Total (ug/L)	Actual Concentration From Soil Diss/Total (ug/Kg)	Actual Concentration From Soil Diss/Total (ug)	Actual Concentration From Tire Chips Diss/Total (ug/Kg)	Actual Concentration From Tire Chips Diss/Total (ug)	Theoretical Potential Concentration From Soil (ug)	Theoretical Potential Concentration From Tire Chips (ug)
Aluminum							
Clay	254 / 6960	285 / 7820	3810 / 104400			246000000	
Clay and Tire Chips	165 / 23600			NA / 32800	NA / 197000	194000000	NA
Peat	358 / 838	2295 / 5370	7020 / 16400			10300000	
Peat and Tire Chips	144 / 933			NA / 234	NA / 1400	7600000	NA
Till	446 / 4920	535 / 5910	7360 / 81200			152000000	
Till and Tire Chips	112 / 3850			NA / NA	NA / NA	116000000	NA
Unwashed Tire Chips	91 / 339	NA / NA	1430 / 5320	181 / 675	1420 / 5320	NA	NA
Calcium							
Clay	5610 / 11100	6300 / 12500	84150 / 166500			365000000	
Clay and Tire Chips	105000 / 215000			196000 / 401000	1180000 / 2410000	28700000	NA
Peat	10000 / 19900	64100 / 128000	196000 / 390000			50700000	
Peat and Tire Chips	55800 / 117000			113000 / 240000	678000 / 1440000	37400000	NA
Till	2920 / 5550	3500 / 6660	48200 / 91600			32300000	
Till and Tire Chips	77700 / 160000			157000 / 324000	942000 / 1940000	24700000	NA
Unwashed Tire Chips	26200 / 52700	NA / NA	NA / NA	52200 / 105000	411000 / 827000	NA	NA

Table 5.7 Continued
Laboratory Simulation of Ground Conditions
Reactor Study
Water Samples
Metals with Secondary Drinking Water Standards or with no Standard

Notes: x=Concentration From Tire Chips, y=Mass From Tire Chips, NA=Not Applicable

	Concentration in Water Diss/Total (ug/L)	Actual Concentration From Soil Diss/Total (ug/Kg)	Actual Concentration From Soil Diss/Total (ug)	Actual Concentration From Tire Chips Diss/Total (ug/Kg)	Actual Concentration From Tire Chips Diss/Total (ug)	Theoretical Potential Concentration From Soil (ug)	Theoretical Potential Concentration From Tire Chips (ug)
Iron							
Clay	72 / 6350	81 / 7130	1080 / 95200			234000000	
Clay and Tire Chips	12700 / 75500			24800 / 136000	149000 / 816000	184000000	NA
Peat	779 / 1660	4990 / 10600	15300 / 32500			9200000	
Peat and Tire Chips	43000 / 113000			104000 / 274000	624000 / 1640000	6770000	NA
Till	301 / 6050	361 / 7260	4970 / 99800			198000000	
Till and Tire Chips	10600 / 67700			21600 / 12900	130000 / 77400	151000000	NA
Unwashed Tire Chips	36600 / 103000	NA / NA	NA / NA	14900 / 205000	117000 / 1610000	NA	NA
Sodium							
Clay	2700 / 4560	3030 / 5120	2700 / 68400			4690000	
Clay and Tire Chips	9420 / 18800			13200 / 28000	79200 / 168000	3690000	NA
Peat	5110 / 9760	32800 / 62600	100000 / 191000			1360000	
Peat and Tire Chips	11800 / 22900			16500 / 23200	99000 / 139000	1000000	NA
Till	2570 / 4890	3080 / 5870	42400 / 80700			4700000	
Till and Tire Chips	10200 / 20700			16000 / 33200	96000 / 199000	3590000	NA
Unwashed Tire Chips	7500 / 15700	NA / NA	NA / NA	14900 / 31300	89400 / 188000	NA	NA

Table 5.7 Continued
Laboratory Simulation of Ground Conditions
Reactor Study
Water Samples
Metals with Secondary Drinking Water Standards or with no Standard

Notes: x=Concentration From Tire Chips, y=Mass From Tire Chips, NA=Not Applicable

	Concentration in Water Diss/Total (ug/L)	Actual Concentration From Soil Diss/Total (ug/Kg)	Actual Concentration From Soil Diss/Total (ug)	Actual Concentration From Tire Chips Diss/Total (ug/Kg)	Actual Concentration From Tire Chips Diss/Total (ug)	Theoretical Potential Concentration From Soil (ug)	Theoretical Potential Concentration From Tire Chips (ug)
Magnesium							
Clay	1270 / 3550	1430 / 3990	19000 / 53200			64700000	
Clay and Tire Chips	19200 / 46600			35200 / 84600	211000 / 508000	50900000	NA
Peat	2640 / 5490	16900 / 35200	51700 / 108000			5020000	
Peat and Tire Chips	15600 / 33100			32000 / 68100	192000 / 409000	3700000	NA
Till	1350 / 3420	1620 / 4100	22300 / 56400			62000000	
Till and Tire Chips	23800 / 50800			47000 / 99600	282000 / 2450000	47400000	NA
Unwashed Tire Chips	2270 / 4640	NA / NA	NA / NA	4520 / 9240	35600 / 72800	NA	NA
Manganese							
Clay	<2 / 31	<2.2 / 35	<30 / 465			2340000	
Clay and Tire Chips	2410 / 4960			4740 / 9700	28400 / 58200	1840000	NA
Peat	94 / 189	602 / 1210	1840 / 3700			456000	
Peat and Tire Chips	1030 / 2100			2310 / 4720	13900 / 28300	336000	NA
Till	3 / 87	3.6 / 104	49.5 / 1440			4330000	
Till and Tire Chips	9120 / 15500			19200 / 32400	115000 / 194000	3310000	NA
Unwashed Tire Chips	437 / 868	NA / NA	NA / NA	870 / 1730	6850 / 13600	NA	NA

Table 5.7 Continued
Laboratory Simulation of Ground Conditions
Reactor Study
Water Samples
Metals with Secondary Drinking Water Standards or with no Standard
Notes: x=Concentration From Tire Chips, y=Mass From Tire Chips, NA=Not Applicable

	Concentration in Water Diss/Total (ug/L)	Actual Concentration From Soil Diss/Total (ug/Kg)	Actual Concentration From Soil Diss/Total (ug)	Actual Concentration From Tire Chips Diss/Total (ug/Kg)	Actual Concentration From Tire Chips Diss/Total (ug)	Theoretical Potential Concentration From Soil (ug)	Theoretical Potential Concentration From Tire Chips (ug)
Zinc							
Clay	<3 / <3	<3.4 / <3.4	<45 / <45			757000	
Clay and Tire Chips	15 / 544			24<x<30 / 1060<x<1070	144<y<180 / 6360<y<6420	596000	NA
Peat	<3 / <3	<19 / <19	<58.8 / <58.8			116000	
Peat and Tire Chips	18 / 427			37<x<44 / 1050	222<y<264 / 6300	85300	NA
Till	<3 / <3	<3.6 / <3.6	<49.9 / <49.9			493000	
Till and Tire Chips	<3 / 52			NA / 103<x<109	NA / 618<y<654	377000	NA
Unwashed Tire Chips	6 / 112	NA / NA	NA / NA	12 / 223	94.5 / 1760	NA	NA

The total manganese levels in the mixed soil and tire chip reactors were approximately 11 to 168 times higher than the manganese levels in the corresponding control reactors (soil alone). The maximum concentration of manganese expressed in terms of mass of tire chips was 32,400 μg/Kg. The concentration of total manganese from the tires in the samples from the reactors that contained only tire chips were 3450 μg/Kg and 6080 μg/Kg.

The results show that when tire chips are in contact with soil and water, there is a significant potential for leaching of manganese. As with iron, the theoretical leaching potential for manganese based on TCLP testing is not available, but manganese was seen in the samples that contained only tire chips. It is possible that the environmental conditions created in the reactors favored release of manganese from the soil and from the tire chips. Manganese is present in steel tire cord and beadwire at concentrations of 0.40% to 0.70% (Dunlop Tire Corporation, 1990). Manganese levels in groundwater are expected to be well above the secondary drinking water standard when using tire chips in construction applications below the groundwater table.

Dissolved zinc was detected in four of the eight reactors. Dissolved zinc was not detected in any of the control reactors or in the reactor containing mixed till and tire chips. The levels in the reactors containing only tire chips were 6 μg/L and 15 μg/L. The concentrations of dissolved zinc in the mixed clay and mixed peat reactors were 15 μg/L and 18 μg/L, respectively. All the values were much less than the secondary drinking water standard for zinc (5000 μg/L).

The highest level of total zinc was in the mixed clay and tire chips reactor. The level was 544 μg/L which corresponds to a concentration in terms of the mass of tire chips of approximately 1060 μg/Kg. The highest level of 544 μg/L is approximately 11% of the secondary drinking water standard of 5000 μg/L. The levels of total zinc in the mixed reactors were much higher (approximately 17 to 181 times higher) than the levels in the corresponding control reactors. The concentrations in terms of mass of tire chips ranged from 103 μg/Kg to 1060 μg/Kg.

As seen in Table 5.7, the leaching potential from the soil itself is great enough to account for the increase in total zinc levels. However, dissolved and total zinc were found in the samples from the reactors containing only tire chips. Again, it appears that conditions were created in the reactors that favored the release of zinc. The source of the zinc cannot be identified, both the soils and the tire chips have the potential to increase the zinc concentration. Based on this research, the composition of tires, and previous research, it is reasonable to expect increased zinc levels when using tire chips, but it is unlikely that the levels will exceed the secondary drinking water standard.

Dissolved aluminum levels were higher in the reactors that contained only soil than in the corresponding mixed reactor that contained soil and tire chips. The secondary drinking water standard for aluminum is a range, from 50 μg/L to 200 μg/L. The concentrations of aluminum in all the reactors that contained soil only exceeded 200 μg/L. The dissolved aluminum concentrations in all samples tested exceeded 50 μg/L. The concentration of aluminum in terms of mass of tires in the samples from the reactors that contained only tire chips were 338 μg/Kg and 181 μg/Kg for the washed mixed tire chips and the unwashed mixed tire chips, respectively.

Unlike dissolved aluminum, the total aluminum concentrations in two of the mixed soil and tire chips reactors (clay and peat) were greater than the aluminum concentrations in the corresponding control reactors (soil and distilled water). The total aluminum concentrations in terms of mass of tire chips were 675 µg/Kg and 388 µg/Kg in the samples from the reactors that contained only tire chips and distilled water.

Based on the aluminum data in Table 5.7, it appears that tire chips leach aluminum. However, the leaching potential for aluminum from the soil matrix is significant. The source of the aluminum increases could be the soil or could be a combination of the soil and the tire chips. It is likely that the largest contributor to the aluminum concentration is the soil, especially at the clay and till sites, since the structure of clay molecules often include aluminum atoms.

The dissolved calcium levels were higher in the mixed soil and tire chips reactor than in the corresponding control reactors (soil only). There is no drinking water standard for calcium. The dissolved calcium concentration expressed in terms of mass of tire chips for the samples from the reactors that contained only tire chips were 52,200 µg/Kg and 30,300 µg/Kg. The highest concentration of dissolved calcium from the tires was 209,000 µg/Kg in the mixed reactor that contained clay and tire chips.

Total calcium levels were also higher in the samples from the reactors that contained tire chips than in the corresponding control reactors. Both the soils and the tire chips show high potential for leaching calcium (Table 5.7). The source of the increased calcium here cannot be identified, however, the environmental conditions created in the reactors promote the release of calcium.

Levels of dissolved magnesium in the mixed soil and tire chip reactors were much higher than the levels of dissolved magnesium in the corresponding control reactors (soil and distilled water only). There is no drinking water standard for magnesium. Dissolved magnesium was approximately 15 times higher in the mixed peat and tire chips reactor than in the reactor with peat alone, while it was approximately 6 times higher in the mixed clay and tire chips reactor than in the reactor with clay alone, and was approximately 18 times higher in the mixed till and tire chips reactor than in the reactor with till alone. The concentration of dissolved magnesium expressed in terms of mass of tire chips from the samples from the reactors that contained only tire chips and distilled water were 4520 µg/Kg and 3520 µg/Kg. Magnesium showed similar behavior to manganese in that levels of magnesium in the mixed soil and tire chips reactor samples were higher than the expected additive effects from the soil and tire chip contributions when considered separately. The highest magnesium concentration from the tire chips found was 47,200 µg/Kg in the mixed till and tire chips reactor. The contributions from the tire chips were higher in the mixed reactors than in the reactors containing only tire chips.

Total magnesium showed similar behavior to dissolved magnesium in that levels of magnesium in the mixed soil and tire chips reactors were higher than the expected additive effects from the soil and tire chip contributions when considered separately. The concentrations of total magnesium expressed in terms of mass of tire chips from the reactors that contained only tire chips were 9240 µg/Kg and 7140 µg/Kg. The highest total magnesium concentration from the tires was 99,600 µg/Kg (mixed till and tire chips reactor).

The dissolved sodium concentration for the control reactors (soil and distilled water only) was highest in the sample from the peat reactor. There is no drinking water standard for sodium, however, high sodium levels in drinking water are of concern for individuals with hypertension. The concentration from the tire chips ranged from 13,800 µg/Kg to 16,500 µg/Kg. Unlike the magnesium and manganese behavior, the sodium results from the mixed reactors are approximately equal to the summation of the expected contributions from the tire chips and the soil. The behavior for total sodium was similar to that of dissolved sodium. However, the levels for total sodium were approximately double those for dissolved sodium.

Dissolved and total silver levels were below the method detection limit of 5 μg/L in all the reactors. The drinking water standard for silver is 100 μg/L. The TCLP testing also supports this data since no silver was found in the TCLP extracts.

5.3 ORGANICS RESULTS

5.3.1 Semivolatile Organic Compounds Results

The semivolatile organic compounds analyzed in the reactor water samples are listed in Table 5.8. Table 5.8 includes those compounds detected and those not detected. The concentrations of the semivolatile organic compounds that were detected are presented in Table 5.9. The semivolatile organic compounds found in the three mixed reactors containing soil, tire chips, and distilled water were 4-acetyl-morpholine, and 2(3H)-benzothiazolone. Aniline was found in three of the five reactors that contained tire chips. In addition, benzoic acid was found in the mixed peat, tire chips, and distilled water reactor. No semivolatile organic compounds were found in the control reactors. The semivolatile compounds other than aniline found in the reactor water samples were reported as tentatively identified compounds with estimated concentrations in μg/L. The tentatively identified compounds in the reactor that contained unwashed tire chips and distilled water were benzoic acid, benzenepropanoic acid, and 2(3H)-benzothiazolone with estimated concentrations of 200 μg/L, 400 μg/L, and 400 μg/L, respectively. The tentatively identified compounds in the reactor that contained washed tire chips and distilled water were 4-acetyl-morpholine (200 μg/L), benzothiazole (200 μg/L), benzoic acid (400 μg/L), benzenepropanoic acid (400 μg/L), and 2(3H)-benzothiazolone (400 μg/L). Aniline was found in the mixed reactors that contained clay and tire chips and till

Table 5.8
Laboratory Simulation of Ground Conditions
Reactor Study
Semivolatile Organics
Water Samples
Notes: MRL=Method Reporting Limit (ug/L), D=Detected, NA=Not Applicable, Empty boxes indicate that the compound was not detected

Compound	MRL	Clay	Clay + Tire Chips	Peat	Peat + Tire Chips	Till	Till + Tire Chips	Unwashed Tire Chips	Washed Tire Chips
Aniline	10		D				D	D	
2-Chlorophenol	10								
bis(2-Chloroethyl)ether	10								
phenol	10								
1,3-Dichlorobenzene	10								
1,4-Dichlorobenzene	10								
1,2-Dichlorobenzene	10								
bis(2-Chloroisopropyl)ether or 2,2'	10								
2-Methylphenol or o-Cresol	10								
Hexachloroethane	10								
n-Nitrosode-n-propylamine	10								
4-Methylphenol or p-Cresol	20								
Nitrobenzene	10								
Isophorone	20								
2-Nitrophenol	10								
2,4-Dimethylphenol	10								
a,a-Dimethylphenethylamine	10								
bis(2-Chloroethoxy)methane	10								
2,4-Dichlorophenol	10								
1,2,4-Trichorobenzene	10								
Naphthalene	10								
4-Chloroaniline	20								
Hexachlorobutadiene	10								
2-Methylnaphthalene	10								
4-chloro-3-Methylphenol	10								
Hexachlorocyclopentadiene	10								
2,4,6-Trichlorophenol	10								
2,4,5-Trichlorophenol	10								
2-Chloronaphthalene	10								
Safrole	10								
2-Nitroaniline	50								
Acenaphthylene	10								
Dimethyl phthalate	20								
2,6-Dinitrotoluene	10								

Table 5.8 Continued
Laboratory Simulation of Ground Conditions
Reactor Study
Semivolatile Organics
Water Samples

Notes: MRL=Method Reporting Limit (ug/L), D=Detected, NA=Not Applicable, Empty boxes indicate that the compound was not detected

Compound	MRL	Clay	Clay + Tire Chips	Peat	Peat + Tire Chips	Till	Till + Tire Chips	Unwashed Tire Chips	Washed Tire Chips
Acenaphthene	10								
3-Nitroaniline	50								
2,4-Dinitrophenol	50								
Dibenzofuran	50								
2,4-Dinitrotoluene	10								
4-Nitrophenol	50								
Fluorene	10								
4-Chlorophenyl phenyl ether	10								
Diethyl phthalate	20								
4-Nitroaniline	50								
4,6-Dinitro-2-methylphenol	20								
n-Nitrosodiphenylamine	10								
4-Bromophenyl phenyl ether	10								
Hexachlorobenzene	10								
4-Aminobiphenyl	10								
Pentachlorophenol	50								
Phenanthrene	10								
Anthracene	10								
Carbazole	10								
di-n-Butyl phthalate	10								
Fluoranthene	10								
Pyrene	10								
Butyl benzyl phthalate	10								
benzo(a)Anthracene	10								
Chrysene	10								
3,3'-Dichlorobenzidine	20								
bis(2-Ethylhexyl)phthalate	20								
di-n-Octyl phthalate	20								
benzo(b)Fluoranthene	10								
benzo(k)Fluoranthene	10								
benzo(a)Pyrene	10								
indeno(123-cd)Pyrene	10								
dibenzo(a,h)Anthracene	10								
benzo(ghi)Perylene	10								
4-Acetyl-morpholine	NA		D		D		D		D
2(3H)-Benzothiazolone	NA		D		D		D	D	D
Benzoic Acid	NA				D			D	D
Benzenepropanoic Acid	NA							D	D
Benzothiazole	NA								D

Table 5.9
Laboratory Simulation of Ground Conditions
Reactor Study
Semivolatile Organics Detected
Water Samples

Notes: MRL=Method Reporting Limit (ug/L), NA=Not Applicable, ND=Not Detected

Compound	MRL	Clay	Clay + Tire Chips	Peat	Peat + Tire Chips	Till	Till + Tire Chips	Unwashed Tire Chips	Washed Tire Chips
Aniline	10	ND	47.7	ND	ND	ND	29.4	24.6	ND
4-Acetyl-morpholine	NA	ND	400	ND	200	ND	200	ND	200
2(3H)-Benzothiazolone	NA	ND	600	ND	400	ND	400	400	200
Benzoic Acid	NA	ND	ND	ND	200	ND	ND	200	400
Benzenepropanoic Acid	NA	ND	ND	ND	ND	ND	ND	400	400
Benzothiazole	NA	ND	ND	ND	ND	ND	ND	ND	400

and tire chips (47.7 µg/L and 29.4 µg/L, respectively) but was not found in the mixed reactor that contained peat. Aniline was also found in the unwashed mixed chip reactor (24.6 µg/L) but was not found in the washed mixed chip reactor. Aniline, benzothiazole, and 2(3H)-benzothiazolone were also found in the TCLP extracts in this study.

Many of the compounds found in the batch reactor samples can be identified as rubber processing chemicals or as end products of other chemicals used in rubber processing. Aniline is used as an antidegradant, benzoic acid is used as a retarder, and benzothiazoles are used as accelerators (Fishbein, 1991). Two compounds found that are probable stable end products of 2-mercaptobenzothiazole (MTB) are 2(3H)-benzothiazolone and benzothiazole (Brownlee et al., 1992). MTB was not found in the reactor water samples but it is used as an accelerator. The stable end products of MTB are formed by methylation, photolysis, and oxidation processes (Brownlee et al., 1992).

5.3.2 Volatile Organic Compounds Results

The volatile organic compounds analyzed in the reactor water samples along with their detection limits are presented in Table 5.10. Table 5.10 lists the compounds detected and the compounds not detected. The concentrations of the compounds that were detected are presented in Table 5.11. Toluene was found in all the reactor water samples and was also found in the blank (1.1 µg/L) that was shipped with the samples. The drinking water standard for toluene is 1000 µg/L, all levels of toluene found were well below the drinking water standard (the highest level found was 3.6 µg/L). Benzene and cis-1,2-dichloroethene were found in the mixed soil, tire chips, and distilled water reactors but were not found in the corresponding control reactors. Benzene and cis-1,2-dichloroethene were also found in the sample from the washed mixed tire chips and distilled water reactor but were not found in the unwashed mixed tire chips and distilled water reactor. The drinking water standard for benzene is 5 µg/L. The concentration of

Table 5.10
Laboratory Simulation of Ground Conditions
Reactor Study
Water Samples
Volatile Organic Compounds

Notes: MDL=Method Detection Limit (ug/L), D=Detected, Empty boxes indicate that the compound was not detected

Compound	MDL	Blank	Clay	Clay + Tire Chips	Peat	Peat + Tire Chips	Till	Till + Tire Chips	Unwashed Tire Chips	Washed Tire Chips
Dichlorodifluoromethane	1.0									
Chloromethane	1.0									
Chloroethene	1.0									
Bromomethane	1.0					D				
Chloroethane	1.0									
Tricholorofluoromethane	1.0									
1,1-Dichloroethene	0.5									
Dichloromethane	0.5		D	D	D		D	D	D	D
MTBE	0.5									
trans-1,2-Dichloroethene	0.5									
1,1-Dichloroethane	0.5									D
cis-1,2-Dichloroethene	0.5			D		D		D		D
2,2-Dichloropropane	0.5									
Bromochloromethane	0.5									
Trichloromethane	0.5		D				D			
1,1,1-Trichloroethane	0.5									
1,1-Dichloropropene	0.5									
Tetrachloromethane	1.0									
Benzene	0.5			D		D		D	D	D
1,2-Dichloroethane	0.5									
Trichloroethene	0.5									D
1,2-Dichloropropane	0.5									
Dibromomethane	0.5									
Bromodichloromethane	1.0		D							
(Z)-1,3-Dichloropropene	0.5									
Toluene	0.5	D	D	D	D	D	D	D	D	D
(E)-1,3-Dichloropropene	0.5									
1,1,2-Trichloroethane	0.5									
1,3-Dichloropropane	0.5									
Tetrachloroethene	0.5									
Dibromochloromethane	0.5									
1,2-Dibromoethane	0.5									
Chlorobenzene	0.5									

Table 5.10 Continued
Laboratory Simulation of Ground Conditions
Reactor Study
Water Samples

Notes: MDL=Method Detection Limit (ug/L), D=Detected, Empty boxes indictae that the compound was not detected

Compound	MDL	Blank	Clay	Clay + Tire Chips	Peat	Peat + Tire Chips	Till	Till + Tire Chips	Unwashed Tire Chips	Washed Tire Chips
1,1,1,2-Tetrachloroethane	0.5									
Ethylbenzene	0.5									
m-Xylene+p-Xylene	0.5									
o-Xylene	0.5									
Styrene(ethyl-benzene)	1.0									
Bromoform	0.5									
iso-Propylbenzene	0.5									
1,1,2,2-Tetrachloroethane	0.5									
1,2,3-Trichloropropane	0.5									
Bromobenzene	0.5									
n-Propylbenzene	0.5									
2-Chlorotoluene	0.5									
1,3,5-Trimethylbenzene	0.5									
4-Chlorotoluene	0.5									
tert-Butylbenzene	0.5									
1,2,4-Trimethylbenzene	0.5									
sec-Butylbenzene	0.5									
4-iso-Propyltoluene	0.5									
1,3-Dichlorobenzene	1.0									
1,4-Dichlorobenzene	0.5									
n-Butylbenzene	1.0									
1,2-Dichlorobenzene	0.5									
1,2-Dibromo-3-chloropropane	1.0									
1,2,4-Trichlorobenzene	1.0									
Hexachlorobutadiene	0.5									
Naphthalene	0.5					D				
1,2,3-Trichlorobenzene	0.5									

Table 5.11
Laboratory Simulation of Ground Conditions
Reactor Study
Water Samples
Volatile Organic Compounds Detected
Notes: MDL=Method Detection Limit (ug/L), ND=Not Detected

Compound	MDL	Blank	Clay	Clay + Tire Chips	Peat	Peat + Tire Chips	Till	Till + Tire Chips	Unwashed Tire Chips	Washed Tire Chips
Bromomethane	1.0	ND	ND	ND	ND	1.6	ND	ND	ND	ND
Dichloromethane	0.5	ND	1.8	1	0.7	ND	0.5	0.8	0.6	0.9
1,1-Dichloroethane	0.5	ND	ND	ND	ND	ND	ND	ND	ND	0.6
cis-1,2-Dichloroethene	0.5	ND	ND	1.2	ND	1	ND	3.2	ND	2.3
Trichloromethane	0.5	ND	13.1	ND	ND	ND	10.6	ND	ND	ND
Benzene	0.5	ND	ND	2.5	ND	2.5	ND	5	3.4	2.6
Trichloroethene	0.5	ND	ND	ND	ND	ND	ND	ND	ND	0.8
Bromodichloromethane	1.0	ND	1.3	ND	ND	ND	ND	ND	ND	ND
Toluene	0.5	1.1	1.1	1.8	1.1	3.6	0.9	1.5	1.5	1.6
Naphthalene	0.5	ND	ND	ND	ND	5.3	ND	ND	ND	ND

benzene in the mixed till and tire chips reactor was 5 μg/L. The levels of benzene in the other samples were below the drinking water standard. The drinking water standard for (Z)-1,2-dichloroethene is 70 μg/L, the concentrations found in the reactor water samples were well below the drinking water standard. Other volatile organic compounds detected were dichloromethane, trichloromethane, bromodichloromethane, naphthalene, 1,1-dichloroethane, and trichloroethene. The drinking water standards for dichloromethane and trichloroethene are 5 μg/L. None of these compounds were found at concentrations above the drinking water standards (where applicable). Dichloromethane was the only volatile organic compound detected here and also in the TCLP extracts.

5.4 COMPARISON TO PREVIOUS STUDIES

Tables 5.12, 5.13, and 5.14 summarize the laboratory leaching study results for the University of Maine Studies and previous laboratory leaching studies. The results are presented in two sets of units: μg/L of extraction fluid and μg/Kg of tire chips. The University of Maine laboratory studies showed that the metals that have the potential to leach from tire chips were barium, cadmium, chromium, iron, lead, manganese, and zinc. As expected, metals tended to leach at higher concentrations at lower pHs. Barium levels were found to increase with increased leaching in the Minnesota Pollution Control Agency Study (1990) and were found above the drinking water standard in the Virginia DOT long term leaching study (Ealding, 1992). Barium was found at concentrations below the drinking water standard in the Scrap Tire Management Council Study (Radian, 1989) and was indicated as a pollutant of concern in the Minnesota Study. Cadmium was found in the Minnesota Study above the Recommended Allowable Limit set by the Minnesota Department of Health for drinking water as were chromium, lead, and zinc. Cadmium was also detected in the Virginia DOT Study, but was below the drinking water standard. Chromium was detected in the Scrap Tire Management Council Study below the drinking

Table 5.12
Summary of Metals Results for Laboratory Leaching Studies
Pollutants with Primary Drinking Water Standards

	As µg/Kg (ppb)	Ba µg/Kg (ppb)	Cd µg/Kg (ppb)	Cr µg/Kg (ppb)	Cu µg/Kg (ppm)	Hg µg/Kg (ppb)	Ni µg/Kg (ppb)	Pb µg/Kg (ppb)	Se µg/Kg (ppb)
Virginia DOT TCLP Conc in Tires	NA	NA	4.4	7.9	235	NA	113	55.6	NA
Virginia DOT (long term) pH 4 Max Conc	<25	2083	3.5	152	328	<1	2460	138	<30
Minnesota Old Tires pH 3.5 Normalized Conc	ND	440	270	510	NA	ND	NA	ND	440
Minnesota New Tires, pH 3.5 Normalized Conc	ND	108	24	31	NA	ND	NA	92	23
Maine TC Below GWT TCLP Max Conc from Tires	ND	7140	2280	1680	NA	ND	NA	4320	ND
Maine Lab Simulation Study, Max Conc from Tires	67.3	454	NA	108	33	NA	NA	NA	NA
	As µg/L (ppb)	Ba µg/L (ppb)	Cd µg/L (ppb)	Cr µg/L (ppb)	Cu µg/L (ppm)	Hg µg/L (ppb)	Ni µg/L (ppb)	Pb µg/L (ppb)	Se µg/L (ppb)
TCLP Regulatory Limit	5000	100000	1000	5000	-	200	-	5000	1000
Virginia DOT TCLP Conc in extract	NA	NA	1.55	2.8	83	NA	39.7	19.6	NA
Wisconsin AFS Elution 3 (neutral)	<10	110	NA	<3	<20	NA	NA	<3	<5
Scrap Tire Mngmnt TCLP Max Conc	2	590	ND	48	NA	0.4	NA	16	ND
Maine TC Below GWT TCLP, Max Conc in extract	ND	357	114	84	NA	ND	NA	216	ND
Maine Lab Simulation Study, Max Conc in extract	34.2	228	<5	67	32	<0.0001	NA	<15	NA

Notes: NA = not available, that is not measured or not reported for that study
ND = non-detect

Table 5.13
Summary of Metals Results for Laboratory Leaching Studies
Pollutants with Secondary Drinking Water Standards
Units of Pollutant per Kilogram of Tire Material

	Ag µg/Kg (ppb)	Al µg/Kg (ppb)	Fe mg/Kg (ppm)	Mn µg/Kg (ppb)	Zn mg/Kg (ppm)
Virginia DOT TCLP Conc in Tires	<2.8	420	341	NA	30
Virginia DOT (long term) pH 4 Max Conc	10	746	31622	NA	153.7
Minnesota Old Tires pH 3.5 Normalized Conc	ND	2020	1081	NA	50
Minnesota New Tires, pH 3.5 Normalized Conc	ND	225	763.4	NA	41
Maine TC Below GWT TCLP Max Conc from Tires	ND	NA	NA	NA	NA
Maine Lab Simulation Study Max Conc from Tires	NA	32760	274	32400	1.07

Notes: NA = not available, that is not measured or not reported for that study
ND = non-detect

Table 5.14
Summary of Metals Results for Laboratory Leaching Studies
Pollutants with Secondary Drinking Water Standards
Units of Pollutant per Liter of Extract

	Ag µg/L (ppb)	Al µg/L (ppb)	Fe mg/L (ppm)	Mn µg/L (ppb)	Zn mg/L (ppm)
SMCL	100[a]	50-200[a]	0.3[a]	50[a]	5[a]
TCLP Regulatory Limit	5000	-	-	-	-
Virginia DOT TCLP Conc in extract	<1.0	148	120	NA	10.6
Wisconsin AFS Elution 3 (neutral)	NA	NA	0.23	300	0.36
Scrap Tire Mngmnt TCLP Max Conc	ND	NA	NA	NA	NA
Maine TC Below GWT TCLP Max Conc in extract	ND	NA	NA	NA	NA
Maine Lab Simulation Study Max Conc in extract	<5.0	23600	113	15500	0.54

Notes: NA = not available, that is not measured or not reported for that study
ND = non-detect
[a] Viessman and Hammer, 1985

water standard, and in the Virginia DOT Study above the drinking water standard. Iron levels consistently exceeded the secondary drinking water standard in the Minnesota, Wisconsin, and Virginia DOT Studies as in the University of Maine Study. Concentrations of lead were found above the primary drinking water standard in the Minnesota, Scrap Tire Management Council, and Virginia DOT Studies. In the Wisconsin Study manganese concentrations increased with continued leaching and were above the secondary drinking water standard, as in the University of Maine Study.

Of the semivolatile organic compounds identified here, several were also found in a toxicity study by Abernethy (1994). Aniline, benzothiazole, and 2(3H)-benzothaizolone were found in the University of Maine TCLP and laboratory reactors studies and in the study by Abernethy (1994). Aniline is used as an antidegradant and benzothiazoles are used as accelerators in the rubber processing industry (Fishbein, 1991).

5.5 SUMMARY

The reactor study results for metals indicate that iron, manganese, and zinc concentrations can be expected to increase when using scrap tires. Levels of iron and manganese consistently exceeded the secondary drinking water standards of 300 μg/L and 50 μg/L, respectively, in the reactor water samples. The zinc levels were below the secondary drinking water standard for zinc (5000 μg/L). It was also shown that scrap tires leach chromium to the environment. In addition, the reactor study results indicate that concentrations of barium, chromium, copper, iron, lead, manganese, and zinc were increased in some of the mixed (soil, tire chips, and distilled water) reactor soil samples when compared to the corresponding control reactor soil samples.

Comparisons of the metal results from the long term laboratory study to the results of the TCLP study discussed in Chapter 4 can be made. The likely metals of concern indicated in the TCLP study were barium, cadmium, chromium, and lead. Lead and cadmium were not detected in the water samples from any of the eight batch reactors, however, barium and chromium were found in the reactor water at levels below the primary drinking water standards of 2000 μg/L and 100 μg/L, respectively. Arsenic, mercury, selenium, and silver were not detected in any of the TCLP extracts in the University of Maine study. Arsenic was found in the clay, tire chips, and distilled water reactor water sample at 38.4 μg/L, but the source of the arsenic is most likely the soil.

Semivolatile organic compounds were detected only in the samples from the reactors that contained tire chips. Compounds that were found include: 4-acetyl-morpholine, 2(3H)-benzothiazolone, aniline, benzenepropanoic acid, benzothiazole, and benzoic acid. The concentrations of aniline found ranged from 24.6 μg/L to 47.7 μg/L. Many of the semivolatile organic compounds found in the reactor samples are chemicals used in tire compounding. Some of the semivolatiles found are likely end-products of tire ingredients.

Volatile organic compounds detected in the reactor water samples included: bromomethane, benzene, trichloroethene, toluene, cis-1,2-dichloroethene, bromodichloromethane, dichloromethane, trichloromethane, naphthalene, and 1,1-dichloroethane. Benzene and cis-1,2-dichloroethene were found in the mixed soil, tire chips, and distilled water samples, but not in the corresponding control reactors. None of the volatile organic compounds found were above the drinking water standard (where applicable).

CHAPTER 6

SMALL SCALE FIELD TRIALS

6.1 INTRODUCTION

Small scale field trials were used to investigate the water quality effects of tire chips placed below the groundwater table. Three sites were chosen for the field portion of this study. One trial was constructed in each of three Maine soil types: glacial marine clay (locally known as Presumpscot Formation), glacial till, and fibrous peat. The two criteria used in the site selection were soil type and topography. Possible sites were chosen using United States Department of Agriculture Soil Survey Maps for Penobscot County, Maine and United States Geological Survey 7.5 minute quadrangle maps with 20 foot contour intervals. Copies of the relevant maps are included in Chapter 3. Hand auger borings or test pits were done at potential sites to confirm the desired soil type and that the groundwater table was near the ground surface for as much of the year as possible. It was necessary that each site be reasonably accessed with the equipment required to install the tire chips and monitoring wells. The site selection process is described in detail in Section 3.6.1. A description of each site is given in Section 3.6.2.

At each site, approximately 1.4 metric tons (1.5 short tons) of mixed steel and glass belted tire chips donated by Pine State Recycling of Nobleboro, Maine were installed in a small trench lined with non-woven geotextile. The trenches were approximately 0.6 m (2 ft) wide, 3 m (10 ft) long, and 1.8 m (6 ft) deep, and were dug using a small backhoe. Approximately 1.5 m (5 ft) of tire chips were placed in each trench, the geotextile was folded over the top and the remaining 0.3 m (1 ft) was backfilled with native soil. The purpose of this arrangement was to keep the tire chips below the groundwater table for as much of the year as possible. The tire chip installation is described in detail in Section 3.6.5.

Monitoring wells were installed at each site: one well within the tire-chip-filled trench, one control well upgradient of the trench, and two or more wells downgradient of the trench. A plan view of the trench and wells at each site is presented as Figure 3.15. The monitoring well installation and subsequent development are described in Sections 3.6.5 and 3.6.6, respectively. The monitoring wells installed at the three sites were sampled quarterly. Samples for metal analysis were collected in early June 1994, late September 1994, mid-November 1994, and late April 1995. Samples for organics analysis were collected in mid-August 1994, mid-November 1994, and late April 1995. The sampling methods used are discussed in Sections 3.2 and 3.6.9.

6.2 METALS RESULTS

The first set of samples for metals analysis were collected approximately five months after the tire chips were installed at each of the three field sites. Samples were analyzed for dissolved and total metals. Dissolved metals are defined as those metals of an unacidified sample that pass through a 0.45 μm filter (APHA, AWWA, and WPCF, 1989). Total metals are defined as the concentration of metals determined on an unfiltered sample after vigorous digestion (APHA, AWWA, and WPCF, 1989). Total metals include all metals organically or inorganically bound in both dissolved and particulate form. In this case, the total metal concentration should give a complete picture of the metals that are present in dissolved or particulate form or that have become organically or inorganically bound. The EPA drinking water standards are for dissolved metals; therefore, total recoverable metals will not be compared to the drinking water standards, but will be used as an indication of the effect of tire chips on water quality and on the environment. Since the amount of particulates in the samples varied considerably from well to well, from sampling date to sampling date, and even from bailer to bailer, the total metals data is difficult to interpret. The observed variations in total metal concentrations seen could be due entirely to differences in the amount of particulate in the samples. This problem is avoided however; in the samples from within the tire chip trenches, since those samples are not installed within the soil matrix. Due to this variation, comparisons of total metals in the upgradient and downgradient samples cannot be made. Dissolved metals will be used for these comparisons.

6.2.1 Metals Naturally Occurring in Soil

Soil samples from each site were digested to determine what metals were naturally present in the soils. The following metals were found in the soils from all three sites: aluminum, barium, calcium, copper, iron, lead, magnesium, manganese, silver, sodium, and zinc. In addition, arsenic and chromium are naturally present in the soil from the clay and till sites. These metals may leach from the soil matrix and, for tests for total metals, may be present in the samples as soil sediment. This makes it difficult to identify the contribution of the tire chips to the measured metals concentrations.

At the clay site, well development did not significantly improve the clarity of the water samples from the two downgradient wells. Improvement was seen in the control well samples after development. The result is that the downgradient well samples carry more sediment than the samples from the control well and the well from within the tire chips. This may result in higher concentrations for some metals that may be present in the soil, for example, aluminum, arsenic, and copper.

To develop the peat site wells, 50 well volumes were bailed from each well. The yield of the surrounding formation at the peat site allowed the wells to recharge rapidly.

The samples from each of the peat site wells had similar water clarity. None of the wells could be identified as having samples that consistently carried more sediment.

The well development at the till site failed to improve the clarity from the downgradient well closest to the trench. The samples from this well carried more sediment than the other samples from the till site, and this well consistently had higher metals concentrations for some metals, such as aluminum, arsenic, barium, chromium, copper, and magnesium. Improvement in the clarity of the samples from the upgradient well and the second downgradient well was seen after development.

6.2.2 Results

The metals results presented here are separated into two groups 1) metals with primary drinking water standards and 2) metals with secondary drinking water standards or no drinking water standards. The results for each site are presented on separate tables: Tables 6.1, 6.2, and 6.3 present the results for the metals with primary drinking water standards for the clay, peat, and till sites, respectively. Tables 6.4, 6.5, and 6.6 present the results for metals with secondary standards or with no standard for the clay, peat, and till sites, respectively.

The clay site results for metals with primary drinking water standards are presented in Table 6.1. The clay site results for other metals including metals with secondary drinking water standards are presented in Table 6.4. A schematic of the clay site wells and tire chip trench is presented as Figure 6.1. The well labeled C1 is the control well located upgradient of the tire chips, while C2 is the well within the tire chip trench. The control well is approximately 7.4 m (24.3 ft) from the well within the tire chip trench. Wells C3 and C4 are both downgradient of the tire chip trench. They are approximately 1.5 m (5 ft) (C3) and 3.4 m (11.2 ft) (C4) from the well within the tire chip trench.

Table 6.1
Clay Site
Metals
with Primary Drinking Water Standards

Field Samples Units: ug/L (ppb)

Notes: NA=Not Available, PDWS=Primary Drinking Water Standard (ug/L)

	As (Diss/Total)	Ba (Diss/Total)	Cd (Diss/Total)	Cr (Diss/Total)	Cu (Diss/Total)	Pb (Diss/Total)
PDWS	50	2000	5	100	1300	15
			Jun-94			
C1/Control	<15 / <15	5.4 / 95.1	<5 / <5	3 / 49.1	5.3 / 34.8	<15 / <15
C2	<15 / <15	19.4 / 78.2	<5 / <5	<2 / 24.7	<3 / 16.3	<15 / <15
C3	<15 / <15	4.8 / 119	<5 / <5	<2 / 60.2	<3 / 40.2	<15 / <15
C4	<15 / 20.6	3.8 / 127	<5 / <5	<2 / 65.8	<3 / 51.7	<15 / <15
			Sep-94			
C1/Control	<15 / 36.7	9 / 246	<5 / <5	<2 / 101	<3 / 51	<15 / <15
C2	<15 / <15	36 / 108	<5 / <5	3 / 26	<3 / 17	<15 / <15
C3	<15 / 122.4	8 / 508	<5 / <5	3.1 / 317	<3 / 171	<15 / 31.5
C4	<15 / 73.8	6 / 407	<5 / <5	<2 / 231	<3 / 115	<15 / 25.9
			Nov-94			
C1/Control	<15 / 37.8	9 / 255	<5 / <5	<2 / 114	<3 / 65	<15 / 22.3
C2	<15 / <15	15 / 56	<5 / <5	6 / 16	<3 / 17	<15 / <15
C3	<15 / 61.2	19 / 384	<5 / <5	5 / 205	<3 / 112	<15 / 17.9
C4	<15 / 40	10 / 225	<5 / <5	<2 / 105	<3 / 64	<15 / 20.0
			Apr-95			
C1/Control	<15 / 63.6	6 / 248	<5 / <5	3 / 128	19 / 78	<15 / 45.9
C2	NA / <15	NA / 77	NA / <5	NA / 39	NA / 14	NA / <15
C3	<15 / 57.8	10 / 221	<5 / <5	4 / 124	<4 / 66	<15 / 39.7
C4	NA / 60.8	NA / 225	NA / <5	NA / 118	NA / 61	NA / 38.1

Table 6.2
Pent Site
Metals
with Primary Drinking Water Standards

Field Samples Units: ug/L (ppb)

Notes: NA=Not Available, PDWS=Primary Drinking Water Standard (ug/L)

	As (Diss/Total)	Ba (Diss/Total)	Cd (Diss/Total)	Cr (Diss/Total)	Cu (Diss/Total)	Pb (Diss/Total)
PDWS	50	2000	5	100	1300	15
				Jun-94		
P1/Control	<15 / <15	25.3 / 71.1	<5 / <5	<2 / 3.1	11 / 11.4	<15 / <15
P2	<15 / <15	41.6 / 109	<5 / <5	<2 / 17	<3 / 36.5	<15 / <15
P3	<15 / <15	36.1 / 159	<5 / <5	<2 / 4.4	5.7 / 28.8	<15 / <15
P4	<15 / <15	19.2 / 77.1	<5 / <5	2 / 2	<3 / 11.4	<15 / <15
P5	<15 / <15	18 / 92.8	<5 / <5	<2 / <2	<3 / 40.2	<15 / <15
P6	<15 / <15	39.9 / 115	<5 / <5	<2 / <2	<3 / 18.1	<15 / <15
				Sep-94		
P1/Control	<15 / <15	33 / 83	<5 / <5	<2 / 5	<3 / 20	<15 / <15
P2	<15 / <15	57 / 206	<5 / <5	<2 / 22	<3 / 12	<15 / <15
P3	<15 / <15	37 / 122	<5 / <5	<2 / 2	<3 / 12	<15 / <15
P4	<15 / <15	33 / 104	<5 / <5	2 / 4	<3 / 10	<15 / <15
P5	<15 / <15	32 / 87	<5 / <5	<2 / 2	<3 / 2	<15 / <15
P6	<15 / <15	37 / 105	<5 / <5	<2 / 3	<3 / 10	<15 / <15
				Nov-94		
P1/Control	NA / NA	NA / NA	NA / NA	NA / NA	NA / NA	NA / NA
P2	<15 / <15	35 / 102	<5 / <5	<2 / 18	<3 / 23	<15 / <15
P3	<15 / <15	35 / 140	<5 / <5	<2 / <2	<3 / 24	<15 / <15
P4	<15 / <15	28 / 87	<5 / <5	<2 / 8	<3 / 13	<15 / <15
P5	<15 / <15	34 / 86	<5 / <5	<2 / 4	<3 / 12	<15 / <15
P6	<15 / <15	26 / 92	<5 / <5	<2 / 2	<3 / 42	<15 / <15
				Apr-95		
P1/Control	<15 / <15	27 / 104	<5 / <5	<2 / 10	<4 / 40	<15 / <15
P2	<15 / <15	24 / 85	<5 / <5	5 / 21	<4 / 20	<15 / <15
P3	<15 / <15	34 / 156	<5 / <5	<2 / 8	<4 / 20	<15 / 22
P4	<15 / <15	22 / 87	<5 / <5	<2 / 5	<4 / 6	<15 / <15
P5	<15 / <15	31 / 68	<5 / <5	5 / 3	4 / <4	<15 / <15
P6	<15 / <15	26 / 68	<5 / <5	3 / 2	<4 / 17	<15 / 38.7

Table 6.3
Till Site
Metals
with Primary Drinking Water Standards
Field Samples Units: ug/L (ppb)

Notes: NA=Not Available, PDWS=Primary Drinking Water Standard (ug/L), *=Well consistently high in particulates

	As (Diss/Total)	Ba (Diss/Total)	Cd (Diss/Total)	Cr (Diss/Total)	Cu (Diss/Total)	Pb (Diss/Total)
PDWS	50	2000	5	100	1300	15
				Jun-94		
TI/Control	<15 / <15	6.2 / 81.4	<5 / <5	<2 / 32.8	4.4 / 24.2	<15 / <15
T2	<15 / 30.2	28.2 / 230	<5 / <5	4.4 / 94.8	<3 / 39.3	<15 / <15
T3	<15 / <15	22 / 80.9	<5 / <5	3 / 28.5	<3 / 17.8	<15 / <15
T4*	<15 / 103	7.9 / 380	<5 / <5	4.2 / 249	7.1 / 172	<15 / 27.2
T5	<15 / 15.7	14.4 / 122	<5 / <5	<2 / 37.5	<3 / 56.5	<15 / <15
				Sep-94		
TI/Control	NA / NA	NA / NA	NA / NA	NA / NA	NA / NA	NA / NA
T2	<15 / 24.4	22 / 247	<5 / <5	<2 / 85	<3 / 49	<15 / 15.4
T3	NA / NA	NA / NA	NA / NA	NA / NA	NA / NA	NA / NA
T4*	NA / NA	NA / NA	NA / NA	NA / NA	NA / NA	NA / NA
T5	NA / NA	NA / NA	NA / NA	NA / NA	NA / NA	NA / NA
				Nov-94		
TI/Control	<15 / 28.1	11 / 227	<5 / <5	<2 / 93	<3 / 60	<15 / <15
T2	<15 / <15	26 / 104	<5 / <5	3 / 33	<3 / 23	<15 / <15
T3	NA / NA	NA / NA	NA / NA	NA / NA	NA / NA	NA / NA
T4*	<15 / 95.6	7 / 380	<5 / <5	<2 / 248	<3 / 222	<15 / <15
T5	<15 / 30	18 / 276	<5 / <5	<2 / 92	18 / 96	<15 / <15
				Apr-95		
TI/Control	<15 / 41.8	6 / 254	<5 / <5	2 / 99	<4 / 56	<15 / 32.6
T2	<15 / 26	25 / 240	<5 / <5	7 / 114	4 / 51	<15 / 35.9
T3	NA / NA	NA / NA	NA / NA	NA / NA	NA / NA	NA / NA
T4*	<15 / 516	5 / 1850	<5 / <5	2 / 1240	<4 / 951	<15 / 356
T5	<15 / 37.5	15 / 204	<5 / <5	2/ 68	4 / 86	<15 / 23.7

Table 6.4
Clay Site
Metals
with Secondary Drinking Water Standards or with no Standard

Field Samples Units: ug/L (ppb)

Notes: NA*=Not Applicable, NA=Not Available, SDWS=Secondary Drinking Water Standard (ug/L)

	Ag (Diss/Total)	Al (Diss/Total)	Ca (Diss/Total)	Fe (Diss/Total)	Mg (Diss/Total)	Mn (Diss/Total)	Na (Diss/Total)	Zn (Diss/Total)
SDWS	100	50-200	NA*	300	NA*	50	NA*	5000
				Jun-94				
C1/Control	14 / 18	<200 / 22400	NA / NA	18.4 / 25200	3060 / 12000	120 / 503	6100 / 13000	<2 / 100
C2	11 / <10	<200 / 6790	NA / NA	17300 / 69400	5140 / 12500	724 / 1570	4900 / 11000	10 / 747
C3	<10 / <10	<200 / 28000	NA / NA	21.6 / 33600	5970 / 19600	322 / 984	6100 / 13000	2.1 / 198
C4	<10 / <10	<200 / 32000	NA / NA	<10 / 39700	4490 / 17400	157 / 468	7700 / 16000	<2 / 72.3
				Sep-94				
C1/Control	<10 / <10	<200 / 51400	17700 / 46300	53 / 57400	3150 / 19600	122 / 1610	5570 / 14100	4 / 167
C2	<10 / <10	<200 / 2010	36300 / 76300	56300 / 209000	6940 / 14800	1850 / 3880	5570 / 14000	123 / 675
C3	<10 / <10	<200 / 148000	38200 / 110000	35 / 198000	8450 / 60300	890 / 3590	6700 / 11600	<2 / 531
C4	<10 / <10	<200 / 113000	22200 / 70500	33 / 15100	4890 / 42900	653 / 2530	5340 / 17900	<2 / 341
				Nov-94				
C1/Control	<5 / <5	<200 / 52000	17200 / 48400	476 / 75500	3400 / 24400	82 / 1900	4530 / 11300	7 / 152
C2	6 / 12	<200 / 1710	33000 / 69400	56400 / 195000	6510 / 14600	1400 / 2830	5240 / 11400	20 / 95
C3	<5 / 12	<200 / 90000	69700 / 168000	300 / 111000	14500 / 60800	764 / 2690	9930 / 22200	4 / 298
C4	<5 / <5	249 / 475000	22800 / 59800	318 / 75400	4720 / 25800	44 / 1360	8340 / 18900	<2 / 132
				Apr-95				
C1/Control	<19 / 20	<150 / 58500	13700 / 42800	<100 / 77800	3100 / 27100	49 / 1340	7310 / 14000	4 / 183
C2	NA / 19	NA / 16300	NA / 53300	NA / 109000	NA / 16800	NA / 1990	NA / 10000	NA / 107
C3	<19 / <19	<150 / 54200	48500 / 115000	<100 / 76800	11700 / 43000	532 / 1650	8420 / 18800	<3 / 171
C4	NA / 26	NA / 54400	NA / 70100	NA / 78000	NA / 32300	NA / 1060	NA / 22200	NA / 174

Table 6.5
Pent Site
Metals
with Secondary Drinking Water Standards or with no Standard

Field Samples Units: ug/L (ppb)

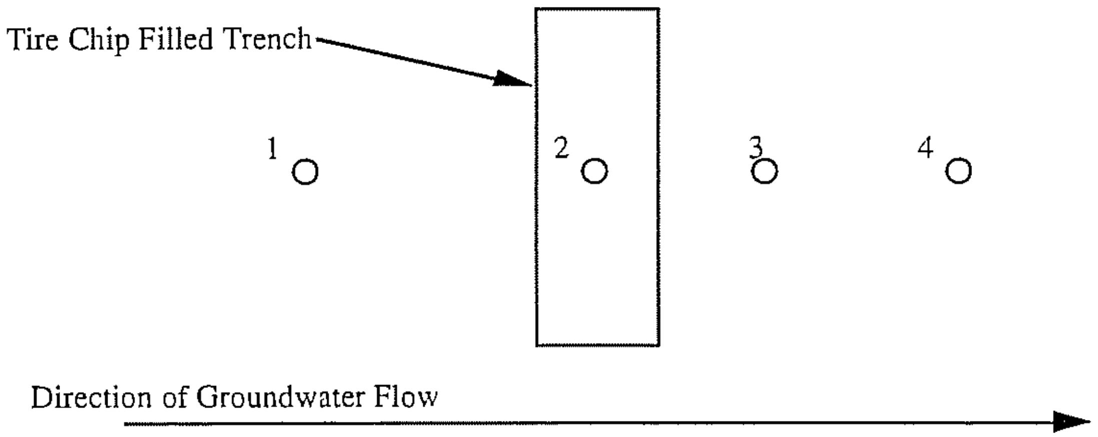
Notes: NA*=Not Applicable, NA=Not Available, Secondary Drinking Water Standard (ug/L)

	Ag (Diss/Total)	Al (Diss/Total)	Ca (Diss/Total)	Fe (Diss/Total)	Mg (Diss/Total)	Mn (Diss/Total)	Na (Diss/Total)	Zn (Diss/Total)
SDWS	100	50-200	NA*	300	NA*	50	NA*	5000
		Jun-94						
	Ag	Al	Ca	Fe	Mg	Mn	Na	Zn
P1/Control	19 / 19	<200 / 1000	NA / NA	514 / 1810	3510 / 7440	574 / 1300	9800 / 20000	2.8 / 14
P2	<10 / <10	<200 / 1090	NA / NA	22500 / 111000	3030 / 6000	732 / 1490	5000 / 9200	44.4 / 2390
P3	<10 / <10	<200 / 7200	NA / NA	279 / 3200	2570 / 6800	726 / 1880	20100 / 42000	5.1 / 25.2
P4	<10 / 22	<200 / 2070	NA / NA	664 / 2700	2680 / 6100	690 / 1710	13600 / 28000	3.3 / 143
P5	<10 / <10	251 / 1630	NA / NA	214 / 1100	2340 / 4180	814 / 1730	12300 / 24000	5.4 / 66.5
P6	<10 / <10	234 / 2640	NA / NA	155 / 59	3450 / 4990	1070 / 1860	12900 / 24000	3.8 / 16.3
		Sep-94						
	Ag	Al	Ca	Fe	Mg	Mn	Na	Zn
P1/Control	<10 / <10	<150 / 816	17200 / 36200	1620 / 412	5580 / 11800	666 / 1440	15900 / 33100	3 / 40
P2	<10 / <10	<150 / 487	23700 / 49500	66800 / 292000	4450 / 9500	1340 / 2830	5320 / 11300	25 / 561
P3	<10 / <10	<150 / 4350	12600 / 29700	974 / 4300	3260 / 7940	954 / 2220	29600 / 57300	5 / 39
P4	<10 / <10	<150 / 1750	17000 / 39300	1640 / 5940	4420 / 9770	786 / 1930	14000 / 32500	<2 / 19
P5	<10 / <10	167 / 1640	10900 / 23800	1830 / 4540	2590 / 5710	916 / 1850	15700 / 30000	2 / 18
P6	<10 / <10	<150 / 1670	15300 / 33700	1180 / 3700	3790 / 8300	845 / 1830	22300 / 40500	2 / 45
		Nov-94						
	Ag	Al	Ca	Fe	Mg	Mn	Na	Zn
P1/Control	NA / NA	NA / NA	NA / NA	NA / NA	NA / NA	NA / NA	NA / NA	NA / NA
P2	<5 / <5	<150 / 809	18400 / 37800	58600 / 212000	3430 / 7380	1150 / 2300	4470 / 10300	15 / 261
P3	<5 / 29	230 / 7580	10200 / 27900	1280 / 8220	2610 / 7780	900 / 2410	26800 / 57500	8 / 17
P4	<5 / <5	<150 / 1970	15200 / 35000	1790 / 9150	3910 / 9020	742 / 1770	13500 / 29100	5 / 8
P5	<5 / <5	243 / 1120	12200 / 30700	1700 / 4580	3030 / 8040	850 / 1720	11600 / 25600	2 / <3
P6	6 / 6	362 / 3430	95400 / 23000	2330 / 9660	2160 / 5220	584 / 1490	13200 / 31000	2 / 31
		Apr-95						
	Ag	Al	Ca	Fe	Mg	Mn	Na	Zn
P1/Control	<19 / 26	250 / 2890	17600 / 41700	3160 / 11600	6480 / 14400	583 / 1370	15600 / 32100	9 / 28
P2	<19 / <19	<150 / 541	20800 / 43500	86900 / 216000	4590 / 9770	1200 / 2440	4950 / 10100	15 / 107
P3	<19 / <19	153 / 9450	12200 / 33100	2460 / 12000	3640 / 10400	1090 / 2680	26400 / 55100	8 / 14
P4	<19 / <19	<150 / 2490	13700 / 36400	2900 / 11400	4090 / 10400	812 / 2100	21200 / 42500	<3 / <3
P5	<19 / <19	223 / 1120	13200 / 29300	2190 / 5650	3880 / 8720	493 / 1080	13100 / 26100	8 / <3
P6	<19 / <19	298 / 3830	11900 / 20600	2450 / 8800	3380 / 5630	658 / 1080	15800 / 34500	7 / 10

Table 6.6
Till Site
Metals
with Secondary Drinking Water Standards or with no Standard
Field Samples Units: ug/L (ppb)
Notes: NA*=Not Applicable, NA=Not Available, SDWS=Secondary Drinking Water Standard (ug/L), *=Well consistently high in particulates

	Ag (Diss/Total)	Al (Diss/Total)	Ca (Diss/Total)	Fe (Diss/Total)	Mg (Diss/Total)	Mn (Diss/Total)	Na (Diss/Total)	Zn (Diss/Total)
SDWS	100	50-200	NA*	300	NA*	50	NA*	5000
				Jun-94				
TI/Control	<10 / <10	<10 / 81400	NA / NA	21.5 / 14200	4240 / 12200	49 / 365	4900 / 11000	<2 / 42.7
T2	<10 / <10	<10 / 230000	NA / NA	4210 / 199000	1110 / 33400	3430 / 7440	8000 / 17000	7.2 / 362
T3	<10 / <10	<10 / 80900	NA / NA	4110 / 110000	1100 / 23900	3190 / 6560	7800 / 16000	7.9 / 313
T4*	<10 / <10	2090 / 380000	NA / NA	2710 / 113000	7030 / 52100	95 / 2620	6200 / 19000	5.6 / 307
T5	<10 / <10	<10 / 122000	NA / NA	33 / 19400	7410 / 19800	288 / 890	8300 / 17000	2.4 / 45.8
				Sep-94				
TI/Control	NA / NA	NA / NA	NA / NA	NA / NA	NA / NA	NA / NA	NA / NA	NA / NA
T2	<10 / <10	<10 / 38700	26200 / 59900	6530 / 117000	5010 / 20900	2340 / 5450	4140 / 9730	76 / 569
T3	NA / NA	NA / NA	NA / NA	NA / NA	NA / NA	NA / NA	NA / NA	NA / NA
T4*	NA / NA	NA / NA	NA / NA	NA / NA	NA / NA	NA / NA	NA / NA	NA / NA
T5	NA / NA	NA / NA	NA / NA	NA / NA	NA / NA	NA / NA	NA / NA	NA / NA
				Nov-94				
TI/Control	<5 / <5	362 / 38100	19100 / 63500	277 / 63700	4500 / 21900	41 / 1010	22100 / 40600	4 / 103
T2	<5 / <5	173 / 64100	27500 / 57500	71700 / 209000	7890 / 19000	2450 / 4990	4220 / 9510	10 / 54
T3	NA / NA	NA / NA	NA / NA	NA / NA	NA / NA	NA / NA	NA / NA	NA / NA
T4*	<5 / <5	190 / 115000	28900 / 91700	352 / 120000	7600 / 55000	39 / 2710	29600 / 66500	<3 / 276
T5	<5 / <5	317 / 43600	18900 / 46700	618 / 69500	7120 / 27500	662 / 2260	34300 / 71000	23 / 99
				Apr-95				
TI/Control	<19 / 19	244 / 43400	10900 / 32500	134 / 69700	3540 / 27100	27 / 1330	5030 / 16700	4 / 134
T2	<19 / 19	<150 / 43500	29900 / 66000	47500 / 213000	12600 / 41600	2500 / 5340	5070 / 11400	.5 / 205
T3	NA / NA	NA / NA	NA / NA	NA / NA	NA / NA	NA / NA	NA / NA	NA / NA
T4*	<19 / 19	179 / 492000	29500 / 175000	<100 / 817000	11400 / 230000	27 / 13500	27600 / 47100	5 / 1540
T5	<19 / 19	170 / 32700	19900 / 46100	<100 / 46700	9950 / 30200	773 / 2160	5100 / 55900	<3 / 83

Figure 6.1
Schematic of Trench and Wells at the Clay Site

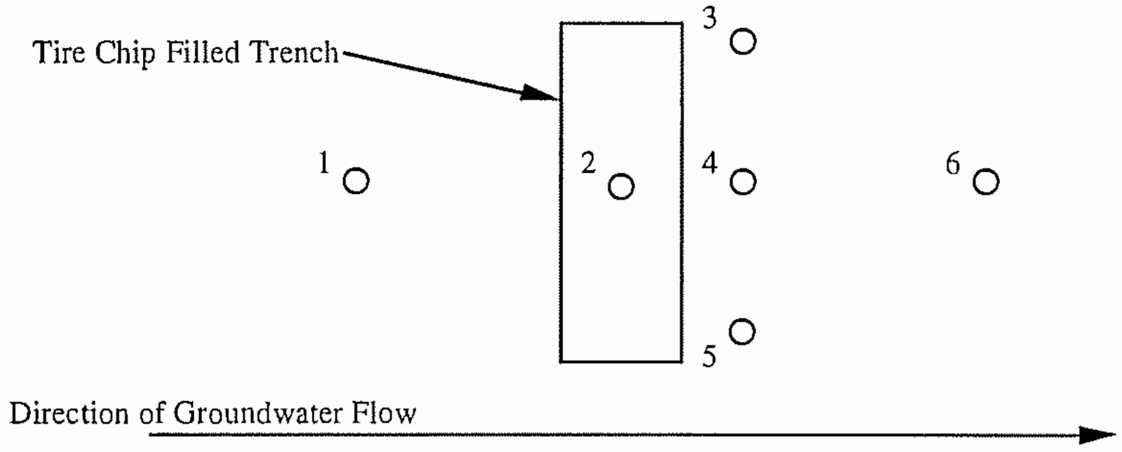


Notes: Not to scale, locations are approximate

The peat site results for metals with primary drinking water standards are presented in Table 6.2. The results for metals with secondary drinking water standards and other metals are presented in Table 6.5. A schematic of the well positioning with respect to the tire chip trench is included as Figure 6.2. The well labeled P1 is the control well (upgradient) at the peat site. It is approximately 9.3 m (30.5 ft) from the well within the tire chips. Well P2 is within the tire chip filled trench. Wells P3, P4, P5, and P6 are all downgradient wells. Wells P3, P4, and P5 are placed in an approximately horizontal line parallel to the tire chip trench. Well P4 is in the center and is approximately 1 m (3.3 ft) from the well within the tire chips. Wells P4 and P5 are approximately 3.4 m (11.2 ft) and 2.4 m (7.9 ft) from well C2, respectively. Well P6 is the final downgradient well and is approximately 3.2 m (10.5 ft) from the well within the tire chips.

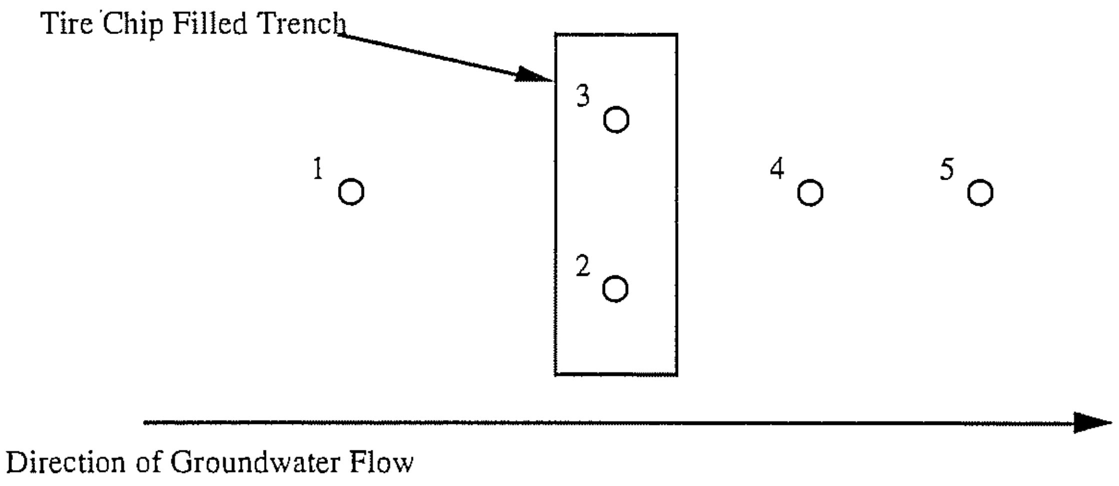
The results for primary metals at the till site are presented in Table 6.3. The results for other metals including those with secondary drinking water standards are presented in Table 6.6. A schematic of the layout of the wells and the tire chip trench is presented as Figure 6.3. The control well at the till site (upgradient of the tires) is labeled T1. The control well is approximately 6.4 m (21 ft) from the drilled well within the tire chips (T2). Two wells were placed within the tire chip trench, they are labeled T2 and T3. After the first round of sampling, well T3 was no longer sampled. Wells T4 and T5 are downgradient of the tire chips and approximately 2.4 m (7.9 ft) and 4.6 m (15 ft) from the well within the tire chip trench. The elevation of the groundwater table varied considerably from season to season at the till site. All the sampling wells except those within the tire chip filled trench were dry at the time of the September, 1994 sampling; therefore samples from the upgradient and downgradient wells could not be collected and analyzed.

Figure 6.2
Schematic of Trench and Wells at the Peat Site



Notes: Not to scale, locations are approximate

Figure 6.3
Schematic of Trench and Wells at the Till Site



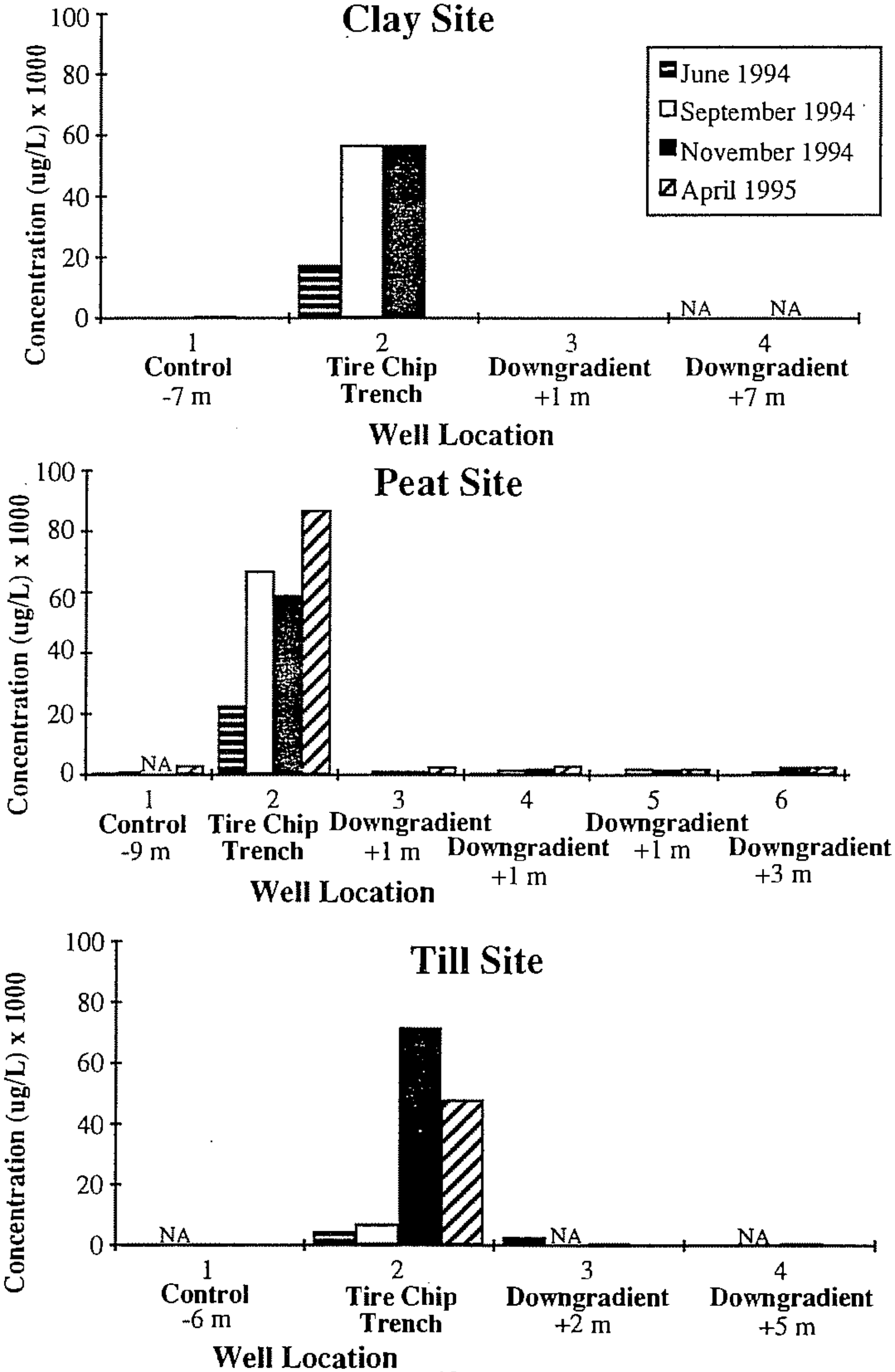
Notes: Not to scale, Locations are approximate

6.2.3 Iron Results

The tire chips used in the small scale field installations were mixed steel and glass belted chips. Since many steel belts are exposed and embedded in the rubber chips, it is reasonable to expect tire chips that are placed below the groundwater table to leach iron to the environment. The reactor study showed that tire chips significantly increased the iron concentrations in the reactor water samples when compared to the iron concentrations in the control reactors. In addition, the soil sample digests from the reactors showed that iron was significantly increased in the peat sample. As seen in Tables 6.4, 6.5, and 6.6, large increases in the dissolved iron levels were seen at the well within the tire chip filled trench, when compared to the control well for each of the four sampling events at all three sites. Figure 6.4 illustrates the increasing dissolved iron concentrations at the tire chip trench for each of the three sites. The concentrations of dissolved iron in the tire chip trench are much higher (up to two orders of magnitude) than the secondary drinking water standard for iron (300 µg/L). Dissolved iron levels in the control well samples and downgradient well samples were often above 300 µg/L. The maximum iron levels measured within the tire chip trenches was 86,900 µg/L for dissolved iron. While the maximum iron levels measured in wells downgradient of the tire chip filled trenches was 4110 µg/L for dissolved iron.

The taste threshold for iron is 40 µg/L to 100 µg/L (Tate and Arnold, 1990). The iron concentrations in the field samples consistently exceeded the taste threshold levels. Tire chips are increasing the iron concentrations in the groundwater at all three sites. However, as seen in Figure 6.4, the concentrations of dissolved iron in the downgradient wells are similar to the concentrations of dissolved iron in the control wells indicating that for times up to 13 months from installation iron is not mobile in these environments due to precipitation.

Figure 6.4 Dissolved Iron



Note: NA indicates that the data is not available

The total iron concentration is higher than the dissolved iron concentration in the samples from within the tire chip trenches. This indicates that there is iron associated with the particulate material in the samples. This is expected because at these high levels of iron, the solubility limit has been exceeded and iron should be present in solid form. Table 6.7 presents the solubility data for $Fe(OH)_3$, $Fe(OH)_2$, and $FeCO_3$ at the approximate pH and alkalinity of the samples from the wells within the trenches. If iron is present as Fe^{3+}, $Fe(OH)_3$ will readily precipitate. Since the wells are shallow and the groundwater table fluctuates (clay and till sites) Fe^{3+} is expected to be present. Since the wells within the tire chip trenches were not installed in the soil matrix, but were installed directly in the tire chips, the source of the increased total iron is the tire chips. The maximum iron levels measured within the tire chip trenches was 292,000 μg/L for total iron. The maximum iron levels measured in wells downgradient of the tire chip filled trenches were 817,000 μg/L for total iron. The highest concentration was found in a sample taken at the till site from a well that was consistently high in particulate matter. The high total iron concentration was likely associated with the soil particles.

Table 6.7
Solubility Data
Field Samples
Iron

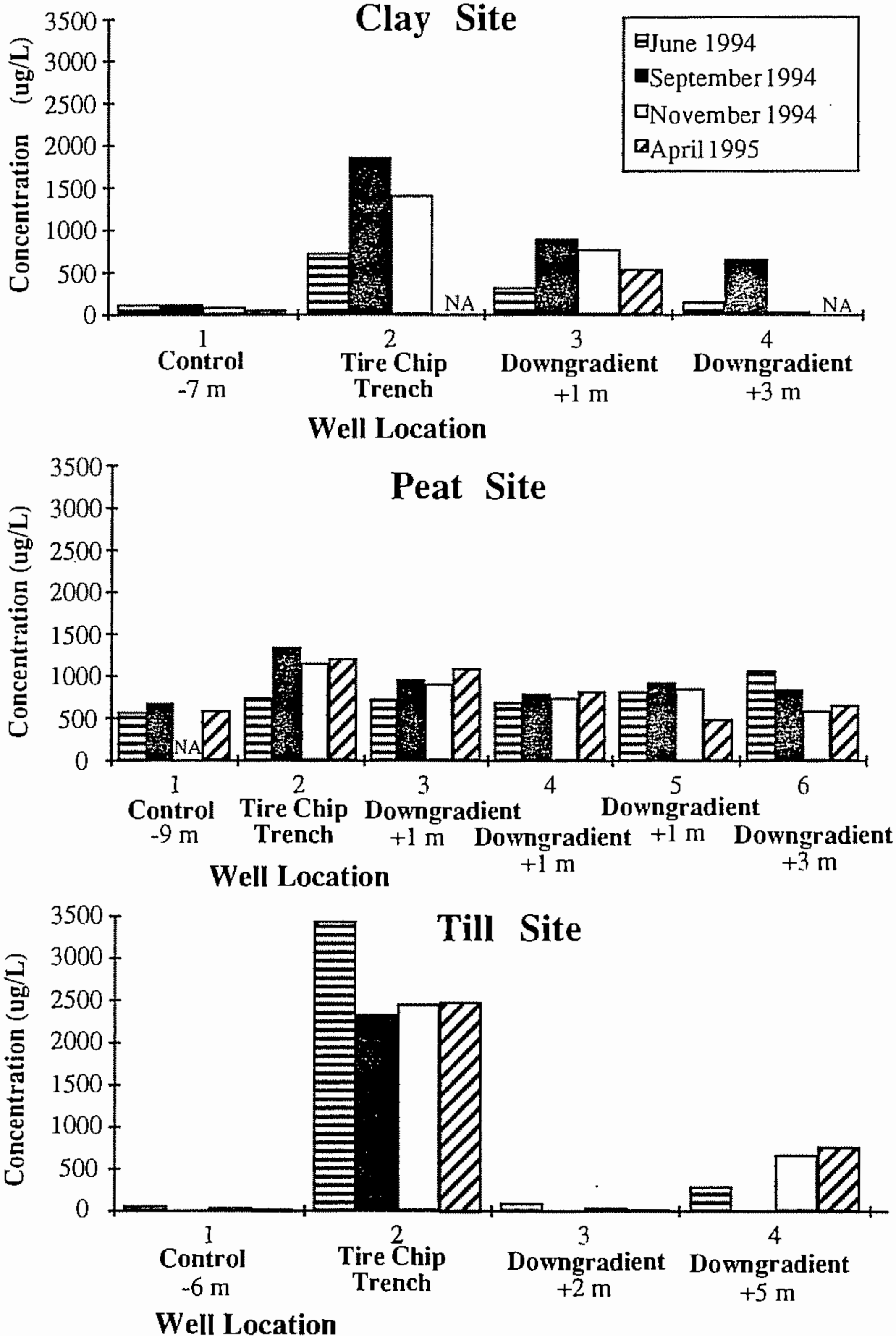
System	Solubility Limit (mg/L)	Alkalinity mg/L as $CaCO_3$	pH
$Fe(OH)_2$	1.8×10^{7}	100	7
$Fe(OH)_3$	9×10^{-3}	100	7
$FeCO_3$	2×10^{3}	100	7

6.2.4 Manganese Results

The typical composition of steel tire cord and beadwire includes 0.40% to 0.70% manganese (Dunlop Tire Corporation, 1990). Thus, leaching of manganese from steel belted tires used below the groundwater table can be expected. Manganese has a secondary drinking water standard of 50 µg/L. A large increase in dissolved manganese is seen when comparing the well sample from within the tire chips to the control well sample at the clay and till sites. There is also an increase at the well within the tire chips at the peat site, but it is less pronounced than at the other two sites. The concentration in the wells downgradient of the tire chip trench was also increased (when compared to the control wells), moving downgradient the concentration decreases as the distance from the tire chips increases. Figure 6.5 illustrates these trends at each of the sites. All the dissolved manganese concentrations for the samples from within the tire chip trenches were above 50 µg/L. The maximum manganese levels measured in samples from within the tire chips was 3430 µg/L for dissolved manganese. While the maximum manganese concentrations in the samples from the downgradient wells was 3190 µg/L for dissolved manganese. Levels of dissolved manganese above the solubility limit were measured since the samples are not at equilibrium. The taste threshold for manganese is 4000 µg/L to 30,000 µg/L (Tate and Arnold, 1990). Manganese concentrations for this study were close to or exceeded 4000 µg/L.

The total manganese concentration is higher than the dissolved manganese concentration in the samples from the wells within the trench at each site. This shows that the particulate material in the samples is contributing manganese. Since the wells within the tires are not within the soil matrices, the tire chips can be identified as the source of the increase in total manganese. The maximum manganese levels measured in samples from within the tire chips were 7440 µg/L for total manganese. While the maximum manganese

Figure 6.5 Dissolved Manganese



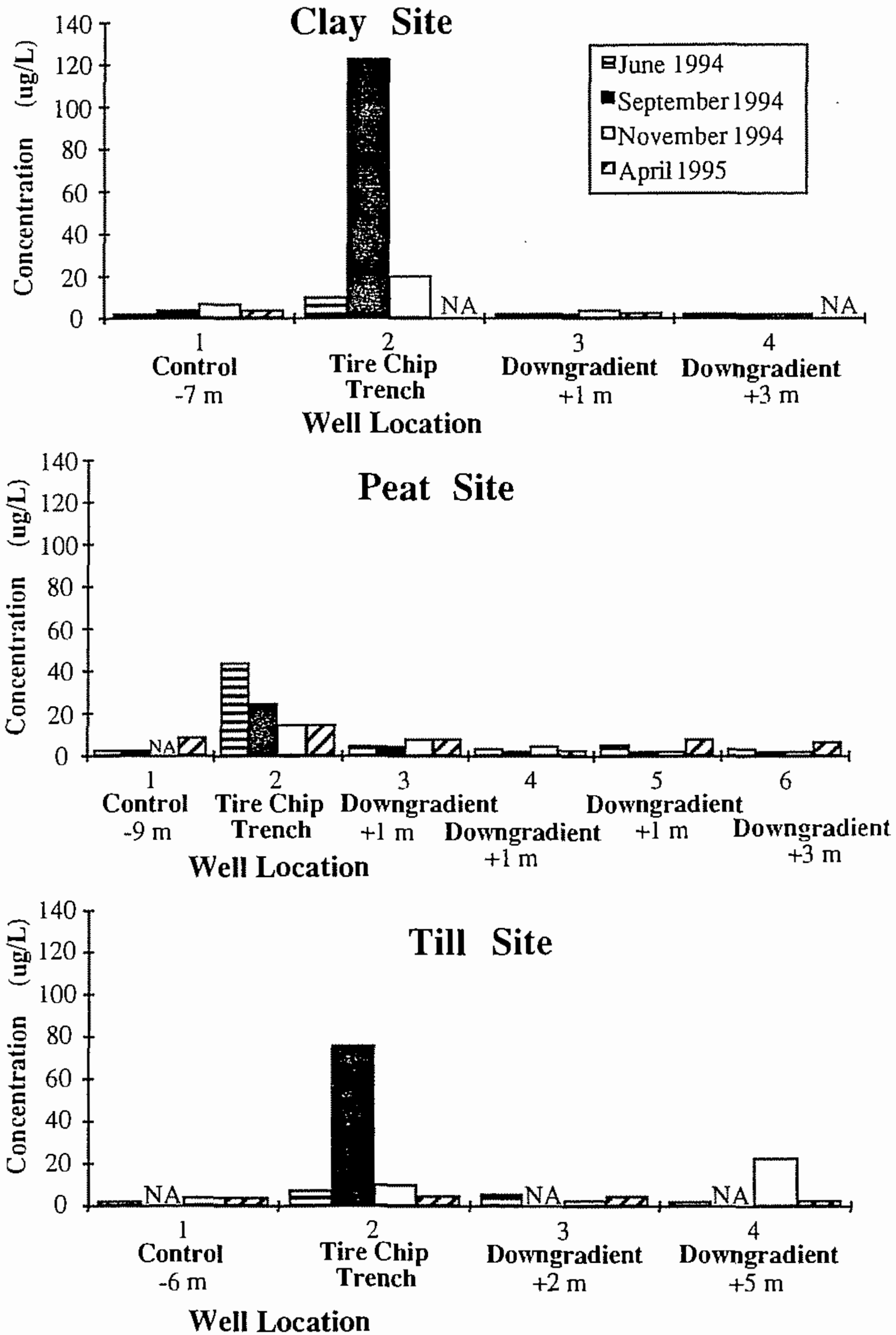
Note: NA indicates that the data is not available

concentrations in the samples from the downgradient wells was 13,500 µg/L for total manganese. Tire chips are contributing significant levels of manganese to the groundwater at the three sites.

6.2.5 Zinc Results

In rubber manufacturing, zinc oxides are used as activators, which make accelerators more effective by forming intermediate complexes (Fishbein, 1991). In addition, zinc is present as a coating on steel cord and beadwire (Dunlop Tire Corporation, 1990). Therefore, leaching of zinc from tire chips placed below the groundwater table could reasonably be expected based on the tire ingredients used. As seen in Tables 6.4, 6.5, and 6.6 dissolved zinc concentrations were higher in the tire chip trench sample than in the control sample for all sampling events for all sites. Figure 6.6 shows the dissolved zinc concentration increasing at the tire chip trench well for all four sampling events. Total zinc concentrations were higher than dissolved zinc concentrations in the tire chip trench samples for all sampling events at each site. This increase in total zinc is due to zinc associated with particulate material in the samples. The source of the increase in zinc can be identified as the tire chips since the tire chip trench wells are installed directly in the tire chips rather than in the soil matrix. All dissolved zinc levels were well below the secondary drinking water standard of 5000 µg/L. The highest total zinc concentration measured was 2390 µg/L. The taste threshold for zinc is 4000 µg/L to 9000 µg/L (Tate and Arnold, 1990). No zinc concentrations measured in this field study exceeded the taste threshold. Tire chips will increase the concentration of zinc in the groundwater, however, the concentrations of zinc are not likely to exceed the drinking water standard. The "background" zinc concentration in the samples from the control wells was less than 10 µg/L for all sampling dates for all sites. Since the dissolved zinc concentrations in the downgradient well do not appear substantially different than the

Figure 6.6 Dissolved Zinc



Note: NA indicates that the data is not available

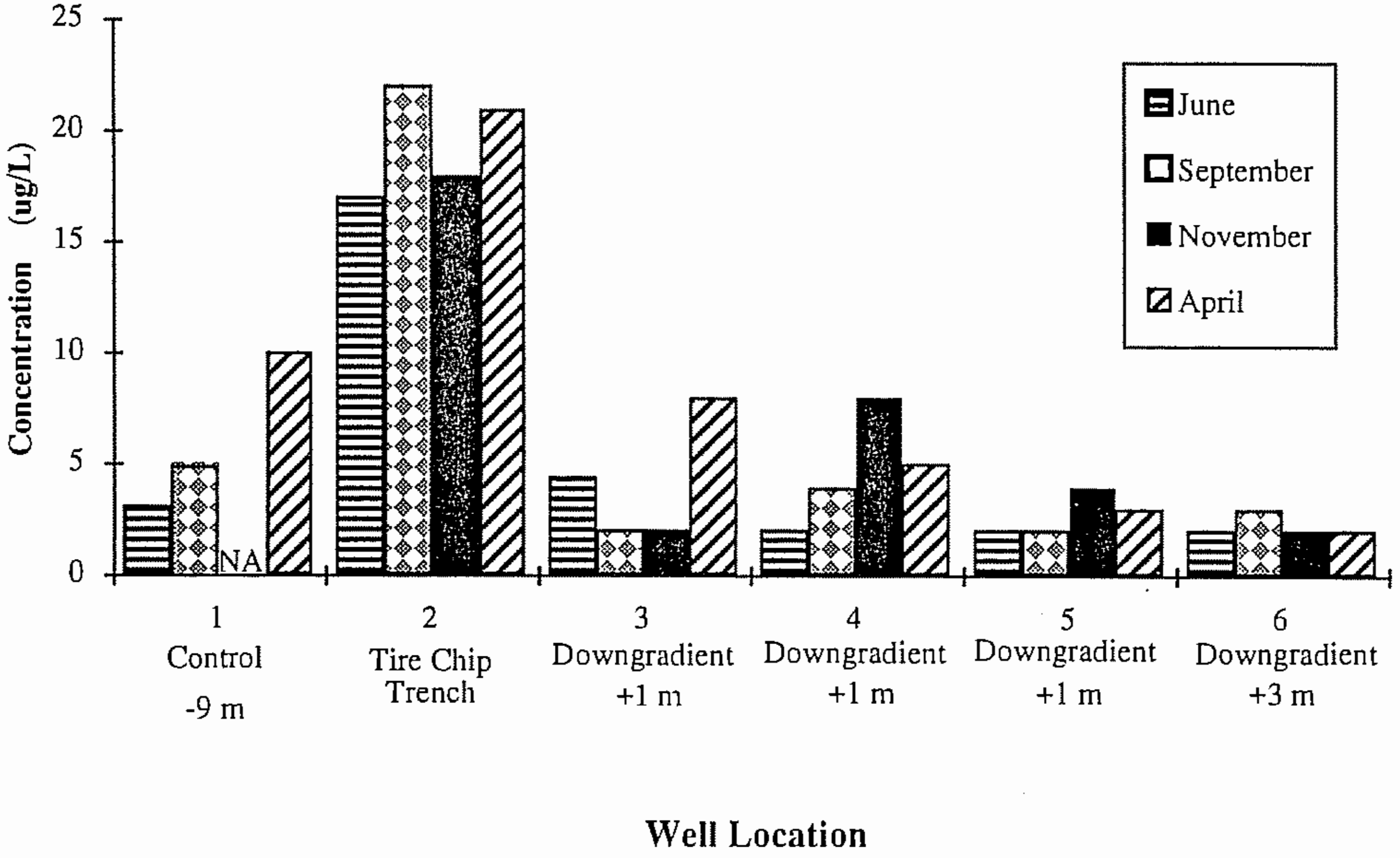
concentrations in the control wells, it appears that the zinc has limited mobility in these environments.

6.2.6 Chromium Results

Chromium is present in steel tire cord and beadwire in trace amounts (Dunlop Tire Corporation, 1990). Chromium was found in the TCLP extracts of all tire samples tested in the laboratory leaching phase of this research. Therefore, chromium has the potential to be present in the leachate. Chromium concentration patterns at the peat site were different than at the clay and till sites. The dissolved chromium concentrations from the peat wells were below or slightly above the method detection limit (2 μg/L). No pattern could be identified in the dissolved chromium concentrations. However, the total chromium concentrations were higher at the well within the trench than at the control well for each of the sampling rounds (Table 6.2), as shown in Figure 6.7. When a sample of peat was digested, no chromium was found in the digestate; therefore, the chromium found in the peat well samples could not be attributable to soil leaching. However, as seen in Figure 6.7, chromium was detected in the control well for two sampling events. Surface flooding of the peat site during most of the year could cause contaminants to be spread from the tire chip trench to other wells. The highest level of total chromium found was 22 μg/L. The tire chips installed at the peat site are increasing the chromium levels.

At the clay and till sites the dissolved chromium levels were all below or near the method detection limit. However, the total chromium levels were considerably higher (Tables 6.1 and 6.3). The highest concentration at the clay site was 317 μg/L, but this concentration was found in the downgradient well that is closest to the tire chip trench. This well appeared to consistently carried more sediment than the control well or the well within the trench. The total chromium concentration was lower in the sample from within the tire chips than in any of the other well samples (upgradient or downgradient). This

Figure 6.7
Peat Site Total Chromium



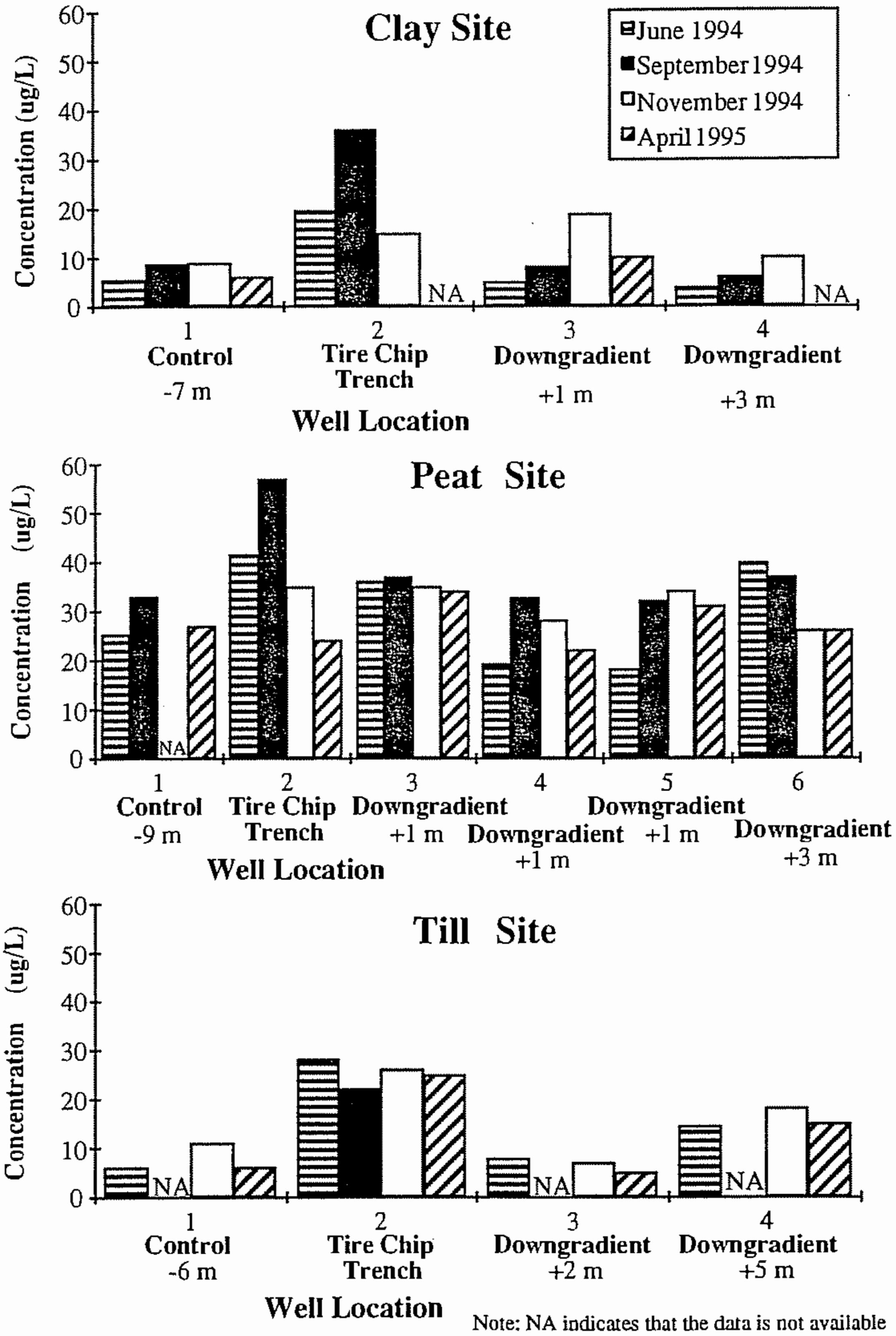
Note: NA indicates that the data is not available

indicates that the soil is influencing the chromium concentration more than the tires. At the till site the total chromium results varied. For the June samples, the total chromium concentration was higher at the well within the trench than at the control well (94.8 µg/L vs. 32.8 µg/L). The concentration was also slightly higher at the well within the trench for the April, 1995 samples. For the November, 1994 samples, the pattern was similar to the behavior at the clay site, where the sample from within the trench had the lowest concentration of any sample. The chromium levels were consistently high in the samples from the downgradient well closest to the tire chip trench. On a qualitative basis, the samples from this well carried more sediment than the other till site well samples. Digestion of samples of both the clay and till showed that chromium was present in the soil. At the clay and till sites leaching of the chromium from the soil makes it difficult to assess what levels of chromium are leaching from the tires. The results of the TCLP portion of this study consistently show that tire chips leach chromium. It appears that tire chips leach small amounts of chromium to the environment but there is little likelihood that the primary drinking water standard (100 µg/L) will be exceeded.

6.2.7 Barium Results

Barium was indicated as a potential pollutant of concern in the laboratory leaching portion of this study. Barium was found in the TCLP extracts in all four tire chip samples tested. At the clay and till sites dissolved barium concentrations were higher at the tire chip wells than at the control wells. At the peat site dissolved barium levels were higher in the tire chip trench samples than in the control well for the June, 1994 and September, 1994 samples. Figure 6.8 illustrates the dissolved barium concentrations for each well for each site. Total barium was higher than dissolved barium in the sample from within the tire chips at each site. The source of the increased total barium is the tire chips. No barium concentrations above the primary drinking water standard (2000 µg/L) for barium

Figure 6.8 Dissolved Barium



Note: NA indicates that the data is not available

were found. Tire chips contribute low levels of barium to the groundwater, but the drinking water standard is not likely to be exceeded.

6.2.8 Other Metals Results

TCLP testing results indicated that cadmium could potentially be leached from tire chips. However, all samples from the field sites had cadmium (dissolved and total) levels below the method detection limit (5 µg/L). All dissolved cadmium concentrations were therefore below the primary drinking water standard (5 µg/L). Tire chips did not leach cadmium to the environment at these three field sites. This is consistent with the findings of the reactor study results where cadmium levels were below the method detection limit (5 µg/L) for all water samples.

Lead was also indicated as a potential contaminant from tire chips by the TCLP testing results and by the reactor study soil digest results (peat reactor and mixed peat and tire chips reactor). The potential for lead to leach from the soil is confirmed by the soil digest data: all three soil types contained lead. However, all samples had dissolved lead concentrations below the method detection limit (15 µg/L) and therefore are below the primary drinking water standard (15 µg/L). In addition, all samples from the peat site had total lead concentrations below the method detection limit. However, total lead concentrations were above the method detection limits for some samples at the clay and till sites. The highest concentrations of total lead found in the control and downgradient wells were 45.9 µg/L and 356 µg/L at the clay and till sites, respectively. The till site April, 1995 sample from within the tire chips had a total lead concentration of 35.9 µg/L, which was slightly higher than the control sample concentration (32.6 µg/L). It is possible that tire chips leach low levels of lead to the environment, however, the effects of the tires are not clear due to leaching of lead that is naturally present in the soil.

Arsenic was not found in any of the TCLP extracts from the laboratory leaching portion of this project. however, potential for arsenic to leach from soil was indicated by the soil sample digest data. Arsenic was found in the digestates of the till and clay samples, but not in the digestate of the peat sample. All of the arsenic concentrations (dissolved and total) in the peat site samples were below the method detection limit (15 µg/L). Dissolved arsenic was also below the method detection limits in all samples from the clay and till sites; therefore, these concentrations are below the primary drinking water standard (50 µg/L). However, total arsenic was above the method detection limit for some clay and till site samples. The highest concentration of total arsenic found at the clay site was 122.4 µg/L, and at the till site was 516 µg/L. In general, the arsenic concentration was lower at the well within the trench than at the control well, with the exception being the June samples at the till site. The arsenic in these samples is most likely due to leaching from soil.

Copper is present in steel tire cord and beadwire in trace amounts (Dunlop Tire Corporation, 1990). Copper was indicated as a potential contaminant in the soil digests performed on the peat samples in the reactor study. Copper is naturally present in the soils as indicated by its presence in the digestates of all three soil types. The dissolved copper levels at all three sites were below the method detection limit or slightly above it. In general, the copper concentrations were lower in the samples from within the tire chip filled trench than in the control wells. The highest concentrations of total copper found at each of the three sites (not at the trench) were 171 µg/L, 40.2 µg/L, and 951 µg/L at the clay, peat, and till sites, respectively. It is likely that the levels of copper found in these samples was due to the soil matrices. The primary drinking water standard for copper is 1300 µg/L. Tire chips may leach some copper but the levels were too low to distinguish from levels naturally present in the soil.

Total aluminum concentrations were lower in the samples from the tire chip trenches than in any of the other samples at the clay site and were lower or the same as the concentration from upgradient and downgradient wells at the peat site. At the till site, the total aluminum concentrations were higher in the sample from within the tires for three of the sampling events. The aluminum levels in these samples is most likely due to leaching from the soil. The reactor study soil digests showed that there were significant levels of aluminum in the soils. Tire chips did not appear to affect the aluminum concentrations at the three field sites.

In general, the highest levels of dissolved and total calcium and magnesium were found in the wells that carried the most sediment. This suggests that the calcium and magnesium are naturally occurring and that the concentrations are not affected by the tire chip installations. There are no drinking water standards for calcium or magnesium. It appears that tires do not affect the concentrations of magnesium and calcium at the clay, till, and peat sites in this study.

Silver (dissolved and total) was below or very close to the method detection limits for all samples in this study (the method detection limit varied from 5 μg/L to 19 μg/L). The secondary drinking water standard for silver is 100 μg/L. Silver was not found in any of the TCLP extracts from the laboratory leaching tests. Silver was not indicated as a contaminant of concern in the reactor study, low levels of silver were found in the soil sample digests. Tire chips are not expected to increase the silver concentrations in groundwater.

Tires did not affect the concentrations of sodium at any of the field sites. Sodium levels were relatively constant for the wells for each sampling event. Two possible sources for the sodium present are naturally occurring sodium and sodium from the bentonite well seals used. Tire chips do not appear to affect sodium concentrations in the groundwater.

6.3 ORGANICS RESULTS

The first set of organics samples were collected approximately seven months after the tire chips were installed at each of the three field sites. Samples were collected twice after the initial sampling (mid-November 1994 and late April 1995).

6.3.1 Volatile Organic Compounds Results

Data for volatile organic compounds found in the field samples is available for the August 1994 and November 1994 sampling events. The data for the volatile samples collected in April 1995 were lost due to a laboratory equipment failure. The volatile organic compounds analyzed in the field samples are listed in Tables 6.8 and 6.9 for the August, 1994 and November, 1994 samples, respectively. These tables indicate which compounds were detected and which were not detected for each sample. The concentrations of those compounds detected are listed in Tables 6.10 and 6.11, for the August 1994 and November 1994 samples, respectively.

Dichloromethane was found in all samples including the laboratory blank (prepared at ERI) and the blank that was shipped with the samples. The concentrations were 1.5 μg/L in the laboratory blank and 5.4 μg/L and 7.6 μg/L in the blanks shipped with the samples. Dichloromethane is used in the preparation of samples analyzed for semivolatile organics. ERI confirmed that the same sample prep room is used for volatile and semivolatile organic samples; therefore, contamination of the samples is possible. In addition, dichloromethane is used as a solvent in the rubber manufacturing industry, making tire chips a possible source (Fishbein, 1991). The total theoretical dichloromethane concentration based on the results of the TCLP testing and knowing the

Table 6.8
Field Samples
Volatile Organics
Samples Collected 8/17/1994
Notes: Sample volume from wells T1, T4, and T5 were insufficient for volatiles analysis, Well T3 has been abandoned),
MDL=Method Detection Limit (ug/L), D=Detected, Empty boxes indicate that the compound was not detected

Compound	MDL (ug/L)	Blank	ERI Blank	C1	C2	C3	C4	P1	P2	P3	P4	P5	P6	T2
Dichlorodifluoromethane	1.0													
Chloromethane	1.0													
Chloroethene	1.0													
Bromomethane	1.0													
Chloroethane	1.0													D
Trichlorofluoromethane	1.0													
1,1-Dichloroethene	0.5													
Dichloromethane	0.5	D	D	D	D	D	D	D	D	D	D	D	D	D
Trans-1,2-Dichloroethene	0.5													
MTBE	0.5													
1,1-Dichloroethane	0.5				D	D			D					D
cis-1,2-Dichloroethene	0.5				D				D					D
2,2-Dichloropropane	0.5													
Bromochloromethane	0.5													
Trichloromethane	0.5													

Table 6.8 Continued
Field Samples
Volatile Organics
Samples Collected 8/17/1994
Notes: Sample volume from wells T1, T4, and T5 were insufficient for volatiles analysis, Well T3 has been abandoned),
MDL=Method Detection Limit (ug/L), D=Detected, Empty boxes indicate that the compound was not detected

Compound	MDL (ug/L)	Blank	ERI Blank	C1	C2	C3	C4	P1	P2	P3	P4	P5	P6	T2
1,1,1-Trichloroethane	0.5				D	D			D					D
1,1-Dichloropropene	0.5													
Tetrachloromethane	1.0													
Benzene	0.5				D				D					D
1,2-Dichloroethane	0.5													
Trichloroethene	0.5					D			D					
1,2-Dichloropropane	0.5													
Dibromomethane	0.5													
Bromodichloromethane	1.0													
cis-1,3-Dichloropropene	0.5													
Toluene	0.5				D	D	D		D	D	D			D
trans-1,3-Dichloropropene	0.5													
1,1,2-Trichloroethane	0.5													
1,3-Dichloropropane	0.5													
Tetrachloroethene	0.5													

Table 6.8 Continued
Field Samples
Volatile Organics
Samples Collected 8/17/1994

Notes: Sample volume from wells T1, T4, and T5 were insufficient for volatiles analysis, Well T3 has been abandoned),

MDL=Method Detection Limit (ug/L), D=Detected, Empty boxes indicate that the compound was not detected

Compound	MDL (ug/L)	Blank	ERI Blank	C1	C2	C3	C4	P1	P2	P3	P4	P5	P6	T2
Dibromochloromethane	0.5													
1,2-Dibromoethane	0.5		D											
Chlorobenzene	0.5													
1,1,1,2-Tetrachloroethane	0.5		D			D				D				
Ethylbenzene	0.5													
m-Xylene+p-Xylene	0.5													
o-Xylene	0.5													
Styrene(ethyl-benzene)	1.0													
Bromoform	0.5		D											
iso-Propylbenzene	0.5													
1,1,2,2-Tetrachloroethane	0.5													
1,2,3-Trichloropropane	0.5													
Bromobenzene	0.5													
n-Propylbenzene	0.5													
2-Chlorotoluene	0.5													

Table 6.8 Continued
Field Samples
Volatile Organics
Samples Collected 8/17/1994
Notes: Sample volume from wells T1, T4, and T5 were insufficient for volatiles analysis, Well T3 has been abandoned),
MDL=Method Detection Limit (ug/L), D=Detected, Empty boxes indicate that the compound was not detected

Compound	MDL (ug/L)	Blank	ERI Blank	C1	C2	C3	C4	P1	P2	P3	P4	P5	P6	T2
1,3,5-Trimethylbenzene	0.5													
4-Chlorotoluene	0.5													
tert-Butylbenzene	0.5													
1,2,4-Trimethylbenzene	0.5													
sec-Butylbenzene	0.5													
4-iso-Propyltoluene	0.5													
1,3-Dichlorobenzene	1.0													
1,4-Dichlorobenzene	0.5													
n-Butylbenzene	1.0													
1,2-Dichlorobenzene	0.5													
1,2-Dibromo-3-chloropropane	1.0		D											
1,2,4-Trichlorobenzene	1.0													
Hexachlorobutadiene	0.5													
Naphthalene	0.5		D		D	D				D	D		D	D
1,2,3-Trichlorobenzene	0.5													

Table 6.9
Field Samples
Volatile Organics
Samples Collected 11/18/1994 and 11/19/1994
Notes: Well P1 was frozen, Well T3 has been abandoned),
MDL=Method Detection Limit (ug/L), D=Detected, Empty boxes indicate that the compound was not detected

Compound	MDL (ug/L)	Blank	C1	C2	C3	C4	P2	P3	P4	P5	P6	T1	T2	T4	T5
Dichlorodifluoromethane	1.0														
Chloromethane	1.0														
Chloroethene	1.0														
Bromomethane	1.0														
Chloroethane	1.0														
Trichlorofluoromethane	1.0														
1,1-Dichloroethene	0.5														
Dichloromethane	0.5	D	D	D	D	D	D	D	D	D	D	D	D	D	D
Trans-1,2-Dichloroethene	0.5														
MTBE	0.5														
1,1-Dichloroethane	0.5			D	D								D		
cis-1,2-Dichloroethene	0.5			D	D		D						D		
2,2-Dichloropropane	0.5														
Bromochloromethane	0.5														
Trichloromethane	0.5														

Table 6.9 Continued
Field Samples
Volatile Organics
Samples Collected 11/18/1994 and 11/19/1994
Notes: Sample volume from wells T1, T4, and T5 were insufficient for volatiles analysis, Well T3 has been abandoned),
MDL=Method Detection Limit (ug/L), D=Detected, Empty boxes indicate that the compound was not detected

Compound	MDL (ug/L)	Blank	C1	C2	C3	C4	P2	P3	P4	P5	P6	T1	T2	T4	T5
1,1,1-Trichloroethane	0.5														
1,1-Dichloropropene	0.5														
Tetrachloromethane	1.0														
Benzene	0.5														
1,2-Dichloroethane	0.5														
Trichloroethene	0.5														
1,2-Dichloropropane	0.5														
Dibromomethane	0.5														
Bromodichloromethane	1.0														
cis-1,3-Dichloropropene	0.5														
Toluene	0.5														
trans-1,3-Dichloropropene	0.5														
1,1,2-Trichloroethane	0.5														
1,3-Dichloropropane	0.5														
Tetrachloroethene	0.5														

Table 6.9 Continued
Field Samples
Volatile Organics
Samples Collected 11/18/1994 and 11/19/1994
Notes: Sample volume from wells T1, T4, and T5 were insufficient for volatiles analysis, Well T3 has been abandoned),
MDL=Method Detection Limit (ug/L), D=Detected, Empty boxes indicate that the compound was not detected

Compound	MDL (ug/L)	Blank	C1	C2	C3	C4	P2	P3	P4	P5	P6	T1	T2	T4	T5
Dibromochloromethane	0.5														
1,2-Dibromoethane	0.5														
Chlorobenzene	0.5														
1,1,1,2-Tetrachloroethane	0.5														
Ethylbenzene	0.5														
m-Xylene+p-Xylene	0.5														
o-Xylene	0.5														
Styrene(ethyl-benzene)	1.0														
Bromoform	0.5														
iso-Propylbenzene	0.5														
1,1,2,2-Tetrachloroethane	0.5														
1,2,3-Trichloropropane	0.5														
Bromobenzene	0.5														
n-Propylbenzene	0.5														
2-Chlorotoluene	0.5														

Table 6.9 Continued
Field Samples
Volatile Organics
Samples Collected 11/18/1994 and 11/19/1994
Notes: Sample volume from wells T1, T4, and T5 were insufficient for volatiles analysis, Well T3 has been abandoned),
MDL=Method Detection Limit (ug/L), D=Detected, Empty boxes indicate that the compound was not detected

Compound	MDL (ug/L)	Blank	C1	C2	C3	C4	P2	P3	P4	P5	P6	T1	T2	T4	T5
1,3,5-Trimethylbenzene	0.5														
4-Chlorotoluene	0.5														
tert-Butylbenzene	0.5														
1,2,4-Trimethylbenzene	0.5														
sec-Butylbenzene	0.5														
4-iso-Propyltoluene	0.5														
1,3-Dichlorobenzene	1.0														
1,4-Dichlorobenzene	0.5														
n-Butylbenzene	1.0														
1,2-Dichlorobenzene	0.5														
1,2-Dibromo-3-chloropropane	1.0														
1,2,4-Trichlorobenzene	1.0														
Hexachlorobutadiene	0.5														
Naphthalene	0.5														
1,2,3-Trichlorobenzene	0.5														

Table 6.10
Field Samples
Volatile Organic Compounds
Samples Collected 8/17/1994
Samples Analyzed: Blank, P1, P2, P3, P4, P5, P6, C1, C2, C3, C4, and T2
(Notes: Sample volume from wells T1, T4, and T5 was insufficient for volatiles analysis, Well T3 is no longer being sampled, Blank prepared at UMaine = blank, Blank prepared at ERI = LBL, ND = Not Detected)
Units: ug/L

Compound	blank	LBL	P1	P1	P2	P3	P4	P5	P6	C1	C2	C3	C4	T2
dichloromethane	5.4, 7.6	1.5	15.5	19.8	15.4	156.6	60.5	80.9	232.9	2.9	5.5	12.6	4.7	2.4
1,1-dichloroethane	ND	ND	ND	ND	2.5	ND	ND	ND	ND	ND	1.9	6.9	ND	14.3
cis-1,2-dichloroethene	ND	ND	ND	ND	16.1	ND	ND	ND	ND	ND	9.2	ND	ND	33.4
1,1,1-trichloroethane	ND	ND	ND	ND	5.6	ND	ND	ND	ND	ND	3	1.9	ND	4.9
benzene	ND	ND	ND	ND	0.7	ND	ND	ND	ND	ND	1.4	ND	ND	1.8
trichloroethene	ND	ND	ND	ND	0.7	ND	ND	ND	ND	ND	ND	0.6	ND	ND
toluene	ND	ND	ND	ND	0.7	1.0	1.1	ND	ND	ND	0.5	1.1	0.7	1.8
1,1,2,2-tetrachloroethane	ND	1.6	ND	ND	ND	0.7	ND	ND	ND	ND	ND	0.6	ND	ND
naphthalene	ND	4.7	ND	ND	ND	2.1	0.8	ND	3.4	ND	0.6	1.6	ND	0.8
chloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1.1
1,2-Dibromoethane	ND	0.7	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,2-Dibromo-3-chloropropane	ND	6.6	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Bromoform	ND	0.6	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

This was lab a contaminati problem.
This compound was ND for tests in 1995 & 1996
Dana N

Note: The extraction procedure used for the semi-volatiles samples is extraction with dichloromethane. Since dichloromethane showed up in all samples including the blanks, contamination is suspected. ERI confirmed that the same prep room is used for volatiles and semi-volatiles.

Pertinent Regulatory Limits:
Dichloromethane: 5ug/L (MCL)
Benzene: 5 ug/L (MCL)
Toluene: 1000 ug/L (MCL) 40ug/L (SMCL)
1,1,1-trichloroethane: 200 ug/L (MCL)
cis-1,2-Dichloroethene: 70 ug/L (MCL)

All of the volatile compounds found are on the EPA Priority Pollutant Target List

Table 6.11
Field Samples
Volatile Organic Compounds
Collected 11/18/1994 and 11/19/1994
Wells: P2, P3, P4, P5, P6, C1, C2, C3, C4, T1, T2, T4, and T5
Notes: Sample volume from well P1 was insufficient for volatile organic analysis (well P1 was frozen),
Well T3 has been abandoned, ND = Not Detected
Units: ug/L

Compound	blank	P2	P3	P4	P5	P6	C1	C2	C3	C4	T1	T2	T4	T5
Dichloromethane	7	15	10.5	11.5	13.5	6.5	38	585.5	50	146.5	316	161.5	878	65.5
1,1-Dichloroethane	ND	ND	ND	ND	ND	ND	ND	7	5	ND	ND	19	ND	ND
cis-1,2-Dichloroethene	ND	6	ND	ND	ND	ND	ND	34.5	8.5	ND	ND	85.5	ND	ND

see
← previous
note

(Note: The extraction procedure used for the semi-volatiles samples is extraction with dichloromethane. ERI confirmed that the same prep room is used for volatiles and semi-volatiles.)

Pertinent Regulatory Limits:
Dichloromethane: 5 ug/L (MCL)
cis-1,2-Dichloroethene: 70 ug/L (MCL)

All of the volatile compounds found are on the EPA Priority Pollutant Target List mass of the tire chips installed at each field site is approximately 60 μg/L. Levels of dichloromethane in the found in the field samples were much higher than 60 μg/L. Thus, it appears that laboratory contamination is causing erroneously high dichloromethane concentrations in the samples; however, tire chips cannot be ruled out as a source of dichloromethane. The primary drinking water standard for dichloromethane is 5 μg/L, levels of dichloromethane in the samples varied from 2.9 μg/L to 232.9 μg/L. Nine of the 12 samples exceeded the drinking water standard for dichloromethane, including two of the samples from within the tire chip trenches. A pattern for increasing or decreasing concentration with respect to the control well and the tire chip trench well could not be identified. However, levels of dichloromethane in most of the field samples were much higher than those in the blanks. In general, the samples from the clay and till sites had lower concentrations than the samples from the peat site. It appears that sample contamination may be affecting the dichloromethane concentrations, but the tire chips cannot be ruled out as source of dichloromethane.

Compounds that were found in the August, 1994 samples from within the tire chip trenches were 1,1-dichloroethane; cis-1,2-dichloroethene; 1,1,1-trichloroethane; benzene, toluene, and naphthalene. The drinking water standard for cis-1,2-dichloroethane is 70 μg/L. The concentrations in the wells from within the tire chips were 16.1 μg/L, 9.2 μg/L, and 33.4 μg/L for the peat, clay, and till sites respectively. Some mobility of some these compounds (1,1-dichloroethane; 1,1,1-trichloroethane; toluene; and naphthalene) is seen at the clay site as concentrations are found in the downgradient well closest to the trench. All concentrations of naphthalene found in the samples were less than the naphthalene concentration in the laboratory (ERI) blank. Only dichloromethane concentrations exceeded the drinking water standard. All the compounds detected are listed as EPA Priority Pollutants.

Fewer compounds were found in the November samples than in the August, 1994 samples. The compounds detected were dichloromethane, 1,1-dichloroethane, and cis-1,2-dichloroethene. Dichloromethane was found in all samples tested, as in the August, 1994 samples. All samples tested exceeded the drinking water standard of 5 μg/L for dichloromethane. In general the concentrations in the clay and till samples were higher than the concentrations in the peat samples, which is the reverse of the results for the August, 1994 samples. The sample concentrations varied from 6.5 μg/L to 878 μg/L.

(Subsequent testing showed that the presence of dichloromethane was due to laboratory contamination, DNH, 6/22/98)

At the wells within the tire chips at the clay and till sites 1,1-dichloroethane, and cis-1,2-dichloroethene were found. In addition, the first downgradient well at the clay site contained concentrations of 1,1-dichloroethane, and cis-1,2-dichloroethene, which indicates that these compounds are mobile in this environment. The well within the trench at the peat site contained cis-1,2-dichloroethene in addition to dichloromethane. The till site sample from within the tire chips had a concentration of cis-1,2-dichloroethene of 85.5 μg/L, which exceeds the primary drinking water standard (70 μg/L). 1,2-dichloroethene is used in rubber manufacturing (Verschueren, 1983).

Table 6.12 presents the data for dichloromethane, 1,1-dichloroethane, and cis-1,2-dichloroethene. The downgradient mobility of dichloromethane, 1,1-dichloroethane, and cis-1,2-dichloroethene was examined. The relative mobility of a compound can be gauged by its octanol-water partition coefficient (log K_{OW}). Lower octanol-water partition coefficients indicate that the compound is more hydrophilic and; therefore, more mobile (will travel further with groundwater flow). The more hydrophobic compounds (higher octanol-water coefficients) will tend to sorb to the organic material in the soil matrix, and therefore will not migrate as rapidly with the groundwater flow. The compounds listed in order of increasing octanol-water partition coefficient and therefore, decreasing mobility, is dichloromethane (log K_{OW}=1.15); 1,1-dichloroethane (log K_{OW}=1.79); cis-1,2-

Table 6.12
Field Samples
Volatile Organics
Dichloromethane, 1,1-Dichloroethane, and cis-1,2-Dichloroethene
MDL=Method Detection Limit, ND=Not Detected, NA=Not Available
Units: ug/L

Compound	Dichloromethane	1,1-Dichloroethane	cis-1,2-Dichloroethene
Method Detection Limit (ug/L)	0.5	0.5	0.5
Blank-August 1994	6.5	ND	ND
Blank-September 1994	7.0	ND	ND
C1-August 1994	2.9	ND	ND
C1-September 1994	38	ND	ND
C2-August 1994	5.5	1.9	9.2
C2-September 1994	585.5	7	34.5
C3-August 1994	12.6	6.9	ND
C3-September 1994	50	5	8.5
C4-August 1994	4.7	ND	ND
C4-September 1994	146.5	ND	ND
P1-August 1994	17.7	ND	ND
P1-September 1994	NA	NA	NA
P2-August 1994	15.4	2.5	16.1
P2-September 1994	15	ND	6
P3-August 1994	156.6	ND	ND
P3-September 1994	10.5	ND	ND
P4-August 1994	60.5	ND	ND
P4-September 1994	11.5	ND	ND
P5-August 1994	80.9	ND	ND
P5-September 1994	13.5	ND	ND
P6-August 1994	232.9	ND	ND
P6-September 1994	6.5	ND	ND
T1-August 1994	NA	NA	NA
T1-September 1994	316	ND	ND
T2-August 1994	2.4	14.3	33.4
T2-September 1994	161.5	19	85.5
T4-August 1994	NA	NA	NA
T4-September 1994	878	ND	ND
T5-August 1994	NA	NA	NA
T5-September 1994	65.5	ND	ND

dichloroethane (log K_{ow}=1.91). Dichloromethane was found in all samples, including control, tire chip trench, and downgradient samples. This appears to be consistent with the high mobility predicted by the low log K_{ow}; however, the overall validity of the data for this compound is suspect because of the potential contamination problem discussed above. Examining the data for the other two compounds, 1,1-dichloroethane was seen in the first downgradient well for the August 1994 and November 1994 samples. However, cis-1,2-dichloroethene was seen in the downgradient well at the clay site only in the November 1994 samples. This is consistent with partitioning theory, as described by K_{ow}, which would predict that 1,1-dichloroethane is more mobile than cis-1,2-dichloroethene.

The volatile organic compounds results indicate that organic compounds may be leached from tire chips. In general, the levels were below the applicable regulatory limits. However, the regulatory limit for cis-1,2-dichloroethene was exceeded for one sampling date at the till site. In addition, mobility of 1,1-dichloroethane; 1,1,1-trichloroethane and cis-1,2-dichloroethene was seen at the clay site, since these compounds were not detected in the control sample but were seen at the well within the tire chips and at the downgradient well closest to the tire chip trench. High levels of dichloromethane were observed; however, this could have been caused by contamination during laboratory testing. Additional testing is needed before conclusions on dichloromethane can be made.

6.3.2 Semivolatile Organics Results

There were three sampling events for semivolatile organic compounds. The sampling was done in August 1994, November 1994, and April 1995. The compounds analyzed in the field samples for each sampling event are listed in Tables 6.13, 6.14, and 6.15. Both detected and non-detected compounds are listed in the tables. The semivolatile compounds that were detected are listed along with their concentrations in Table 6.16. More compounds were found at each subsequent sampling date. Most

Table 6.13
Field Samples
Semivolatile Organics
Samples Collected 8/17/1994
Notes: Sample volume from wells C4, T1, T4, and T5 was insufficient for semivolatile organics analysis, Well T3 was abandoned, MRL=Method Reporting Limit (ug/L), D=Detected,
Empty boxes indicate that the compound was not detected

Compound	MRL ug/L	C1	C2	C3	P1	P2	P3	P4	P5	P6	T2
Pyridine	20										
N-Nitrosodimethylamine	10										
2-Picoline	20										
N-Nitrosodiethylamine	10										
Ethyl methanesulfonate	10										
Pentachloro-ethane	10										
Aniline	10		D			D					
2-Chlorophenol	10										
bis(2-Chloroethyl)ether	10										
Phenol	10										
1,3-Dichlorobenzene	10										
1,4-Dichlorobenzene	10										
1,2-Dichlorobenzene	10										
Benzyl alcohol	20										
bis(2-Chloroisopropyl)ether	10										
2-Methylphenol(o-Cresol)	10										
Acetophenone	10										
N-Nitrosopyrrolidine	10										
Hexachloroethane	10										
o-Toluidine	10										
N-Nitrosomorpholine	10										
N-Nitrosodi-n-propylamine	10										
4-Methylphenol(p-Cresol)	20										
Nitrobenzene	10										
N-Nitrosopiperidine	20										
Isophorone	20										
2-Nitrophenol	10										
2,4-Dimethylphenol	10										
a,a-dimethylphenethylamine	10										
bis(2-Chloroethoxy)methane	10										
O,O,O-Triethyl phosphorothioate	10										
2,4-Dichlorophenol	10										
1,2,4-Trichlorobenzene	10										
Naphthalene	10										
2,6-Dichlorophenol	10										
4-Chloroaniline	20										
Hexachloropropene	10										
Hexachlorobutadiene	10										

Table 6.13 Continued
Field Samples
Semivolatile Organics
Samples Collected 8/17/1994
Notes: Sample volume from wells C4, T1, T4, and T5 was insufficient for semivolatile organics analysis, Well T3 was abandoned, MRL=Method Reporting Limit (ug/L), D=Detected,
Empty boxes indicate that the compound was not detected

Compound	MRL ug/L	C1	C2	C3	P1	P2	P3	P4	P5	P6	T2
p-Phenylenediamine	10										
N-Nitrosodi-n-butylamine	10										
Isafrole(1,3-benzodioxole-)	10										
2-Methylnaphthalene	20										
4-Chloro-3-methylphenol	10										
1,2,4,5-Tetrachlorobenzene	10										
Hexachlorocyclopentadiene	10										
2,4,6-Trichlorophenol	10										
2,4,5-Trichlorophenol	10										
2-Chloronaphthalene	10										
Safrole	10										
2-Nitroaniline	50										
1,4-Naphthoquinone	10										
1,3-Dinitrobenzene	10										
Acenaphthylene	10										
3-Nitroaniline	50										
2,4-Dinitrophenol	50										
Dibenzofuran	10										
Pentachlorobenzene	10										
1-Naphthylamine	10										
2,4-Dinitrotoluene	10										
4-Nitrophenol	50										
2-Naphthylamine	20										
2,3,4,6-Tetrachlorophenol	10										
Fluorene	10										
4-Chlorophenyl phenyl ether	10										
Diethyl phthalate	20										
5-Nitro-o-toluidine	20										
4-Nitroaniline	50										
4,6-Dinitro-2-methylphenol	20										
N-Nitrosodiphenylamine	10										
Diphenylamine	10										
4-Bromophenyl phenyl ether	10										
1,3,5-Trinitrobenzene	10										
Phenacetin	10										
Hexachlorobenzene	10										
4-Aminobiphenyl	10										
Pentachlorophenol	50										

Table 6.13 Continued
Field Samples
Semivolatile Organics
Samples Collected 8/17/1994
Notes: Sample volume from wells C4, T1, T4, and T5 was insufficient for semivolatile organics analysis, Well T3 was abandoned, MRL=Method Reporting Limit (ug/L), D=Detected,
Empty boxes indicate that the compound was not detected

Compound	MRL ug/L	C1	C2	C3	P1	P2	P3	P4	P5	P6	T2
Pentachloronitrobenzene	10										
Phenanthrene	10										
Anthracene	10										
di-n-butyl phthalate	10										
4-Nitroquinoline-1-oxide	10										
Methapyrilene	10										
Fluoranthene	10										
Pyrene	10										
p-(Dimethylamino)azobenzene	10										
3,3'-Dimethylbenzidine	10										
Butyl benzyl phthalate	10										
2-Acetylaminofluorene	10										
benzo(a)anthracene	10										
Chrysene	10										
3,3'Dichlorobenzidine	20										
bis(2-Ethylhexyl) phthalate	20										
di-n-Octyl phthalate	20										
Benzo(b)fluoranthene	10										
Benzo(k)fluoranthene	10										
7,12-Dimethylbenz(a)anthracene	10										
benzo(a)pyrene	10										
Hexachlorophene	10										
3-Methylcolanthrene	10										
indeno(1,2,3-cd)pyrene	10										
dibenzo(a,h)anthracene	10										
benzo(g,h,i)perylene	10										

Table 6.14
Field Samples
Semivolatile Organics
Samples Collected 11/18/1994 and 11/19/1994
Notes: Samples P1 and T1 were broken during shipping, Well T3 was abandoned, MRL=Method Reporting Limit (ug/L), D=Detected,
Empty boxes indicate that the compound was not detected

Compound	MRL ug/L	C1	C2	C3	C4	P2	P3	P4	P5	P6	T2	T4	T5
Aniline	10		D			D					D		
2-Chlorophenol	10												
bis(2-Chloroethyl)ether	10												
Phenol	10		D			D					D		
1,3-Dichlorobenzene	10												
1,4-Dichlorobenzene	10												
1,2-Dichlorobenzene	10												
bis(2-Chloroisopropyl)ether	10												
Hexachloroethane	10												
N-Nitrosodi-n-propylamine	10												
4-Methylphenol(p-Cresol)	20												
Nitrobenzene	10												
Isophorone	20												
2-Nitrophenol	10												
2,4-Dimethylphenol	10												
a,a-dimethylphenethylamine	10												
bis(2-Chloroethoxy)methane	10												
2,4-Dichlorophenol	10												
1,2,4-Trichlorobenzene	10												
Naphthalene	10												
4-Chloroaniline	20												
Hexachlorobutadiene	10												
p-Phenylenediamine	10												
4-Chloro-3-methylphenol	10												
1,2,4,5-Tetrachlorobenzene	10												
Hexachlorocyclopentadiene	10												
2,4,6-Trichlorophenol	10												
2,4,5-Trichlorophenol	10												
2-Chloronaphthalene	10												
Safrole	10												
2-Nitroaniline	50												
Acenaphthylene	10												
Dimethyl phthalate	20												
2,6-Dinitrotoluene	10												
Acenaphthene	10												
3-Nitroaniline	50												
2,4-Dinitrophenol	50												
2,4-Dinitrotoluene	10												
4-Nitrophenol	50												
Fluorene	10												
4-Chlorophenyl phenyl ether	10												
Diethyl phthalate	20												
4-Nitroaniline	50												

Table 6.14 continued
Field Samples
Semivolatile Organics
Samples Collected 11/18/1994 and 11/19/1994
Notes: Samples P1 and T1 were broken during shipping, Well T3 was abandoned, MRL=Method Reporting Limit (ug/L), D=Detected,
Empty boxes indicate that the compound was not detected

Compound	MRL ug/L	C1	C2	C3	C4	P2	P3	P4	P5	P6	T2	T4	T5
4,6-Dinitro-2-methylphenol	20												
N-Nitrosodiphenylamine	10												
4-Bromophenyl phenyl ether	10												
Hexachlorobenzene	10												
4-Aminobiphenyl	10												
Pentachlorophenol	50												
Phenanthrene	10												
Anthracene	10												
di-n-butyl phthalate	10												
Fluoranthene	10												
Pyrene	10												
Butyl benzyl phthalate	10												
benzo(a)anthracene	10												
Chrysene	10												
3,3'Dichlorobenzidine	20												
bis(2-Ethylhexyl) phthalate	20												
di-n-Octyl phthalate	20												
Benzo(b)fluoranthene	10												
Benzo(k)fluoranthene	10												
benzo(a)pyrene	10												
indeno(1,2,3-cd)pyrene	10												
dibenzo(a,h)anthracene	10												
benzo(g,h,i)perylene	10												

Table 6.15
Field Samples
Semivolatile Organics
Samples Collected 4/24/1995 and 4/25/1995

Notes: Sample volume from well T5 was insufficient for semivolatile analysis, Well T3 was abandoned,
MRL=Method Reporting Limit (ug/L), D=Detected,
Empty boxes indicate that the compound was not detected, NA=Not Applicable

Compound	MRL ug/L	C1	C2	C3	C4	P1	P2	P3	P4	P5	P6	T2	T4
Aniline	10											D	
2-Chlorophenol	10												
bis(2-Chloroethyl)ether	10												
Phenol	10		D				D					D	
1,3-Dichlorobenzene	10												
1,4-Dichlorobenzene	10												
1,2-Dichlorobenzene	10												
bis(2-Chloroisopropyl)ether	10												
Hexachloroethane	10												
N-Nitrosodi-n-propylamine	10												
4-Methylphenol(p-Cresol)	20		D				D					D	
Nitrobenzene	10												
Isophorone	20												
2-Nitrophenol	10												
2,4-Dimethylphenol	10												
a,a-dimethylphenethylamine	10												
bis(2-Chloroethoxy)methane	10												
2,4-Dichlorophenol	10												
1,2,4-Trichlorobenzene	10												
Naphthalene	10												
4-Chloroaniline	20												
Hexachlorobutadiene	10												
p-Phenylenediamine	10												
4-Chloro-3-methylphenol	10												
1,2,4,5-Tetrachlorobenzene	10												
Hexachlorocyclopentadiene	10												
2,4,6-Trichlorophenol	10												
2,4,5-Trichlorophenol	10												
2-Chloronaphthalene	10												
Safrole	10												
2-Nitroaniline	50												
Acenaphthylene	10												
Dimethyl phthalate	20												
2,6-Dinitrotoluene	10												
Acenaphthene	10												
3-Nitroaniline	50												
2,4-Dinitrophenol	50												
2,4-Dinitrotoluene	10												
4-Nitrophenol	50												
Fluorene	10												
4-Chlorophenyl phenyl ether	10												
Diethyl phthalate	20												
4-Nitroaniline	50												

Table 6.15
Field Samples
Semivolatile Organics
Samples Collected 4/24/1995 and 4/25/1995

Notes: Sample volume from well T5 was insufficient for semivolatile analysis, Well T3 was abandoned,
MRL=Method Reporting Limit (ug/L), D=Detected,
Empty boxes indicate that the compound was not detected, NA=Not Applicable

Compound	MRL ug/L	C1	C2	C3	C4	P1	P2	P3	P4	P5	P6	T2	T4
4,6-Dinitro-2-methylphenol	20												
N-Nitrosodiphenylamine	10												
4-Bromophenyl phenyl ether	10												
Hexachlorobenzene	10												
4-Aminobiphenyl	10												
Pentachlorophenol	50												
Phenanthrene	10												
Anthracene	10												
di-n-butyl phthalate	10												
Fluoranthene	10												
Pyrene	10												
Butyl benzyl phthalate	10												
benzo(a)anthracene	10												
Chrysene	10												
3,3'Dichlorobenzidine	20												
bis(2-Ethylhexyl) phthalate	20												
di-n-Octyl phthalate	20												
Benzo(b)fluoranthene	10												
Benzo(k)fluoranthene	10												
benzo(a)pyrene	10												
indeno(1,2,3-cd)pyrene	10												
dibenzo(a,h)anthracene	10												
benzo(g,h,i)perylene	10												
Cyclohexanol	NA		D										
Benzoic Acid	NA		D									D	
Benzothiazole	NA		D										
2,6-bis-(1,1-dimethylethyl)-	NA												
2,5-cyclohexadiene-1,4-dione	NA		D										
IH-Isoindole-1,3(2H)-dione	NA		D										
2(3H)-Benzothiazolone	NA		D	D			D					D	
4-(2-Benzothaizolylthio)-morpholine	NA		D										
N-(1,1-Dimethylethyl)-formamide	NA			D									
Butanoic Acid	NA											D	

Table 6.16
Field Samples
Semivolatile Organics Detected
Units: ug/L (ppb)
Notes: Wells C2, T2, and P2 are within the tire chip filled trenches,
MRL=Method Reporting Limit (ug/L), NA=Not Applicable, ND=Not Detected,
In addition to the compounds listed below there were unknown comounds in some of the samples for the April samples: C2 1 unknown, C3 5 unknowns, C4 3 unknowns, T2 2 unknowns, T4 2 unknowns, P2 2 unknowns

Compound	MRL	C2-August 1994	C2-November 1994	C2-April 1995		C3-August 1994	C3-November 1994	C3-April 1995		P2-August 1994	P2-November 1994	P2-April 1995		T2-August 1994	T2-November 1994	T2-April 1995
Aniline	10	NA	91	ND		ND	ND	ND		57.6	20.3	ND		31.3	63.6	40
Phenol	10	ND	16	21.5		ND	ND	ND		ND	55.2	26.6		ND	25.7	50.7
p-Cresol	10	ND	ND	42		ND	ND	ND		ND	ND	32		ND	ND	86
Cyclohexanol	NA	ND	ND	40		ND	ND	ND		ND	ND	ND		ND	ND	ND
Benzoic Acid	NA	ND	ND	30		ND	ND	ND		ND	ND	ND		ND	ND	100
Benzothiazole	NA	ND	ND	50		ND	ND	ND		ND	ND	ND		ND	ND	ND
2,6-bis-(1,1-dimethylethyl)-2,5-cyclohexadiene-1,4-dione	NA	ND	ND	40		ND	ND	ND		ND	ND	ND		ND	ND	ND
1H-Isoindole-1,3(2H)-dione	NA	ND	ND	40		ND	ND	ND		ND	ND	ND		ND	ND	ND
2(3H)-Benzothiazolone	NA	ND	ND	100		ND	ND	100		ND	ND	200		ND	ND	100
4-(2-Benzothiazolylthio)-morpholine	NA	ND	ND	50		ND	ND	ND		ND	ND	ND		ND	ND	ND
N-(1,1-dimethylethyl)-Formamide	NA	ND	ND	ND		ND	ND	30		ND	ND	ND		ND	ND	ND
Butanoic Acid	NA	ND	ND	ND		ND	ND	ND		ND	ND	ND		ND	ND	100

importantly, nine of tentatively identified compounds were found in the April, 1995 samples that were not found in the samples from the two previous sampling events. This could indicate that some compounds are not immediately leached upon installation, but are leached after a period of several months.

The only semivolatile organic found in the August, 1994 samples was aniline. Aniline was found in each of the samples from within the tire trenches at each of the sites for the November, 1994 samples. Aniline was found only in the till site tire trench sample in the April, 1995 samples. Aniline is used as an antidegradant in the rubber processing industry (Fishbein, 1991). It was found in the samples from the wells within the trenches at the till and peat sites (31.3 µg/L and 57.6 µg/L, respectively). Water quality standards have not been developed for aniline; however, the Merck Index (Budavari et al., 1989) indicates that the symptoms of acute exposure to aniline include cyanosis, vertigo, headache, and mental confusion. The symptoms of chronic exposure include anemia, anorexia, weight loss, and cutaneous lesions (Budavari et al., 1989). Intoxication may occur from inhalation, ingestion, or cutaneous absorption. Symptoms of illness occur at 20 ppm, and a level of 10 ppm is felt to be unacceptable (Verschueren, 1983). The mean lethal dose may be between 15 and 30 grams of pure aniline (MDL Information Systems, Inc., 1995).

Phenol was found in each of the samples from within the tire trenches at each of the sites for the November, 1994 and April, 1995 samples. The concentrations were less than 55.2 µg/L for all samples. Water quality standards have not been developed for phenol; however, ingestion of small amounts of phenol may cause many symptoms including nausea, vomiting, convulsions, coma, and death from respiratory failure or cardiac arrest (Budavari et al., 1989). A dose as low as 1 gram is fatal to humans; fatal poisoning may also occur due to skin absorption (Budavari et al., 1989). The effects of ingesting phenol contaminated well water have been diarrhea, dark urine, and sores and burning in the mouth (MDL Information Systems, Inc., 1995).

For the April, 1995 samples, p-cresol was found in each of the samples from within the tires at each of the sites. In addition, several tentatively identified compounds were found, including cyclohexanol; benzoic acid; benzothiazole; butanoic acid; and 2(3H)-benzothiazolone. Several of these compounds were also found in the TCLP extracts: aniline; 2(3H)-benzothiazolone; 1H-Isoindole-1,3(2H)-dione; benzothiazole; and 4-(2-benzothiazolylthio)-morpholine. Also, the reactor samples water samples from the reactors that contained tire chips also contained some of these organic compounds: aniline; 2(3H)-benzothiazolone; benzothiazole; and benzoic acid. These compounds can be identified as tire ingredients or end products of tire ingredients. Each sample from within the tire chips contained 2(3H)-benzothiazolone. Benzothiazoles are used as accelerators in the rubber processing industry (Fishbein, 1991). The estimated concentrations of 2(3H)-benzothiazolone ranged from 100 µg/L at two clay site wells (tire chip trench well and downgradient well closest to the trench) and the till site well (tire chip trench well) to 200 µg/L at the peat site well (within the tire chip filled trench). Benzoic acid was found in the tire chip trench samples from the clay and till sites. Benzoic acid is used as a retarder in making tires (Fishbein, 1991). Large doses of benzoic acid may cause sore throat, gastric pain, nausea, and vomiting, in one case a 67 Kg man ingested 50 grams with no adverse effects (MDL Information Systems, Inc., 1994). A daily intake of 4 to 6 grams produced no toxic effects other than gastric irritation (MDL Information Systems, Inc., 1994). As with volatile organic compounds, mobility of one semivolatile compound is seen at the clay site. The sample from the downgradient well closest to the tire chip trench contained 2(3H)-benzothiazolone at the same estimated concentration as the well within the tire chip trench.

These semivolatile compounds do not have drinking water standards and their threat to human health has not been quantified. Thus, the presence of these compounds is a cause for concern. This warrants further field sampling to more accurately assess the presence and persistence of these compounds. The data from the field study indicate that one semivolatile compound may be mobile in some environments.

6.4 OTHER RESULTS

In addition to metals and organics other parameters that were studied in this research were BOD, COD, TOC, alkalinity, pH, conductivity, chloride, and sulfate. As seen in Table 6.17, the BOD of all samples tested was below 10 mg/L. Tire chips did not appear to affect the BOD of the groundwater samples. BOD in groundwater samples would be expected to be low since BOD is a measure of the amount of oxygen required by microorganisms to breakdown decomposable organic matter. High BOD is generally seen in samples that contain highly organic wastes, which is not the case in these groundwater samples. As expected, the COD of the samples is higher than the BOD since almost all organics are oxidized chemically but only a portion of the organics will be oxidized biologically. The COD test measures biologically oxidizable and inert organic matter. The COD results of this field study are presented in Table 6.18. The COD was higher in the samples from within the tire chip trenches when compared to the control well samples for the June 1994 and September 1994 sampling events. The same trend was not seen in the November 1994 and April 1995 samples. The TOC of the samples was lower than the COD, as expected. Materials will be oxidized in the COD test that are not measured by the TOC test. As seen in Table 6.19, TOC was higher in the samples from within the tire chip trenches than in the control well for each of the three sites for both the September, 1994 and the April, 1995 samples. TOC was only tested in September 1994 and April 1995.

Table 6.17
BOD Results
Units: mg/L
Notes: *=Approximate Value
NA=Not Available

Date Well	August 1994 mg/L	September 1994 mg/L	April 1995 mg/L
C1	1	NA	2*
C2	1	NA	8*
C3	1	4	8*
C4	1	0	4*
T1	NA	NA	2*
T2	1	NA	8*
T3	NA	NA	NA
T4	NA	NA	NA
T5	NA	NA	NA
P1	3	1	5*
P2	2	NA	8*
P3	NA	3	7*
P4	3	3	2*
P5	4	3	7*
P6	4	3	6*

Table 6.18
COD Data
(average of three or more values for each sample)
Units: mg/L
Notes: NA=Not Available

Date Well	June 1994 mg/L	September 1994 mg/L	November 1994 mg/L	April 1995 mg/L
C1	0	17	220	NA
C2	54	220	220	44
C3	3.7	180	420	NA
C4	0	7.5	200	NA
T1	0	NA	250	NA
T2	260	54	230	540
T3	210	NA	NA	NA
T4	1.2	NA	470	NA
T5	NA	NA	200	NA
P1	140	330	NA	340
P2	250	550	340	240
P3	160	180	260	260
P4	130	320	230	250
P5	140	110	120	210
P6	130	220	250	190

Table 6.19
TOC Data
Units: mg/L
Notes: NA=Not Available

Date Well	September 1994 TOC mg/L	April 1995 TOC mg/L
C1	1.7	0.80
C2	64	23.0
C3	6.2	8.40
C4	1.3	2.0
T1	NA	6.60
T2	17	79
T3	NA	NA
T4	NA	NA
T5	NA	NA
P1	15	17.0
P2	87	43.0
P3	13	17
P4	12	18.0
P5	23	14.0
P6	17	30

In comparison, typical untreated domestic wastewater, the ratio of BOD/COD is 0.4 to 0.8 and the BOD/TOC ratio varies from 1 to 1.6 (Metcalf and Eddy, Inc., 1991). The BOD/COD ratio for these field samples would be much lower than that for typical domestic wastewater. In this case the BOD/COD ratio varies from approximately 0.002 to 0.04. This reflects the low biodegradability of the organic matter and the comparatively high COD of the samples.

The pH and conductivity results are presented in Table 6.20. The conductivity of the sample from within the tire chip trench was higher than the conductivity of the control sample for all sampling events for all sites, except the November, 1994 samples from the till site in which the conductivities were equal. Increased conductivity at the tire chip trenches is expected due to the significant increase in metals ions such as iron and manganese that have leached from the tire chips. The peat site was the only site that had an increase in pH due to the tire chip installation. Table 6.21 presents the average pHs for the wells at the three sites. The groundwater pH was lower at the peat site than at the clay and till sites. At the clay site the average pH of the samples from within the tires was 6.8, while the average for all other samples (upgradient and downgradient) was also 6.8. The corresponding pHs at the till site were 7.0 and 6.9. At the peat site however, the average pH for the samples from within the tire chips was 6.9 and the average pH for the upgradient and downgradient samples combined was 6.1.

Alkalinity is a measure of a sample's ability to neutralize acids. It is expressed in milligrams per liter as equivalent calcium carbonate. The alkalinity results for the field samples are presented in Table 6.22. In general, alkalinities of 400 mg/L to 500 mg/L as calcium carbonate are considered too high for public water supply (Jackson, 1993). All alkalinity concentrations measured in this field study were well below 400 mg/L, the highest being 180 mg/L. At the clay and till sites, the alkalinity increased at the well

Table 6.20
pH and Conductivity Results
Units: pH standard units, Conductivity umhos/cm
Notes: *=Data Suspect (not considered reliable),
NA=Not Available

Date Well	June 1994 pH/Cond	September 1994 pH/Cond	November 1994 pH/Cond	April 1995 pH/Cond
C1	7.1 / 0.094	6.7 / 0.108	7.4 / 0.087	6.8 / 0.123
C2	7.4 / 0.196	6.6 / 0.397	6.6 / 0.294	6.7 / 0.282
C3	6.9 / 0.140	6.6 / 0.208	6.7 / 0.298	6.3 / 0.335
C4	6.9 / 0.112	6.6 / 0.127	6.7 / 0.121	6.6 / 0.208
T1	7.3 / 0.093	NA	7.4 / 0.134	6.8 / 0.133
T2	7.4 / 0.349	6.3 / 0.209	7.0 / 0.134	6.8 / 0.486
T3	7.5 / 0.344	NA	NA	NA
T4	7.1 / 0.133	NA	6.9 / 0.215	6.3 / 0.267
T5	6.9 / 0.131	NA	6.9 / 0.196	6.5 / 0.265
P1	5.8 / 0.127	6.1 / 0.187	NA	6.1 / 0.245
P2	6.9 / 0.223	7.0 / 0.423	6.9 / 0.285	7.5 / 0.477
P3	6.0 / 0.136	6.1 / 0.184	6.0* / 0.135	6.4 / 0.244
P4	6.0 / 0.122	6.0 / 0.177	6.0* / 0.130	6.6 / 0.233
P5	5.7 / 0.092	5.9 / 0.123	6.0* / 0.099	6.5 / 0.208
P6	6.0 / 0.128	6.0 / 0.172	6.0* / 0.090	6.4 / 0.132

Table 6.21
Average pH Results
Units: pH standard units

Site	Average of Control Well Samples	Average of Samples from All Wells	Average of Samples from Tire Chip Trench Wells	Average of Samples from All Wells Except Tire Chip Trench Wells
Clay	7.0	6.8	6.8	6.8
Till	7.2	6.9	7.0	6.9
Peat	6.0	6.5	6.9	6.1

Table 6.22
Alkalinity Data

Units: mg/L as CaCO3
Notes: NA=Not Available

Date Well	**June 1994** mg/L	**September 1994** mg/L	**November 1994** mg/L	**April 1995** mg/L
C1	50	68	74	56
C2	100	160	110	110
C3	100	NA	190	180
C4	94	82	100	120
T1	70	NA	100	48
T2	140	80	170	140
T3	130	NA	NA	NA
T4	76	NA	160	NA
T5	NA	NA	150	NA
P1	72	140	NA	120
P2	60	120	100	180
P3	70	120	100	110
P4	70	110	92	100
P5	56	82	70	80
P6	64	110	68	62

within the tire chip trench when compared to the control well. The increase in alkalinity could be due to an increase in hydroxides of metals ions that have leached from the tires. In addition, the well seals may contribute sodium ions to the system which may also increase the hydroxides present.

The final two parameters were chloride and sulfate. September 1994 and April 1995 samples were analyzed for chloride and sulfate. As seen in Table 6.23, the levels of chloride were all below 5 mg/L. The drinking water standard for chloride is 250 mg/L, based on taste considerations (Jackson, 1993). The tire chips did not seem to affect the chloride concentrations. The sulfate values were all below 20 mg/L, as seen in Table 6.23. Sulfate should not be present in drinking water at levels above 250 mg/L due to laxative effects on humans (Jackson, 1993). In general, the sulfate concentrations at the tire chip trenches were lower than the sulfate concentrations in the control wells. Tire chips are not expected to increase sulfate concentrations in groundwater.

6.5 COMPARISON TO OTHER STUDIES

In the Minnesota Pollution Control Agency Study, barium, cadmium, chromium, and lead exceeded the RALs set by the Minnesota Department of Health for drinking water at an existing tire site (a background sample was collected in which none of the RALs were exceeded). The groundwater samples in the Minnesota study were taken from open boreholes. The primary drinking water standard for lead was equaled or exceeded for two sampling events at the East Lysimeter in the Wisconsin Department of Transportation Study. The results for lead for the University of Maine Study were inconclusive. Dissolved lead was below the method detection limit (15 ppb) for all sampling events for all wells. Total lead in the samples from the wells within the tire chips was less than the method detection limit (15 ppb) or approximately equal to the background levels for most sampling events. It could not be determined from this study if

Table 6.23

Chloride and Sulfate Data

Units: mg/L

Notes: NA=Not Available

Date Well	September 1994 Cl^- mg/L	September 1994 SO_4^{2-} mg/L	April 1995 Cl^- mg/L	April 1995 SO_4^{2-} mg/L
C1	1.5	6.7	2.1	17
C2	2.9	0.95	1.9	5.2
C3	NA	NA	2.6	7.6
C4	1.6	9.6	2.2	4.9
T1	NA	NA	2.1	8.0
T2	2.2	22	3.1	4.5
T3	NA	NA	NA	NA
T4	NA	NA	3.8	10
T5	NA	NA	1.8	12
P1	3.2	3.3	3.7	6.9
P2	3.8	0.12	3.3	3.1
P3	3.0	6.3	2.8	10
P4	3.4	3.6	3.1	3.6
P5	2.4	6.6	3.3	6.7
P6	3.2	2.7	2.6	6.5

lead was leached from tire chips. No cadmium was detected in the University of Maine Field Study samples. Based on the results of the Maine Study, it appears that tire chips leach low levels of chromium to groundwater, but the levels are unlikely to exceed the drinking water standards.

The secondary drinking water standard for manganese (50 µg/L) was consistently exceeded at the East and West Lysimeters in the Wisconsin Study. Manganese levels also exceeded the secondary drinking water standard in the University of Maine Study. Iron levels exceeded the secondary drinking water standard in the Wisconsin Study, in the University of Maine Study, and in the surface water and monitoring wells at the tire pond.

In addition, the samples from a separate existing tire site exceeded the RALs for List 1 (carcinogenic) and List 2 (noncarcinogenic) PAHs in the Minnesota Study. Organic compounds were also found in the field samples from the University of Maine Study. Additional sampling and analysis is needed to quantify the level of concern posed by organics.

The results of these field studies show that tire chips will adversely affect groundwater quality due to leaching of unacceptable levels of metals and organics. Levels of metals with primary drinking water standards are unlikely to exceed the drinking water standards due to leaching from tire chips. However, levels of iron and manganese can be expected to increase to well above the applicable secondary drinking water standards. More sampling data is required to determine if organics are a concern with leaching from tire chip installations below the groundwater table.

6.6 SUMMARY

In this study, tire chips were placed below the groundwater table to evaluate the effects on groundwater quality. Three field sites were chosen, one in each of three Maine soil types: glacial marine clay (locally known as Presumpscot Formation), glacial till, and fibrous peat. Approximately 1.5 tons of tire chips were installed in a small trench. Groundwater monitoring wells were installed within the trench, upgradient of the trench, and downgradient of the trench. Samples were collected quarterly for one year to evaluate the effects of tire chips on water quality.

The results of the field study show that high levels of iron leach from the tire chips, which is expected due to exposed and embedded steel belts in the tire chips. The levels of iron leached exceed the secondary drinking water standard (300 μg/L). In addition to iron, manganese is leached from tire chips. Small percentages of manganese are part of the composition of the steel tire cord and beadwire. Manganese concentrations also exceeded the secondary drinking water standard (50 μg/L). Manganese migration to the downgradient wells was seen at the downgradient wells at each of the sites. Another metal that is leached from tires, but at low levels, is zinc. Zinc oxides are used in the rubber manufacturing process and zinc is present as a coating on steel bead and cord wire. Zinc concentrations are increased by tire chip installations, but the drinking water standard (5000 μg/L) is not likely to be exceeded since the background zinc level was very low. Based on metals leaching, tires could be used at sites where the levels of contamination expected could be accepted. Often groundwater that is to be used for water supply has to be treated to remove iron and manganese.

Chromium is present in trace amounts in steel tire cord and beadwire. It appears that tire chips leach low levels of chromium to the environment. The primary drinking water standard for chromium is 100 μg/L but it is unlikely that tire chips will cause this level to be exceeded. Barium is also leached from tire chips, but at levels well below the primary drinking water standard (2000 μg/L). Low levels of lead may leach from tire chips, but the results for lead for this field study were inconclusive. Lead was detected in some samples from within the tire chip trenches, but was near background levels.

In addition to leaching of metals, tire chips leached organics to the groundwater in this field study. Volatile organic compounds that were found in the August, 1994 groundwater samples include: dichloromethane; 1,1-dichloroethane; (Z)-1,2-dichloroethene; 1,1,1-trichloroethane; benzene; toluene; and naphthalene. The only compound that exceeded its drinking water standard (5 μg/L) was dichloromethane. It appears that sample contamination during laboratory preparation procedures was causing the high levels of dichloromethane in the samples, but since dichloromethane is used as a solvent in the rubber processing industry, leaching of dichloromethane from tire chips could not be ruled out.

The November, 1994 samples analyzed for volatile organic compounds contained fewer compounds: dichloromethane, 1,1-dichloroethane, and (Z)-1,2-dichloroethene. The same behavior of dichloromethane was seen in the November, 1994 samples that was seen in the August, 1994 samples. The till site sample from within the tire chips had a concentration of (Z)-1,2-dichloroethene of 85.5 μg/L, which exceeds the drinking water standard (70 μg/L). In addition, some mobility of these compounds was seen at the clay site.

There were three sampling events for semivolatile organics: August 1994, November 1994, and April 1995. More compounds were found upon each subsequent sampling. A group of tentatively identified compounds were found in the April, 1995 samples that were not found in the August, 1994 or November, 1994 samples. Aniline was found in the samples from the tire chip trenches at the peat and till sites for the August, 1994 sampling. Aniline is an antidegradant used in the rubber processing industry. In addition to aniline, phenol was found in each of the November, 1994 samples from within the tire chip trenches. Phenol and p-Cresol were found in the April, 1995 samples from within the tire chip trenches. Aniline was found only in the till site tire trench sample. In addition, a group of tentatively identified compounds were found in the April, 1995 samples, including 2(3H)-benzothiazolone; 1H-Isoindole-1,3(2H)-dione; benzothiazole; butanoic acid; benzoic acid, and cyclohexanol. These compounds can be identified as tire ingredients or end products of tire ingredients.

These semivolatile organic compounds do not have drinking water standards. Data on their threats to human health is too limited to determine if the levels found in this study are high enough to cause concern. The data from the field study indicate that these compounds may be mobile in some environments. Further sampling of the field sites is needed to establish the presence and persistence of semivolatile organic compounds.

It is recommended that tire chip use in construction be limited to above the groundwater table applications pending further sampling of the existing tire chip field trial installations.

CHAPTER 7

SUMMARY

7.1 INTRODUCTION

Storage and disposal of the 240 million scrap tires that are generated in the United States each year causes many problems. These problems include use of valuable and limited landfill space, fire hazards, and health threats due to mosquito vectored diseases. To avoid the disposal and storage problems, alternate uses for tires have been sought. These uses include cutting scrap tires into chips to be used as lightweight and insulating fills in roadways, embankments, and retaining walls. Use of tire chips as a construction material would be especially advantageous in wet or swampy areas because they are much lighter than traditional fills, such as gravel, which tend to cause problems with slope stability and excessive settlement of the underlying soils. Tire chips are also good thermal insulators, which can be used to reduce the depth of frost penetration in cold climates. However, these applications may bring tire chips into direct contact with groundwater, raising concerns of possible contamination. The focus of this research was to evaluate the effects of tire chips placed below the groundwater table on groundwater quality.

A three part study was designed to meet the goal of the project. The three phases of the project were: 1) laboratory leaching tests; 2) laboratory simulation of ground conditions; and 3) small scale field trials. The toxicity characteristic leaching procedure (TCLP) was used to evaluate potential pollutants from tire chips. The laboratory simulation of ground conditions was a batch reactor study that investigated the long-term leachability of tire chips and compared leaching of contaminants from soil to leaching of contaminants from tire chips. Finally, small scale field trials were used to evaluate the long-term effects of using tire chips as a construction material below the groundwater table. Each of the three phases of this study and their results are summarized below.

7.2 TOXICITY CHARACTERISTIC LEACHING PROCEDURE TESTING

TCLP is used to determine if a waste is a significant hazard to human health due to leaching of toxic compounds. In addition to this function, TCLP can also be used as an indication of potential pollutants that may leach from a waste. In this study, four different tire chip samples were subjected to TCLP testing and subsequent analysis. The four samples were: unwashed mixed glass and steel belted chips, washed mixed steel and glass belted chips, unwashed glass belted chips, and washed glass belted chips. The samples were tested washed and unwashed to examine the possibility that pollutants from tire chips could be due to dirt and debris on the surface of the tires, rather than to the tires themselves. Particle size reduction is required by the TCLP testing method. The tire chip size was reduced to passing the 9.5-mm (0.375-in.) sieve.

7.2.1 Metals Results

The TCLP regulated metals are: arsenic, barium, cadmium, chromium, lead, mercury, selenium, and silver. Arsenic, mercury, selenium, and silver were not detected in the leachates of any of the tire samples. Barium, cadmium, chromium, and lead were detected in each of the tire chip sample leachates. The concentrations of these metals were well below the TCLP regulatory limits for all samples.

The results for comparing washed samples to unwashed samples were mixed. In general, it appears that washing the tire chips did not significantly affect the metal concentrations, however, to fully investigate the effects of washed vs. unwashed tire chip leaching, more samples should be tested. The results of the TCLP metals testing shows that the potential metals of concern are barium, cadmium, chromium, and lead.

7.2.2 Organics Results

The only TCLP regulated organic compound found in the TCLP extracts was 1,2-dichloroethane. The highest concentration measured was 7 μg/L, which is well below the regulatory limit of 500 μg/L. In addition, dichloromethane, which is not regulated by TCLP, was found in each of the sample extracts. The levels of dichloromethane found ranged from 4 μg/L to 10 μg/L. Several additional semivolatile compounds were detected: aniline; 1-(2-butoxyethoxy)-ethanol; benzothiazole; 1H-isoindole-1,3(2H)-dione; 2(3H)-benzothiazolone; 4-(2-benzothiazolylthio)-morpholine; and 2,5-cyclohexadiene-1,4-dione. These compounds can be identified as tire ingredients or the products of the breakdown of tire ingredients, which is consistent with finding that they leach from tires. None of the organic compounds exceeded TCLP regulatory limits.

7.2.3 TCLP Conclusions

Based on the toxicity characteristic leaching procedure, tire chips are not classified as a hazardous waste. The TCLP testing indicated that barium, cadmium, chromium, and lead are potential pollutants of concern with scrap tire leaching. In addition, leaching potential for organic compounds, both volatile an semivolatile, was indicated.

When comparing the University of Maine Study with previous laboratory leaching studies, the results seem reasonable. In addition to the metals of concern identified by the Maine Study, mercury was also indicated in another leaching study.

7.3 LABORATORY SIMULATION OF GROUND CONDITIONS

The laboratory simulation of ground conditions was a batch reactor study. Eight reactors were set up. The reactors were 20 L (5 gal) Pyrex glass jars. Three reactors were controls that contained soil and water only. The three soil types used were clay, till, and peat. The soils were bulk soil samples that were collected at each of the three field sites chosen for the small scale field trials. Three reactors were set up with tire chips, soil, and distilled water, one each corresponding to the control reactors. Two additional reactors contained only tire chips and distilled water. Designing the experiment this way allowed direct comparison of the metals, semivolatile organic compounds, and volatile organic compounds found in the reactors with soil and water only to the same parameters in the corresponding reactors that contained tire chips. The reactors were stored at ambient temperature in the dark for approximately ten months. The reactors were not mixed or disturbed during that time.

Water samples and soil samples were collected from the reactors. The water samples were analyzed for total and dissolved metals, volatile organic compounds, and semivolatile organic compounds. The soil samples were digested and analyzed for total metals.

7.3.1 Metals Results

Leaching of metals from tire chips was examined by analyzing two types of samples collected from the reactors: soil samples and water samples. Results from the different types of analyses were compared to determine if the tire chips were the source of the increase in concentrations. The results of the soil digests showed that tire chips increased the metals concentrations in the digestates for barium, chromium, copper, lead, iron, manganese, and zinc. The concentrations of these metals released from the soils during a rigorous acid digestion procedure were higher than the concentrations of the same metals released from the soils in the control reactors (no tire chips) during the same digestion procedure. The water samples results showed that several metals are leached from tire chips or are leached from soil due to the environmental conditions created by placing tire chips in contact with water and soil. Metals that were increased due to the tire chips were chromium, iron, manganese, and zinc. Metals that may be leached from tire chips but are also leached from soil were aluminum, barium, calcium, magnesium, and sodium. The source of these compounds could not be identified as the soil or the tire chips, but it is known that conditions were created that caused increases in those metals. Chromium, copper, iron, and manganese can be expected to leach from tires because they are components of the steel tire cord and beadwire.

7.3.2 Organics Results

The semivolatile organic compounds detected in the reactor water samples were: aniline; 4-acetyl-morpholine, benzoic acid, and 2(3H)-benzothiazolone. None of these compounds were found in the control reactor samples, therefore the source of the compounds appears to be the tires. This is consistent with the results of the TCLP testing. Some of these compounds were also found in the TCLP extracts. These semivolatile compounds are either tire ingredients or end-products of tire ingredients.

The volatile organic compounds detected in the reactor water samples include: toluene (also found in the blank), benzene, naphthalene, dichloromethane, and cis-1,2-dichloroethene. None of the compounds found were above the drinking water standard (where applicable). Dichloromethane was the only compound found in the reactor study that was also found in the TCLP extracts.

7.4 SMALL SCALE FIELD TRIALS

Three sites were chosen for the small scale field trials, one each in marine clay (locally known as Presumpscot Formation), glacial till, and fibrous peat. The site selection criteria were soil type and topography. The sites needed 1) to have the groundwater table elevation near the ground surface for as much of the year as possible, 2) to have the desired soil type, and 3) to be reasonably accessed with the equipment required to install the tire chips and monitoring wells. At each site approximately 1.4 metric tons (1.5 short tons) were installed in a small trench lined with non-woven geotextile. The size of the trench at each site was approximately 3m (10 ft) long, 1.8 m (6 ft) deep, and 0.6 m (2 ft) wide. The trenches were dug perpendicular to the inferred direction of groundwater flow. Monitoring wells were installed within the trench, upgradient of the trench, and downgradient of the trench at each site. The monitoring wells were sampled quarterly for water quality parameters.

7.4.1 Metals Results

The tire chips increased the iron concentration at each of the sites. The iron concentrations in the samples from within the tire chip trench are up to two orders of magnitude higher than the secondary drinking water standard for iron (300 μg/L). The iron does not appear to have migrated downgradient at any of the sites. Manganese is also increased by the tire chips. The secondary drinking water standard for manganese is 50 μg/L and is consistently exceeded in the well within the tire chip trench. Unlike iron, the manganese was observed to migrate downgradient with the groundwater flow. Zinc was also increased by the tire chip installations; however, the concentration was well below the drinking water standard (5000 μg/L). Chromium concentrations were increased by the tire chips, but only at the peat site. The levels were all below the primary drinking water standard for chromium (100 μg/L).

It is recommended that tire chips only be used in locations where increased levels of iron and manganese can be accepted. Groundwater is often high in iron and manganese and is sometimes treated to remove these metals if it is to be used as a drinking water supply.

7.4.2 Organics Results

The volatile organic compounds detected in the field samples for both the August 1994 and the November 1994 samples were 1,1-dichloroethane, cis-1,2-dichloroethene, and dichloromethane. Dichloromethane is used as a solvent in the rubber processing industry, making tire chips a possible source. The total theoretical dichloromethane concentration based on the results of the TCLP testing and knowing the mass of the tire chips installed at each field site is approximately 60 µg/L. Levels of dichloromethane in the field samples were much higher than that. It is possible that environmental conditions in the field are causing the high dichloromethane concentrations. However, it is also possible that there is a laboratory contamination problem that is giving erroneously high dichloromethane levels. Dichloromethane was detected in all samples tested including the laboratory blank (prepared at ERI) and the blanks shipped with the samples. Levels of dichloromethane were found that were significantly higher than those levels found in the blanks. However, no pattern could be seen in the concentrations found with respect to control well versus downgradient wells. Dichloromethane is used in the preparation of samples analyzed for semivolatile organics. ERI confirmed that the same prep room is used for volatile samples and semivolatle samples; therefore, laboratory contamination cannot be ruled out.

The apparent downgradient mobility of the three volatile compounds found in both sets of samples is typical of that of contamination situations. The most hydrophilic compound (dichloromethane) travels the furthest with the groundwater flow and the least hydrophilic compound (cis-1,2-dichloroethene) travels the least with the groundwater flow. Based on this theory, the volatile organic compound data seems reasonable. Cis-1,2-dichloroethene was measured at a concentration above the primary drinking water standard (70 µg/L) in the till sample from within the tire chips on one sample date.

Without additional data it is not possible to determine if significant levels of dichloromethane and cis-1,2-dichloroethene leach from tire chips.

Semivolatile organic compounds that appear to be of concern based on the small scale field trials are: aniline; phenol; p-cresol; benzothiazole; 1H-isoindole-1,3-(2H)-dione; 4-(2-benzothiazolylthio)-morpholine, and 2(3H)-benzothiazolone. All of these compounds but aniline and phenol were found only on the third sampling date. These compounds can be identified as tire components or as end products of tire ingredients, which is consistent with finding them in the leachate. These semivolatile organic compounds do not have drinking water standards. Data on their threat to human health is too limited to determine if the levels found in this study are high enough to cause concern.

At present, it is recommended that tire chips used in construction be limited to applications above the groundwater table. Monitoring of the small scale field trials should continue to better identify what organic compounds are present.

7.5 RECOMMENDATIONS FOR FUTURE RESEARCH

7.5.1 Metals

Due to the complication of interpreting total metals results due to the significant variation (qualitative) in the particulate content of the samples, total metals should only be measured in the samples from within the tire chip trench. The exception to this would be chromium at the peat site which should be measured in both forms. Continued monitoring of dissolved metals should include: barium, chromium, iron, manganese, and zinc. To determine the effects of the tire chips on the soil matrix directly, soil core samples should be collected and analyzed. Control soil samples should be taken upgradient of the tire chip trench at each site. Soil samples should be taken downgradient of the tire chip filled trench at each site. One sample taken immediately downgradient from the trench, just outside the pocket of tire chips, and other samples taken at intervals further from the trench between the trench and the well the furthest downgradient.

7.5.2 Organics

To investigate the potential laboratory contamination problem with dichloromethane, two sets of volatile organic compound samples should be collected at the next sampling date. One set of samples should be analyzed at ERI, and the second set should be analyzed at a second independent testing laboratory. Monitoring and analysis of volatile and semivolatile organic compounds should continue at the field trial sites to get a better understanding of the contamination potential due to organic compounds. Another test to rule out or confirm the possibility of particulate rubber in the samples causing the semivolatile organic compounds to be artificially high, would be to test filtered and unfiltered samples. Caution must be used since sorption of organics to the filtering apparatus and to the filter itself is often a problem.

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Appendix A:
Scrap Tire Material Safety Data Sheet

Whole Scrap Tire

MATERIAL SAFETY DATA SHEET

Page 1

N/D = Not Determined (Unknown) N/A = Not Applicable

SECTION I IDENTIFICATION

CHEMICAL NAME Rubber Compound (Mixture) containing natural and synthetic rubber that is physically/chemically bound with carbon black, clay, titanium dioxide, zinc oxide, sulfur and petroleum hydrocarbons.

COMMON NAME Scrap Tire (Whole)

MANUFACTURERS	TRADENAMES	EMERGENCY TELEPHONE NO.
	Scrap Tire (Whole)	

SECTION II HAZARDOUS INGREDIENTS

CHEMICAL NAME	CAS NUMBER	%	HEALTH HAZARD	OSHA (PEL) ACGIH (TLV)	PHYSICAL HAZARD
Carbon black	1333-86-4	16-36	Irritant	3.5 mg/M^3	Non-hazardous
Clay	12141-46-7	<1.0	Irritant	N/D	Non-hazardous
Titanium dioxide	13463-67-7	<1.5	Irritant	10 mg/M^3	Non-hazardous
Zinc oxide	1314-13-2	<2.0	Irritant	5.0 mg/M^3	Non-hazardous
Sulfur	7704-34-9	<1.5	Irritant	N/D	Non-hazardous
Petroleum hydrocarbons	8002-29-7	5-13	Irritant Carcinogen	5.0 mg/M^3	Non-Hazardous

SECTION III PHYSICAL DATA

APPEARANCE	ODOR	MELT POINT	SPECIFIC GRAVITY	BOILING POINT
Solid Black Rubber	Rubber	N/D	1.085-1.331	N/A

BULK DENSITY	% VOLATILE BY VOLUME	VAPOR DENSITY (AIR=1)	VAPOR PRESS.	% SOL. H_2O
N/A	0	N/A	N/A	Insoluble

OTHER N/D

N/D = Not Determined (Unknown)   N/A = Not Applicable

SECTION IV   FIRE AND EXPLOSION HAZARD DATA

FLASH POINT & METHOD	IGNITION TEMP.	FLAMMABLE LIMITS LOWER	FLAMMABLE LIMITS UPPER
N/D	N/D	N/D	N/D

FIRE EXTINGUISHING AGENTS AND SPECIAL PROCEDURES

Any of the following extinguishing agents may be used to combat fires of this material: water (dispersed with fog nozzles), carbon dioxide, dry chemical, Halon or alcohol foam. Water, dispersed with fog nozzles, may be used to cool fire-exposed containers and to prevent pressure build-up.

Full protective clothing and MSHA/NIOSH (Mine Safety and Health Administration/National Institute for Occupational Safety and Health) approved, positive pressure, self-contained breathing apparatus should be used while firefighting. Thermal decomposition by-products may present a health hazard.

UNUSUAL EXPLOSIVE HAZARDS   None

PRODUCTS EVOLVED WHEN SUBJECTED TO HEAT OR COMBUSTION

Potentially carcinogenic materials (including nitrosamines), carbon oxides (carbon monoxide and carbon dioxide), acrid fumes, and flammable hydrocarbons may be liberated as a result of thermal decomposition or combustion. Avoid the smoke and fumes that result from thermal decomposition or combustion.

SECTION V   HEALTH EFFECTS - Effects of Exposure

LD50 ORAL (INGESTION)	LD50 DERMAL (SKIN CONTACT)	LC50 (INHALATION)
N/D	N/D	N/D

THRESHOLD LIMIT VALUE (TLV)	PRIMARY ROUTE OF EXPOSURE
N/D	skin (dermal) contact

EFFECT OF ACUTE (SHORT TERM) EXPOSURE:

No known health effects due to acute (short term) exposure.

EFFECT OF CHRONIC (REPEATED) EXPOSURE:

This material contains untreated naphthenic or aromatic extender oil. This oil could be released from the surface through skin contact. Prolonged contact with these oils has been shown to cause skin cancer in laboratory studies with animals. Untreated naphthenic and aromatic oils are classified as carcinogenic by IARC (International Agency for Research on Cancer). Prolonged or repeated contact may cause skin irritation or sensitization (allergic skin reaction).

MEDICAL CONDITIONS AGGRAVATED BY EXPOSURE: Skin Disorders

N/D = Not Determined (Unknown)   N/A = Not Applicable

SECTION VI   EMERGENCY AND FIRST AID PROCEDURES

EYES: Not expected to be a problem.

SKIN: Wash thoroughly with soap and water. If reddening or irritation develops, obtain supportive medical attention.

INGESTION: Not expected to be a problem.

INHALATION: Not expected to be a problem.

OTHER INSTRUCTIONS:

Employees who have prolonged contact with material should practice good personal hygiene by frequent washing of hands and arms with soap and water. Remove contaminated clothing and launder before reuse. Shower at the end of each work day.

SECTION VII   CHEMICAL REACTIVITY

CONDITIONS CAUSING INSTABILITY   Stable under normal conditions.

INCOMPATIBILITY (MATERIALS TO AVOID)   None.

HAZARDOUS DECOMPOSITION PRODUCTS

Potentially carcinogenic materials (including nitrosamines), carbon oxides (carbon monoxide and carbon dioxide), acrid fumes, and flammable hydrocarbons may be liberated as a result of thermal decomposition or combustion. Avoid the smoke and fumes that result from thermal decomposition or combustion.

SECTION VIII   SPILL, LEAK, AND DISPOSAL INFORMATION

STEPS TO BE TAKEN IN CASE MATERIAL IS SPILLED OR RELEASED

WASTE DISPOSAL: Reclaim or recycle material if possible. Dispose of material-in accordance with applicable federal, state and local guidelines and regulations.

MATERIAL SAFETY DATA SHEET

N/D = Not Determined (Unknown) N/A = Not Applicable

SECTION IX SPECIAL PROTECTION INFORMATION

All rubber products should be handled so as to prevent eye contact and excessive or repeated skin contact. Appropriate skin protection should be employed. Inhalation of dusts should be avoided.

EYES: Not required for normal use.

SKIN: Use of protective gloves is recommended. Wash hands before eating, smoking or using the restroom.

INHALATION: Under normal conditions of use, respiratory protection should not be required.

ADDITIONAL PERSONAL PROTECTION INFORMATION:

Employees who have prolonged contact with material should practice good personal hygiene by frequent washing of hands and arms with soap and water. Remove contaminated clothing and launder before reuse. Shower at the end of each work day.

SECTION X STORAGE INFORMATION

PRECAUTIONS TO BE TAKEN IN HANDLING AND STORING

Store indoors in a cool, dry, well ventilated area under ambient conditions. (Temperatures: 32-100°F (0°-38°C)). Do not store in direct sunlight. Store and dispose of material in accordance with applicable federal, state and local guidelines and regulations.

SECTION XI ADDITIONAL COMMENTS

Components of this product are included in the EPA Toxic Substances Control Act (TCSA) Chemical Substances Inventory.

FOR ADDITIONAL INFORMATION

NAME	COMPANY	TELEPHONE

Prepared by: ____________ rlz/rmd Date: 15-Jun-1990

Appendix B:
Examples of Compounds in Classes of Rubber Chemicals

Examples of Compounds in Classes of Rubber Chemicals

(Adapted from Fishbein, 1991)

Antidegradants: aniline, cresols, hydroquinone, phenol, simple amines and hydroxy derivatives of these compounds. There are ten structural classes of commercial antidegradants:

a) aldehyde-amines
b) ketone-amines
c) diaryldiamines
d) diaryl amines
e) ketone-diarylamines
f) substituted phenols
g) bisphenols
h) hydroquinones
i) amino phenols
j) phosphites

The most commonly used antioxidants are in the amines, phenols, and thioesters categories.

Accelerators: sulfur, dithiocarbamates, guanidines, thiazoles, thioureas, thiuramsulfides, sulfenamides, aldehyde/amines, xanthates, and thiophosphates.

Activators: zinc oxide, litharge (PbO), red lead (Pb_3O_4), magnesium oxide, and sodium carbonate. In addition, organic acids are used to increase the solubility of the metals in the rubber formation (stearic acid or lauric acid).

Retarders: benzoic acid, salicyclic acid, phthalic anhydride, N-nitrosodiphenylamine (NDDA), and N-(cyclohexylthio)-phthalimide (CTP).

Blowing Agents: dinitro pentamethylenetetramine, azobisbutyronitrile, azobisformamide, benzene sulfonyl hydrazide, and para, para oxybis(benzenesulfonyl hydrazide).

Plasticizers: phthalate esters, adipate esters, sebacate esters, and cumarone-indene resins.

Processing Aids: paraffinic, naphthenic, and aromatic mineral oils. Talc, coal-tar pitch, vegetable oils, organic phosphates, and polymerisates of unsaturated vegetable or animal oils with sulfur or sulfur chloride.

Reinforcing Agents: carbon black, amorphous silica.

Fillers and Diluents: clay, calcium carbonate, barytes, magnesium carbonate, barium sulfate, aluminum silicate, zinc carbonate, zinc sulfide, and titanium dioxide.

Bonding Agents: Proprietary mixtures believed to contain isocyanates and/or p-dinitrosobenzene. Also, resorcinol-hexamethylene tetramine bonding systems.

Solvents: aliphatic hydorcarbons, acetone, methyl ethyl ketone, methylene chloride, perchloroethylene, trichloroethylene, 1,1,1-trichloroethane, benzene, toluene, xylene, tetrahydrofuran, and dimethylformamide.

Miscellaneous Agents:

Flame Retardants: antimony trioxide, aluminum hydrate.

Colourants: carbon black, titanium dioxide, chrome oxide, iron oxide, zinc chromate, phthalocyanine, ultramarine blue.

Mould Release Agents: soaps, synthetic detergents, silicones, fluorinated hydrocarbons, polyethylenes.

Emulsifiers: rosins, rosin-derivatives, tall oil mixed soaps, sodium lauryl sulfate, sodium decylbenzene sulfonate, sodium salt.

Appendix C:
Minnesota Pollution Control Agency Study Results

TABLE 3: SUMMARY OF ANALYTICAL RESULTS FOR METALS TESTING OF NEW TIRE COMPOSITES IN UG/L OF LEACHATE

TCT No.	144656	145000	145010	145020
Analyte	Leach Test #1	Leach Test #2	Leach Test #3	Leach Test #4
Ag	< 5	< 5	< 5	< 5
Al	1020	213	< 18	< 54
As	< 83	34	< 28	< 53
Ba	488	205	48	265
Ca	27600	4560	1950	1712
Cd	110	7	< 5	< 5
Cr	142	2	< 5	< 2
Fe	346000	41200	80	25
Hg	< 0.5	< 0.5	< 0.5	< 0.5
Mg	3530	1190	288	202
Pb	417	< 51	< 38	< 39
S	2440	2800	1630	1630
Se	106	< 54	< 45	< 28
Sn	< 630	73	115	< 330
Zn	18600	8525	824	< 5

TABLE 4: SUMMARY OF ANALYTICAL RESULTS FOR METALS TESTING OF OLD TIRE COMPOSITES IN UG/L OF LEACHATE

TCT No.	144659	145005	145013	145021
Analyte	Leach Test #1	Leach Test #2	Leach Test #3	Leach Test #4
Ag	< 5	< 5	< 5	< 5
Al	934	351	36	< 54
As	< 83	< 11	< 28	< 53
Ba	205	62	174	107
Ca	10900	5290	1820	2405
Cd	125	< 6	< 5	< 5
Cr	235	< 2	< 5	< 2
Fe	500000	23300	531	718
Hg	< 0.5	< 0.5	< 0.5	< 0.5
Mg	1320	817	295	288
Pb	< 47	< 51	< 38	< 39
S	3540	4390	1990	2710
Se	203	< 54	< 45	< 28
Sn	< 630	31	32	< 330
Zn	23500	17500	3380	< 5

TABLE 5: SUMMARY OF ANALYTICAL RESULTS FOR METALS TESTING OF ASPHALT IN UG/L OF LEACHATE

TCT No.	144662	145008	145015	145024
Analyte	Leach Test #1	Leach Test #2	Leach Test #3	Leach Test #4
Ag	< 5	< 5	< 5	< 5
Al	3510	189*	< 18	< 54
As	< 83	< 11	< 28	< 53
Ba	734	344	38	394
Ca	1110000	605000	12500	108960
Cd	< 3	< 6	< 5	< 5
Cr	8	< 2	< 5	< 2
Fe	20850	1590	20	16
Hg	< 0.5	< 0.5	< 0.5	< 0.5
Mg	474000	177000	1870	7109
Pb	< 47	< 51	< 38	< 39
S	6030	3620	560	840
Se	105	< 54	< 45	< 28
Sn	1180	15	28	< 330
Zn	135	63	24	< 5

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February 19, 19
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Table 6
Summary of Chemical Analysis - Metals
Waste Tire Project
4231-90-177

Sample Number	Type	Ag	Al	As	Ba	Ca	Cd	Cr	Fe	Hg	Hg	Pb	S	Se	Sn	Zn
144656	New #1	ND	2.25	ND	1.08	608.96	0.24	0.31	763.40	ND	7.79	0.92	5.38	0.23	ND	41
144659	Old #1	ND	2.02	ND	0.44	23.57	0.27	0.51	1081.08	ND	2.85	ND	7.65	0.44	ND	50.
144662	Asphalt	ND	79.38	ND	16.60	25101.96	ND	0.18	471.51	ND	10719.22	ND	136.36	2.37	26.68	3.
145000	New #2	ND	0.45	0.07	0.44	9.69	0.01	ND	07.55	ND	2.53	ND	5.95	ND	0.16	18.
145005	Old #2	ND	0.75	ND	0.13	11.24	ND	ND	49.52	ND	1.74	ND	9.33	ND	0.07	37.
145008	Asphalt	ND	3.78	ND	6.88	12100.00	ND	ND	31.80	ND	3540.00	ND	72.40	ND	0.30	1
145010	New #3	ND	ND	ND	0.19	7.80	ND	ND	0.32	ND	1.15	ND	6.52	ND	0.46	3.
145013	Old #3	ND	0.14	ND	0.70	7.28	ND	ND	2.12	ND	1.18	ND	7.96	ND	0.13	13.
145015	Asphalt	ND	ND	ND	0.76	250.00	ND	ND	0.40	ND	37.40	ND	11.20	ND	0.56	0.
145020	New #4	ND	ND	ND	1.06	6.85	ND	ND	0.10	ND	0.81	ND	6.52	ND	ND	
145021	Old #4	ND	ND	ND	0.43	9.62	ND	ND	2.87	ND	1.15	ND	10.84	ND	ND	
145024	Asphalt	ND	ND	ND	7.88	1846.00	ND	ND	0.32	ND	142.18	ND	16.80	ND	ND	
159099	PC-W-tire	<0.01	1.8	<0.1	<0.01	14.4	<.003	<.01	4.4	<.001	2.8	<.02	633	<0.1	<.05	<
159114	FL-W-tire	<0.01	180	<0.1.	1.93	1080	0.032	0.35	298	<.001	383	0.23	737	<0.1	0.37	C
159121	FL-W-back	<0.01	4.3	<0.1	0.04	36.6	<.003	<.01	5.8	0.001	6.2	<0.02	566	<0.1	<.05	<.
159117	FL-S-tire	<0.01	1170	4	45	10700	<0.2	1.5	2240	<0.04	1060	<1.0	1530	0.4	5.5	
159108	FL-S-back	<0.01	4680	<2	34	4930	<0.2	8.3	7160	0.04	1530	<1.0	370	<1	<2.5	
159071	PC-S-tire	<0.01	3300	<1	66	6040	<0.2	5.4	4690	<0.04	1180	43	1400	0.6	60	1
161251	Tire grab1	<0.5	3490	<5	23	659	<0.2	4.9	5220	<0.26	630	6.9	84	<5	<2.5	1
161254	Tire grab2	<0.5	3310	<5	16	759	<0.6	6	11000	<0.26	660	31	150	<5	<2.5	2
159099	Field pH	6.1														
159114	Field pH	6.9														
159121	Field pH	6.6														
RAL				0.050	1.500		0.005	0.120	0.300	0.001		0.020		0.045		5.0
Chronic		0.050	0.147	0.030	1.000		0.001	0.010	0.300	0.001						5.0
Co-disposal		0.500		0.100	10.000		0.100	0.500	3.000	0.020	0.500	0.500		0.100		50.0
EP Toxicity		5.000		5.000	100.000		1.000	5.000		0.200		5.000		1.000		
TCLP		5.000		5.000	100.000		1.000	5.000		0.200		5.000		1.000		

For samples 144656-145024 the results were expressed as mg/kg (milligrams per kilogram) of of tire sample ("normali
For samples 159099-161254 the results were expressed as mg/kg of soil or mg/l (milligrams per liter) of water as rec
Mg/kg and mg/l are equivalent to parts per million.
The equivalent concentrations in the estimated porewater volume are 0.8 times the leachate values reported (see page

Condition #1 = pH 3.5 leach
Condition #2 = pH 5.0 leach
Condition #3 = 0.9% NaCl leach
Condition #4 = pH 8.0 leach

FL = Floodwood Road Site
PC = Pine County Road Site
S = soil sample
W = water sample
Tire grab = soil sample under stockpile

Table 7

Summary of Chemical Analysis
Polynuclear Aromatic Hydrocarbons
and Total Petroleum Hydrocarbons
Waste Tire Project
4231-90-177

		Total Petroleum Hydrocarbons		PAH (carcinogenic)		PAH (non-carcinogenic)	
Sample Number	Type	418.1 mg/l	Normalized 418.1 mg/kg	Sum of List 1 ng/l	Normalized Sum of List 1 ng/kg	Sum of List 2 ng/kg	Normalized Sum of List 2 ng/kg
144656	New #1	ND	ND	ND	ND	430	949
144659	Old #1	ND	ND	230	497	130	281
144662	Asphalt	2.70	0.06	ND	ND	153	3460
145000	New #2	ND	ND	200	425	498	1058
145005	Old #2	ND	ND	88	187	248	527
145008	Asphalt	ND	ND	ND	ND	340	6800
145010	New #3	ND	ND	339	1354	479	1916
145013	Old #3	ND	ND	100	400	171	684
145015	Asphalt	17.50	0.35	36	728	436	8716
145020	New #4	35.50	0.14	790	3159	1271	5083
145021	Old #4	31.50	0.13	239	954	605	2421
145024	Asphalt	25.40	0.51	6	118	317	6330
159099	PC-W-tire	0.5		44		2257	
159114	FL-W-tire	<0.5		7		12	
159121	FL-W-back	11.8		3		114	
159117	FL-S-tire	NR		<550 ppb		<550 ppb	
159108	FL-S-back	NR		<550 ppb		<550 ppb	
159071	PC-S-tire	NR		<550 ppb		<550 ppb	
161251	Tire grab1	17.6		<410 ppb		<410 ppb	
161254	Tire grab2	55.5		<430 ppb		<430 ppb	
159099	Field pH	6.1					
159114	Field pH	6.9					
159121	Field pH	6.6					
Detection Limit		0.5 mg/l		4-20 ppt		4-20 ppt	
RAL				28		280	
Chronic				21		280	

All PAH concentrations expressed as ng/l (nanograms per liter) or
ng/kg (nanograms per kilogram) which is equivalent to parts per trillion
For samples 144656-145024, the concentrations are expressed in ng/kg (nanograms per kilogram) of tire material.
The equivalent concentrations in the estimated porewater volume are 0.8 times the values reported (see page 3

Condition #1 = pH 3.5 leach
Condition #2 = pH 5.0 leach
Condition #3 = 0.9% NaCl leach
Condition #4 = pH 8.0 leach

FL = Floodwood Road Site
PC = Pine County Road site
S = soil sample
W = water sample
Tire grab = soil sample under stockpile

Appendix D:
Wisconsin Department of Transportation Study Results

Table 10.1 Water Quality Data from West Lysimeter

SAMPLE	Unit	Limits for Primary and Secondary Drinking Water Standards	4/11/90	5/9/90	6/6/90	7/5/90	8/3/90	9/4/90	12/14/90	3/28/91	10/10/91	6/1/92
pH	su		7.6	7.5	7.6	7.9	7.3	7.5	7.8	7.2	7.1	7.8
Alkalinity	mg/L		381	557	656	722	710	726	760	729	766	910
Barium	µg/L	1000 (P)	240	240	230	210	360	470	690	430	430	160
B O D	mg/L		41	15	<6	5.2	17	40	LA	4.1	<3	—
Calcium	mg/L		190	180	160	140	120	110	160	240	200	300
Chloride	mg/L	250 (S)	770	570	300	230	120	150	480	760	580	810
C O D	mg/L		200	110	84	120	140	230	290	140	71	240
Conduc-tivity	µmhos/cm		3880						2660	3100	2960	3840
Iron	mg/L	0.3 (S)	0.05	<0.05	0.24	0.57	0.26	4	0.25	0.96	0.13	0.56
Lead	µg/L	50 (P)	<3	<3	<3	<3	<3	<3	<3	5	<3	<3
Magnesium	mg/L		190	160	150	130	120	130	180	220	240	320
Manganese	µg/L	50 (S)	170	200	220	350	2500	2100	1900	1200	45	2600
Sodium	mg/L		330	290	220	130	86	89	140	87	58	230
Sulfate	mg/L	250 (S)	130	97	130	150	140	110	117.5	140	95	42
Total solids	mg/L	500 (S)	3010	2150	1400	1330	1180	1290	1850	2610	1770	2240
Zinc	µg/L	5000 (S)	19	12	17	ND	16	44	19	30	13	750
Hardness	mg/L		1300	1100	1000	900	780	830	1100	1500	1500	2100

Table 10.2 Water Quality Data from East Lysimeter

SAMPLE	Unit	Limits for Primary and Secondary Drinking Water Standards	4/11/90	5/9/90	6/6/90	7/5/90	8/3/90	9/4/90	12/14/90	3/28/91	10/10/91	6/1/92
pH	su			7.7	7.4	7.8	7.5	7.3		7.7	7.3	7.4
Alkalinity	mg/L			533	567	625	671	705		792	616	657
Barium	µg/L	1000 (P)	220	210	240	190	270	310		350	190	570
B O D	mg/L			14	10	39	75	57		70	5.7	—
Calcium	mg/L		200	170	180	110	130	140		340	290	180
Chloride	mg/L	250 (S)		460	340	130	170	200		1400	900	1200
C O D	mg/L		280	170	220	320	290	390		560	200	78
Conduc-tivity	µmhos/cm									5150	3880	4820
Iron	mg/L	0.3 (S)	1.3	<0.05	0.12	0.54	5.3	0.36		0.7	0.15	1.6
Lead	µg/L	50 (P)	9	<3	5	4	15	6		22	<3	<3
Magnesium	mg/L		200	150	150	96	110	120		390	240	270
Manganese	µg/L	50 (S)	230	270	300	1200	1700	2300		3200	3200	1300
Sodium	mg/L		280	220	260	98	120	140		200	210	210
Sulfate	mg/L	250 (S)		140	140	92	150	180		450	290	260
Total solids	mg/L	500 (S)		2000	1480	1110	1290	1510		4630	2460	3080
Zinc	µg/L	5000 (S)	84	46	44	540	560	120		560	84	33
Hardness	mg/L		1300	1100	1100	660	780	860		2500	1700	1500

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Environmental Science Section (608) 262-3458 DNR LAB ID 113133790

Inorganic chemistry (#1 of 12 on 07/18/89)

Id: Point/Well/..: Field #: BL1 Route: 0000
Collection Date: 05/12/89 Time: 00:00 County: 00 (Unknown)
From: AFS BLANK ELUTION #1
To: KOZIAR
DNR
MADISON
Source: Other
Account number: LH002 Collected by: KOZIAR
Blank
Date Received: 05/19/89 Labslip #: I9086278 Reported: 07/06/89

Comment: Partial report; RESULTS ARE PROVISIONAL AND MAY CHANGE.

PH LAB	6.30	SU
ALKALINITY	3.	MG/L
ARSENIC, AA FURNACE	<10	UG/L
BARIUM, ICP	<40	UG/L
BOD 5 DAY analysis rejected	*<3	MG/L #1
CALCIUM, ICP	<1.0	MG/L
CHLORIDE	<0.3	MG/L
CHROMIUM, AA FURNACE	<3	UG/L
COD LOW LEVEL, COLORIMETRIC	<5	MG/L
COPPER, ICP	<20	UG/L
HARDNESS, CALCULATION METHOD	<6.	MG/L
IRON, ICP	<0.05	MG/L
MAGNESIUM, ICP	<1.	MG/L
MANGANESE, ICP	<40	UG/L
NITRATE PLUS NITRITE-N DISSOLVED, LOW RANGE	0.10	MG/L
TOTAL KJELDAHL NITROGEN	0.3	MG/L
SELENIUM, AA FURNACE	<5	UG/L
SODIUM, ICP	<1	MG/L
SULFATE, LOW RANGE	<1.0	MG/L
TITANIUM, ICP	ND (LOD=3 UG/L)	
ZINC, ICP	ND (LOD=10 UG/L)	

--- Footnotes ---
Remark #1: ACTUAL VALUE 1.3

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Inorganic chemistry (#2 of 12 on 07/18/89)

Id: Point/Well/..: Field #: BL2 Route: 0000
Collection Date: 05/12/89 Time: 00:00 County: 00 (Unknown)
From: AFS BLANK ELUTION #2
To: KOZIAR
DNR Source: Other
MADISON
Account number: LH002 Collected by: KOZIAR
Blank
Date Received: 05/19/89 Labslip #: I9086279 Reported: 07/06/89

Comment: Partial report; RESULTS ARE PROVISIONAL AND MAY CHANGE.

PH LAB	6.00	SU
ALKALINITY	3.	MG/L
ARSENIC, AA FURNACE	<10	UG/L
BARIUM, ICP	<40	UG/L
BOD 5 DAY	*<3	MG/L #1
analysis rejected		
CALCIUM, ICP	<1.0	MG/L
CHLORIDE	<0.3	MG/L
CHROMIUM, AA FURNACE	<3	UG/L
COD LOW LEVEL, COLORIMETRIC	<5	MG/L
COPPER, ICP	<20	UG/L
HARDNESS, CALCULATION METHOD	<6.	MG/L
IRON, ICP	<0.05	MG/L
LEAD, AA FURNACE	<3	UG/L
MAGNESIUM, ICP	<1.	MG/L
MANGANESE, ICP	<40	UG/L
NITRATE PLUS NITRITE-N DISSOLVED, LOW RANGE	0.20	MG/L
TOTAL KJELDAHL NITROGEN	0.3	MG/L
SELENIUM, AA FURNACE	<5	UG/L
SODIUM, ICP	1.	MG/L
SULFATE, LOW RANGE	<1.0	MG/L
TITANIUM, ICP	ND (LOD=3 UG/L)	
ZINC, ICP	ND (LOD=10 UG/L)	

--- Footnotes ---
Remark #1: ACTUAL VALUE 1.8

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Inorganic chemistry (#3 of 12 on 07/18/89)

Id: Point/Well/..: Field #: BL3 Route: 0000
Collection Date: 05/12/89 Time: 00:00 County: 00 (Unknown)
From: AFS BLANK
To: KOZIAR
DNR
MADISON
Source: Other
Account number: LH002 Collected by: KOZIAR
Blank
Date Received: 05/19/89 Labslip #: I9086280 Reported: 07/06/89

Comment: Partial report; RESULTS ARE PROVISIONAL AND MAY CHANGE.

PH LAB	6.25	SU
ALKALINITY	3.	MG/L
ARSENIC, AA FURNACE	<10	UG/L
BARIUM, ICP	<40	UG/L
BOD 5 DAY analysis rejected	*<3	MG/L #1
CALCIUM, ICP	<1.0	MG/L
CHLORIDE	<0.3	MG/L
CHROMIUM, AA FURNACE	<3	UG/L
COD LOW LEVEL, COLORIMETRIC	<5	MG/L
COPPER, ICP	<20	UG/L
HARDNESS, CALCULATION METHOD	<6.	MG/L
IRON, ICP	<0.05	MG/L
LEAD, AA FURNACE	<3	UG/L
MAGNESIUM, ICP	<1.	MG/L
MANGANESE, ICP	<40	UG/L
NITRATE PLUS NITRITE-N DISSOLVED, LOW RANGE	0.08	MG/L
TOTAL KJELDAHL NITROGEN	0.2	MG/L
SELENIUM, AA FURNACE	<5	UG/L
SODIUM, ICP	<1	MG/L
SULFATE, LOW RANGE	<1.0	MG/L
TITANIUM, ICP	ND (LOD=3 UG/L)	
ZINC, ICP	ND (LOD=10 UG/L)	

--- Footnotes ---
Remark #1: ACTUAL VALUE 1.5

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Environmental Science Section   (608) 262-3458   DNR LAB ID 113133790

Inorganic chemistry (#4 of 12 on 07/18/89)

Id: Point/Well/..:   Field #: EPBL   Route: 0000
Collection Date: 05/12/89 Time: 00:00 County: 00 (Unknown)
From: EP TOXICITY TEST BLANK WASH TIRES
To: KOZIAR
DNR   Source: Other
MADISON
Account number: LH002   Collected by: KOZIAR
Blank
Date Received: 05/19/89   Labslip #: I9086281   Reported: 06/09/89

Comment: Partial report; RESULTS ARE PROVISIONAL AND MAY CHANGE.

BARIUM EP-TOXICITY TEST, ICP	<1	MG/L
CADMIUM EP-TOXICITY TEST, ICP	<0.2	MG/L
CHROMIUM EP-TOXICITY TEST, ICP	<1	MG/L
EP-TOXICITY TEST	000	
LEAD EP-TOXICITY TEST, ICP	<1	MG/L
MERCURY EP-TOXICITY TEST	<0.004	MG/L

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       Inorganic chemistry (#5 of 12 on 07/18/89)

Id:             Point/Well/..:          Field #: EP1        Route: SW00
Collection Date: 05/12/89 Time: 00:00  County: 00 (Unknown)
From: EP TOX TEST WASTE TIRES
To: KOZIAR
    DNR                             Source: Other
    MADISON
Account number: SW022             Collected by: KOZIAR
Date Received: 05/12/89    Labslip #: I9084288    Reported: 06/09/89

Comment: Partial report; RESULTS ARE PROVISIONAL AND MAY CHANGE.
         -------------------------------------------------------

BARIUM EP-TOXICITY TEST, ICP                          <1          MG/L
CADMIUM EP-TOXICITY TEST, ICP                         <0.2        MG/L
CHROMIUM EP-TOXICITY TEST, ICP                        <1          MG/L
EP-TOXICITY TEST                                       000
LEAD EP-TOXICITY TEST, ICP                            <1          MG/L

MERCURY EP-TOXICITY TEST                              <0.004      MG/L
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Environmental Science Section      (608) 262-3458     DNR LAB ID 113133790

       Inorganic chemistry (#6 of 12 on 07/18/89)

Id:             Point/Well/..:          Field #: EP2        Route: SW00
Collection Date: 05/12/89 Time: 00:00  County: 00 (Unknown)
From: DUPLICATE EP TOX TEST ON WASTE TIRES
To: KOZIAR
    DNR                             Source: Other
    MADISON
Account number: SW022             Collected by: KOZIAR
Date Received: 05/12/89    Labslip #: I9084289    Reported: 06/09/89

Comment: Partial report; RESULTS ARE PROVISIONAL AND MAY CHANGE.
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BARIUM EP-TOXICITY TEST, ICP                          <1          MG/L
CADMIUM EP-TOXICITY TEST, -ICP                        <0.2        MG/L
CHROMIUM EP-TOXICITY TEST, ICP                        <1          MG/L
EP-TOXICITY TEST                                       000
LEAD EP-TOXICITY TEST, ICP                            <1          MG/L

MERCURY EP-TOXICITY TEST                              <0.004      MG/L
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       Inorganic chemistry (#7 of 12 on 07/18/89)

Id:            Point/Well/..:          Field #: 1-1        Route: SW00
Collection Date: 05/12/89  Time: 00:00  County: 00 (Unknown)
From: AFS ELUTION 1 WASTE TIRES
To: KOZIAR
    DNR                             Source: Other
    MADISON
Account number: SW022             Collected by: KOZIAR
Date Received: 05/12/89    Labslip #: I9084290    Reported: 07/13/89

Comment: Partial report; RESULTS ARE PROVISIONAL AND MAY CHANGE.
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PH LAB                                                 7.30        SU
ALKALINITY                                             18.         MG/L
ARSENIC, AA FURNACE                                   <10          UG/L
BARIUM, ICP                                            110.        UG/L
BOD 5 DAY                                              22          MG/L

CALCIUM, ICP                                           7.0         MG/L
CHLORIDE                                               3.6         MG/L
CHROMIUM, AA FURNACE                                  <3           UG/L
COD LOW LEVEL, COLORIMETRIC                            68.         MG/L
COPPER, ICP                                           <20          UG/L

HARDNESS, CALCULATION METHOD                           19.         MG/L
IRON, ICP                                             <0.05        MG/L
LEAD, AA FURNACE                                       15.         UG/L
MAGNESIUM, ICP                                        <1.          MG/L
MANGANESE, ICP                                         84.         UG/L

NITRATE PLUS NITRITE-N DISSOLVED, LOW RANGE            0.37        MG/L
TOTAL KJELDAHL NITROGEN                                3.0         MG/L
SAMPLE PREP/HAND I                                     SA PB
SELENIUM, AA FURNACE                                  <5           UG/L
SODIUM, ICP                                            3.          MG/L

SULFATE, LOW RANGE                                     6.4         MG/L
TITANIUM, ICP                                          ND (LOD=3 UG/L)
ZINC, ICP                                              38.         UG/L
    detected between 10 (LOD) and 40 (LOQ) UG/L
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       Inorganic chemistry (#8 of 12 on 07/18/89)

Id:             Point/Well/..:          Field #: 1-2         Route: SW00
Collection Date: 05/12/89  Time: 00:00  County: 00 (Unknown)
From: AFS ELUTION 2 WASTE TIRES
To: KOZIAR
    DNR                            Source: Other
    MADISON
Account number: SW022            Collected by: KOZIAR
Date Received: 05/12/89    Labslip #: I9084291    Reported: 07/13/89

Comment: Partial report; RESULTS ARE PROVISIONAL AND MAY CHANGE.
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PH LAB                                                 7.38        SU
ALKALINITY                                             18.         MG/L
ARSENIC, AA FURNACE                                   <10          UG/L
BARIUM, ICP                                            110.        UG/L
BOD 5 DAY                                              **          MG/L #1
    analysis rejected

CALCIUM, ICP                                           6.0         MG/L
CHLORIDE                                               0.8         MG/L
CHROMIUM, AA FURNACE                                  <3           UG/L
COD LOW LEVEL, COLORIMETRIC                            31.         MG/L
COPPER, ICP                                           <20          UG/L

HARDNESS, CALCULATION METHOD                           15.         MG/L
IRON, ICP                                             <0.05        MG/L
LEAD, AA FURNACE                                       3.          UG/L
MAGNESIUM, ICP                                        <1.          MG/L
MANGANESE, ICP                                         89.         UG/L

NITRATE PLUS NITRITE-N DISSOLVED, LOW RANGE            0.29        MG/L
TOTAL KJELDAHL NITROGEN                                1.5         MG/L
SAMPLE PREP/HAND I                                     SA PB
SELENIUM, AA FURNACE                                  <5           UG/L
SODIUM, ICP                                            1.          MG/L

SULFATE, LOW RANGE                                     1.0         MG/L
TITANIUM, ICP                                          ND (LOD=3 UG/L)
ZINC, ICP                                              54.         UG/L

--- Footnotes ---
Remark #1: TOXIC (2ML BOD61,25ML BOD18,100ML BOD13)
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Inorganic chemistry (#9 of 12 on 07/18/89)

Id: Point/Well/..: Field #: 1-3 Route: SW00
Collection Date: 05/12/89 Time: 00:00 County: 00 (Unknown)
From: AFS ELUTION 3 WASTE TIRES
To: KOZIAR
DNR
MADISON
Source: Other
Account number: SW022 Collected by: KOZIAR
Date Received: 05/12/89 Labslip #: I9084292 Reported: 07/13/89

Comment: Partial report; RESULTS ARE PROVISIONAL AND MAY CHANGE.

PH LAB	7.13	SU
ALKALINITY	19.	MG/L
ARSENIC, AA FURNACE	<10	UG/L
BARIUM, ICP	110.	UG/L
BOD 5 DAY	6.4	MG/L
CALCIUM, ICP	5.0	MG/L
CHLORIDE	0.3	MG/L
CHROMIUM, AA FURNACE	<3	UG/L
COD LOW LEVEL, COLORIMETRIC	27.	MG/L
COPPER, ICP	<20	UG/L
HARDNESS, CALCULATION METHOD	13.	MG/L
IRON, ICP	0.23	MG/L
LEAD, AA FURNACE	<3	UG/L
MAGNESIUM, ICP	<1.	MG/L
MANGANESE, ICP	300.	UG/L
NITRATE PLUS NITRITE-N DISSOLVED, LOW RANGE	ND (LOD=0.02 MG/L)	
TOTAL KJELDAHL NITROGEN	1.3	MG/L
SELENIUM, AA FURNACE	<5	UG/L
SODIUM, ICP	1.	MG/L
SULFATE, LOW RANGE	1.0	MG/L
TITANIUM, ICP	ND (LOD=3 UG/L)	
ZINC, ICP	360.	UG/L

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Inorganic chemistry (#10 of 12 on 07/18/89)

Id: Point/Well/..: Field #: D1 Route: SW00
Collection Date: 05/12/89 Time: 00:00 County: 00 (Unknown)
From: AFS DUPLICATE ELUTION 1 WASTE TIRES
To: KOZIAR
DNR Source: Other
MADISON
Account number: SW022 Collected by: KOZIAR
Date Received: 05/12/89 Labslip #: I9084293 Reported: 07/13/89

Comment: Partial report; RESULTS ARE PROVISIONAL AND MAY CHANGE.

PH LAB	7.43	SU
ALKALINITY	18.	MG/L
ARSENIC, AA FURNACE	<10	UG/L
BARIUM, ICP	97.	UG/L
BOD 5 DAY	25	MG/L
CALCIUM, ICP	7.0	MG/L
CHLORIDE	3.7	MG/L
CHROMIUM, AA FURNACE	<3	UG/L
COD LOW LEVEL, COLORIMETRIC	72.	MG/L
COPPER, ICP	<20	UG/L
HARDNESS, CALCULATION METHOD	19.	MG/L
IRON, ICP	0.05	MG/L
LEAD, AA FURNACE	14.	UG/L
MAGNESIUM, ICP	<1.	MG/L
MANGANESE, ICP	82.	UG/L
NITRATE PLUS NITRITE-N DISSOLVED, LOW RANGE	0.29	MG/L
TOTAL KJELDAHL NITROGEN	3.2	MG/L
SAMPLE PREP/HAND I	SA PB	
SELENIUM, AA FURNACE	<5	UG/L
SODIUM, ICP	4.	MG/L
SULFATE, LOW RANGE	6.5	MG/L
TITANIUM, ICP	ND (LOD=3 UG/L)	
ZINC, ICP	40.	UG/L

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Inorganic chemistry (#11 of 12 on 07/18/89)

Id: Point/Well/..: Field #: D2 Route: SW00
Collection Date: 05/12/89 Time: 00:00 County: 00 (Unknown)
From: AFS DUPLICATE ELUTION 2 WASTE TIRES
To: KOZIAR
DNR Source: Other
MADISON
Account number: SW022 Collected by: KOZIAR
Date Received: 05/12/89 Labslip #: I9084294 Reported: 07/13/89

Comment: Partial report; RESULTS ARE PROVISIONAL AND MAY CHANGE.

PH LAB	7.17	SU
ALKALINITY	17.	MG/L
ARSENIC, AA FURNACE	<10	UG/L
BARIUM, ICP	97.	UG/L
BOD 5 DAY	**	MG/L #1
analysis rejected		
CALCIUM, ICP	6.0	MG/L
CHLORIDE	0.9	MG/L
CHROMIUM, AA FURNACE	<3	UG/L
COD LOW LEVEL, COLORIMETRIC	32.	MG/L
COPPER, ICP	<20	UG/L
HARDNESS, CALCULATION METHOD	15.	MG/L
IRON, ICP	<0.05	MG/L
LEAD, AA FURNACE	<3	UG/L
MAGNESIUM, ICP	<1.	MG/L
MANGANESE, ICP	87.	UG/L
NITRATE PLUS NITRITE-N DISSOLVED, LOW RANGE	0.12	MG/L
TOTAL KJELDAHL NITROGEN	1.6	MG/L
SELENIUM, AA FURNACE	<5	UG/L
SODIUM, ICP	1.	MG/L
SULFATE, LOW RANGE	1.1	MG/L
TITANIUM, ICP	ND (LOD=3 UG/L)	
ZINC, ICP	22.	UG/L
detected between 10 (LOD) and 40 (LOQ) UG/L		

--- Footnotes ---
Remark #1: TOXIC (2ML BOD55,25ML BOD20,100ML BOD14)

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       Inorganic chemistry (#12 of 12 on 07/18/89)

Id:            Point/Well/..:            Field #: D3         Route: SW00
Collection Date: 05/12/89  Time: 00:00  County: 00 (Unknown)
From: AFS DUPLICATE ELUTION 3 WASTE TIRES
To: KOZIAR
    DNR                                Source: Other
    MADISON
Account number: WS022                Collected by: KOZIAR
Date Received: 05/12/89    Labslip #: I9084295    Reported: 07/13/89

Comment: Partial report; RESULTS ARE PROVISIONAL AND MAY CHANGE.
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PH LAB                                                  7.18       SU
ALKALINITY                                              18.        MG/L
ARSENIC, AA FURNACE                                    <10         UG/L
BARIUM, ICP                                             120.       UG/L
BOD 5 DAY                                               6.6        MG/L

CALCIUM, ICP                                            5.0        MG/L
CHLORIDE                                               <0.3        MG/L
CHROMIUM, AA FURNACE                                   <3          UG/L
COD LOW LEVEL, COLORIMETRIC                             24.        MG/L
COPPER, ICP                                            <20         UG/L

HARDNESS, CALCULATION METHOD                            13.        MG/L
IRON, ICP                                               0.16       MG/L
LEAD, AA FURNACE                                       <3          UG/L
MAGNESIUM, ICP                                         <1.         MG/L
MANGANESE, ICP                                          250.       UG/L

NITRATE PLUS NITRITE-N DISSOLVED, LOW RANGE             0.06       MG/L
TOTAL KJELDAHL NITROGEN                                 1.2        MG/L
SELENIUM, AA FURNACE                                   <5          UG/L
SODIUM, ICP                                             1.         MG/L
SULFATE, LOW RANGE                                     <1.0        MG/L

TITANIUM, ICP                                           ND (LOD=3 UG/L)
ZINC, ICP                                               630.       UG/L
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Environmental Science Section (608) 262-2797 DNR LAB ID 113133790

Organic chemistry (#1 of 17 on 06/27/89, unseen)

Id: Point/Well/..: Field #: BL-1 Route: SW00
Collection Date: 05/12/89 Time: 00:00 County: 00 (Unknown)
From: AFS BLANK, ELUTION #1
Description: INORGANIC SAMPLE 86278
To: KOZIAR
DNR, SW/2 Source: Other
MADISON
Account number: SW023 Collected by:
Date Received: 05/19/89 Labslip #: 09003639 Reported: 06/20/89

ACENAPHTHENE	<2.0	UG/L
ACENAPHTHYLENE	<2.0	UG/L
ANTHRACENE	<2.0	UG/L
BENZO (B&K) FLUORANTHENE	<10.	UG/L
BENZO (A) ANTHRACENE	<5.0	UG/L
BENZO (G,H,I) PERYLENE	<40.	UG/L
BENZO (A) PYRENE	<10.	UG/L
CHRYSENE	<2.0	UG/L
DIBENZO (A,H) ANTHRACENE	<40.	UG/L
FLUORENE	<2.0	UG/L
FLUORANTHENE	<2.0	UG/L
INDENO (1,2,3-CD) PYRENE	<40.	UG/L
NAPHTHALENE	<2.0	UG/L
PHENANTHRENE	<2.0	UG/L
PYRENE	<2.0	UG/L
BUTYL BENZYL PHTHALATE	<2.0	UG/L
2-CHLORONAPHTHALENE	<2.0	UG/L
1,2-DIPHENYLHYDRAZINE	<2.0	UG/L
1,3-DICHLOROBENZENE	<2.0	UG/L
1,4-DICHLOROBENZENE	<20.	UG/L
1,2-DICHLOROBENZENE	<6.0	UG/L
DIMETHYL PHTHALATE	<2.0	UG/L
DIETHYL PHTHALATE	<20.	UG/L
DI-N-OCTYLPHTHALATE	<10.	UG/L
DI-N-BUTYL PHTHALATE	<2.0	UG/L
2,4-DINITROTOLUENE	<5.0	UG/L
2,6-DINITROTOLUENE	<2.0	UG/L
BIS (2-CHLOROETHYL) ETHER	<5.0	UG/L
BIS (2-ETHYL HEXYL) PHTHALATE	<10.	UG/L
4-CHLOROPHENYL PHENYL ETHER	<2.0	UG/L

... continuing Labslip # 09003639,   Field # BL-1

4-BROMOPHENYL PHENYL ETHER	<2.0	UG/L
BIS (2-CHLOROETHOXY) METHANE	<2.0	UG/L
BIS (2-CHLOROISOPROPYL) ETHER	<2.0	UG/L
HEXACHLOROBENZENE	<30.	UG/L
HEXACHLOROETHANE	<2.0	UG/L
HEXACHLOROBUTADIENE	<2.0	UG/L
HEXACHLOROCYCLOPENTADIENE	<10.	UG/L
ISOPHORONE	<2.0	UG/L
NITROBENZENE	<2.0	UG/L
N-NITROSODIMETHYLAMINE	<2.0	UG/L
N-NITROSODIPHENYLAMINE	<2.0	UG/L
N-NITROSODI-N-PROPYLAMINE	<2.0	UG/L
1,2,4-TRICHLOROBENZENE	<2.0	UG/L
BENZIDINE	NA	
3,3-DICHLOROBENZIDINE	NA	
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Organic chemistry (#2 of 17 on 06/27/89, unseen)

Id: Point/Well/..:   Field #: BL-2   Route: SW00
Collection Date: 05/12/89   Time: 00:00   County: 00 (Unknown)
From: AFS BLANK ELUTION #2
Description: INORGANIC SAMPLE 86279
To: KOZIAR
DNR SW/2   Source: Other
MADISON
Account number: SW023   Collected by:
Date Received: 05/19/89   Labslip #: 09003640   Reported: 06/20/89

ACENAPHTHENE	<2.0	UG/L
ACENAPHTHYLENE	<2.0	UG/L
ANTHRACENE	<2.0	UG/L
BENZO (B&K) FLUORANTHENE	<10.	UG/L
BENZO (A) ANTHRACENE	<5.0	UG/L
BENZO (G,H,I) PERYLENE	<40.	UG/L
BENZO (A) PYRENE	<10.	UG/L
CHRYSENE	<2.0	UG/L
DIBENZO (A,H) ANTHRACENE	<40.	UG/L
FLUORENE	<2.0	UG/L
FLUORANTHENE	<2.0	UG/L
INDENO (1,2,3-CD) PYRENE	<40.	UG/L
NAPHTHALENE	<2.0	UG/L
PHENANTHRENE	<2.0	UG/L
PYRENE	<2.0	UG/L
BUTYL BENZYL PHTHALATE	<2.0	UG/L
2-CHLORONAPHTHALENE	<2.0	UG/L
1,2-DIPHENYLHYDRAZINE	<2.0	UG/L
1,3-DICHLOROBENZENE	<2.0	UG/L
1,4-DICHLOROBENZENE	<20.	UG/L
1,2-DICHLOROBENZENE	<6.0	UG/L
DIMETHYL PHTHALATE	<2.0	UG/L
DIETHYL PHTHALATE	<20.	UG/L
DI-N-OCTYLPHTHALATE	<10.	UG/L
DI-N-BUTYL PHTHALATE	<2.0	UG/L
2,4-DINITROTOLUENE	<5.0	UG/L
2,6-DINITROTOLUENE	<2.0	UG/L
BIS (2-CHLOROETHYL) ETHER	<5.0	UG/L
BIS (2-ETHYL HEXYL) PHTHALATE	<10.	UG/L
4-CHLOROPHENYL PHENYL ETHER	<2.0	UG/L

... continuing Labslip # 09003640, Field # BL-2

4-BROMOPHENYL PHENYL ETHER	<2.0	UG/L
BIS (2-CHLOROETHOXY) METHANE	<2.0	UG/L
BIS (2-CHLOROISOPROPYL) ETHER	<2.0	UG/L
HEXACHLOROBENZENE	<30.	UG/L
HEXACHLOROETHANE	<2.0	UG/L
HEXACHLOROBUTADIENE	<2.0	UG/L
HEXACHLOROCYCLOPENTADIENE	<10.	UG/L
ISOPHORONE	<2.0	UG/L
NITROBENZENE	<2.0	UG/L
N-NITROSODIMETHYLAMINE	<2.0	UG/L
N-NITROSODIPHENYLAMINE	<2.0	UG/L
N-NITROSODI-N-PROPYLAMINE	<2.0	UG/L
1,2,4-TRICHLOROBENZENE	<2.0	UG/L
BENZIDINE	NA	
3,3-DICHLOROBENZIDINE	NA	

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Organic chemistry (#3 of 17 on 06/27/89, unseen)

Id: Point/Well/..: Field #: 1-1 Route: SW00
Collection Date: 05/12/89 Time: 00:00 County: 00 (Unknown)
From: AFS - ELUTION 1
Description: WASTE TIRES - INORGANIC SAMPLE 84290
To: PAUL KOZIAR
DNR SW/2 Source: Other
MADISON
Account number: SW023 Collected by: KOZIAR
Date Received: 05/17/89 Labslip #: 09003580 Reported: 06/20/89

ACENAPHTHENE	<2.0	UG/L
ACENAPHTHYLENE	<2.0	UG/L
ANTHRACENE	<2.0	UG/L
BENZO (B&K) FLUORANTHENE	<10.	UG/L
BENZO (A) ANTHRACENE	<5.0	UG/L
BENZO (G,H,I) PERYLENE	<40.	UG/L
BENZO (A) PYRENE	<10.	UG/L
CHRYSENE	<2.0	UG/L
DIBENZO (A,H) ANTHRACENE	<40.	UG/L
FLUORENE	<2.0	UG/L
FLUORANTHENE	<2.0	UG/L
INDENO (1,2,3-CD) PYRENE	<40.	UG/L
NAPHTHALENE	<2.0	UG/L
PHENANTHRENE	<2.0	UG/L
PYRENE	<2.0	UG/L
BUTYL BENZYL PHTHALATE	<2.0	UG/L
2-CHLORONAPHTHALENE	<2.0	UG/L
1,2-DIPHENYLHYDRAZINE	<2.0	UG/L
1,3-DICHLOROBENZENE	<2.0	UG/L
1,4-DICHLOROBENZENE	<20.	UG/L
1,2-DICHLOROBENZENE	<6.0	UG/L
DIMETHYL PHTHALATE	<2.0	UG/L
DIETHYL PHTHALATE	<20.	UG/L
DI-N-OCTYLPHTHALATE	<10.	UG/L
DI-N-BUTYL PHTHALATE	<2.0	UG/L
2,4-DINITROTOLUENE	<5.0	UG/L
2,6-DINITROTOLUENE	<2.0	UG/L
BIS (2-CHLOROETHYL) ETHER	<5.0	UG/L
BIS (2-ETHYL HEXYL) PHTHALATE	<10.	UG/L
4-CHLOROPHENYL PHENYL ETHER	<2.0	UG/L

... continuing Labslip # 09003580,   Field # 1-1

4-BROMOPHENYL PHENYL ETHER	<2.0	UG/L
BIS (2-CHLOROETHOXY) METHANE	<2.0	UG/L
BIS (2-CHLOROISOPROPYL) ETHER	<2.0	UG/L
HEXACHLOROBENZENE	<30.	UG/L
HEXACHLOROETHANE	<2.0	UG/L
HEXACHLOROBUTADIENE	<2.0	UG/L
HEXACHLOROCYCLOPENTADIENE	<10.	UG/L
ISOPHORONE	<2.0	UG/L
NITROBENZENE	<2.0	UG/L
N-NITROSODIMETHYLAMINE	<2.0	UG/L
N-NITROSODIPHENYLAMINE	<2.0	UG/L
N-NITROSODI-N-PROPYLAMINE	<2.0	UG/L
1,2,4-TRICHLOROBENZENE	<2.0	UG/L
BENZIDINE	NA	
3,3-DICHLOROBENZIDINE	NA	
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Organic chemistry (#4 of 17 on 06/27/89, unseen)

Id: Point/Well/..: Field #: D-1 Route: SW00
Collection Date: 05/12/89 Time: 00:00 County: 00 (Unknown)
From: AFS DUP ELUTION 1
Description: WASTE TIRES - INORGANIC SAMPLE 84293
To: PAUL KOZIAR
DNR SW/2 Source: Other
MADISON
Account number: SW023 Collected by: KOZIAR
Date Received: 05/17/89 Labslip #: 09003581 Reported: 06/20/89

ACENAPHTHENE	<2.0	UG/L
ACENAPHTHYLENE	<2.0	UG/L
ANTHRACENE	<2.0	UG/L
BENZO (B&K) FLUORANTHENE	<10.	UG/L
BENZO (A) ANTHRACENE	<5.0	UG/L
BENZO (G,H,I) PERYLENE	<40.	UG/L
BENZO (A) PYRENE	<10.	UG/L
CHRYSENE	<2.0	UG/L
DIBENZO (A,H) ANTHRACENE	<40.	UG/L
FLUORENE	<2.0	UG/L
FLUORANTHENE	<2.0	UG/L
INDENO (1,2,3-CD) PYRENE	<40.	UG/L
NAPHTHALENE	<2.0	UG/L
PHENANTHRENE	<2.0	UG/L
PYRENE	<2.0	UG/L
BUTYL BENZYL PHTHALATE	<2.0	UG/L
2-CHLORONAPHTHALENE	<2.0	UG/L
1,2-DIPHENYLHYDRAZINE	<2.0	UG/L
1,3-DICHLOROBENZENE	<2.0	UG/L
1,4-DICHLOROBENZENE	<20.	UG/L
1,2-DICHLOROBENZENE	<6.0	UG/L
DIMETHYL PHTHALATE	<2.0	UG/L
DIETHYL PHTHALATE	<20.	UG/L
DI-N-OCTYLPHTHALATE	<10.	UG/L
DI-N-BUTYL PHTHALATE	<2.0	UG/L
2,4-DINITROTOLUENE	<5.0	UG/L
2,6-DINITROTOLUENE	<2.0	UG/L
BIS (2-CHLOROETHYL) ETHER	<5.0	UG/L
BIS (2-ETHYL HEXYL) PHTHALATE	<10.	UG/L
4-CHLOROPHENYL PHENYL ETHER	<2.0	UG/L

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Environmental Science Section (608) 262-2797 DNR LAB ID 113133790

Organic chemistry (#5 of 17 on 06/27/89, unseen)

Id: Point/Well/..: Field #: D-2 Route: SW00
Collection Date: 05/12/89 Time: 00:00 County: 00 (Unknown)
From: AFS DUP ELUTION 2
Description: WASTE TIRE - INORGANIC SAMPLE 84294
To: PAUL KOZIAR
DNR SW/2 Source: Other
MADISON
Account number: SW023 Collected by: KOZIAR
Date Received: 05/19/89 Labslip #: 09003641 Reported: 06/20/89

ACENAPHTHENE	<2.0	UG/L
ACENAPHTHYLENE	<2.0	UG/L
ANTHRACENE	<2.0	UG/L
BENZO (B&K) FLUORANTHENE	<10.	UG/L
BENZO (A) ANTHRACENE	<5.0	UG/L
BENZO (G,H,I) PERYLENE	<40.	UG/L
BENZO (A) PYRENE	<10.	UG/L
CHRYSENE	<2.0	UG/L
DIBENZO (A,H) ANTHRACENE	<40.	UG/L
FLUORENE	<2.0	UG/L
FLUORANTHENE	<2.0	UG/L
INDENO (1,2,3-CD) PYRENE	<40.	UG/L
NAPHTHALENE	<2.0	UG/L
PHENANTHRENE	<2.0	UG/L
PYRENE	<2.0	UG/L
BUTYL BENZYL PHTHALATE	<2.0	UG/L
2-CHLORONAPHTHALENE	<2.0	UG/L
1,2-DIPHENYLHYDRAZINE	<2.0	UG/L
1,3-DICHLOROBENZENE	<2.0	UG/L
1,4-DICHLOROBENZENE	<20.	UG/L
1,2-DICHLOROBENZENE	<6.0	UG/L
DIMETHYL PHTHALATE	<2.0	UG/L
DIETHYL PHTHALATE	<20.	UG/L
DI-N-OCTYLPHTHALATE	<10.	UG/L
DI-N-BUTYL PHTHALATE	<2.0	UG/L
2,4-DINITROTOLUENE	<5.0	UG/L
2,6-DINITROTOLUENE	<2.0	UG/L
BIS (2-CHLOROETHYL) ETHER	<5.0	UG/L
BIS (2-ETHYL HEXYL) PHTHALATE	<10.	UG/L
4-CHLOROPHENYL PHENYL ETHER	<2.0	UG/L

... continuing Labslip # 09003641,   Field # D-2

4-BROMOPHENYL PHENYL ETHER	<2.0	UG/L
BIS (2-CHLOROETHOXY) METHANE	<2.0	UG/L
BIS (2-CHLOROISOPROPYL) ETHER	<2.0	UG/L
HEXACHLOROBENZENE	<30.	UG/L
HEXACHLOROETHANE	<2.0	UG/L
HEXACHLOROBUTADIENE	<2.0	UG/L
HEXACHLOROCYCLOPENTADIENE	<10.	UG/L
ISOPHORONE	<2.0	UG/L
NITROBENZENE	<2.0	UG/L
N-NITROSODIMETHYLAMINE	<2.0	UG/L
N-NITROSODIPHENYLAMINE	<2.0	UG/L
N-NITROSODI-N-PROPYLAMINE	<2.0	UG/L
1,2,4-TRICHLOROBENZENE	<2.0	UG/L
BENZIDINE	NA	
3,3-DICHLOROBENZIDINE	NA	
PRIORITY POLLUTANTS - BASE NEUTRAL PREP - GCMS	C	

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Organic chemistry (#6 of 17 on 06/27/89, unseen)

Id: Point/Well/..: Field #: 1-2 Route: SW00
Collection Date: 05/12/89 Time: 00:00 County: 00 (Unknown)
From: AFS ELUTION 2
Description: WASTE TIRES INORGANIC SAMPLE 84291
To: PAUL KOZIAR
DNR, SW/2 Source: Other
MADISON
Account number: SW023 Collected by: KOZIAR
Date Received: 05/19/89 Labslip #: 09003642 Reported: 06/20/89

ACENAPHTHENE	<2.0	UG/L
ACENAPHTHYLENE	<2.0	UG/L
ANTHRACENE	<2.0	UG/L
BENZO (B&K) FLUORANTHENE	<10.	UG/L
BENZO (A) ANTHRACENE	<5.0	UG/L
BENZO (G,H,I) PERYLENE	<40.	UG/L
BENZO (A) PYRENE	<10.	UG/L
CHRYSENE	<2.0	UG/L
DIBENZO (A,H) ANTHRACENE	<40.	UG/L
FLUORENE	<2.0	UG/L
FLUORANTHENE	<2.0	UG/L
INDENO (1,2,3-CD) PYRENE	<40.	UG/L
NAPHTHALENE	<2.0	UG/L
PHENANTHRENE	<2.0	UG/L
PYRENE	<2.0	UG/L
BUTYL BENZYL PHTHALATE	<2.0	UG/L
2-CHLORONAPHTHALENE	<2.0	UG/L
1,2-DIPHENYLHYDRAZINE	<2.0	UG/L
1,3-DICHLOROBENZENE	<2.0	UG/L
1,4-DICHLOROBENZENE	<20.	UG/L
1,2-DICHLOROBENZENE	<6.0	UG/L
DIMETHYL PHTHALATE	<2.0	UG/L
DIETHYL PHTHALATE	<20.	UG/L
DI-N-OCTYLPHTHALATE	<10.	UG/L
DI-N-BUTYL PHTHALATE	<2.0	UG/L
2,4-DINITROTOLUENE	<5.0	UG/L
2,6-DINITROTOLUENE	<2.0	UG/L
BIS (2-CHLOROETHYL) ETHER	<5.0	UG/L
BIS (2-ETHYL HEXYL) PHTHALATE	<10.	UG/L
4-CHLOROPHENYL PHENYL ETHER	<2.0	UG/L

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... continuing Labslip # 09003642, Field # 1-2

4-BROMOPHENYL PHENYL ETHER	<2.0	UG/L
BIS (2-CHLOROETHOXY) METHANE	<2.0	UG/L
BIS (2-CHLOROISOPROPYL) ETHER	<2.0	UG/L
HEXACHLOROBENZENE	<30.	UG/L
HEXACHLOROETHANE	<2.0	UG/L
HEXACHLOROBUTADIENE	<2.0	UG/L
HEXACHLOROCYCLOPENTADIENE	<10.	UG/L
ISOPHORONE	<2.0	UG/L
NITROBENZENE	<2.0	UG/L
N-NITROSODIMETHYLAMINE	<2.0	UG/L
N-NITROSODIPHENYLAMINE	<2.0	UG/L
N-NITROSODI-N-PROPYLAMINE	<2.0	UG/L
1,2,4-TRICHLOROBENZENE	<2.0	UG/L
BENZIDINE	NA	
3,3-DICHLOROBENZIDINE	NA	
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Organic chemistry (#7 of 17 on 06/27/89, unseen)

Id: Point/Well/..: Field #: BL-3 Route: SW00
Collection Date: 05/12/89 Time: 00:00 County: 00 (Unknown)
From: AFS BLANK ELUTION #3
Description: INORGANIC SAMPLE 86280
To: KOZIAR
DNR, SW/2 Source: Other
MADISON
Account number: SW023 Collected by: KOZIAR
Date Received: 05/25/89 Labslip #: 09003693 Reported: 06/20/89

ACENAPHTHENE	<2.0	UG/L
ACENAPHTHYLENE	<2.0	UG/L
ANTHRACENE	<2.0	UG/L
BENZO (B&K) FLUORANTHENE	<10.	UG/L
BENZO (A) ANTHRACENE	<5.0	UG/L
BENZO (G,H,I) PERYLENE	<40.	UG/L
BENZO (A) PYRENE	<10.	UG/L
CHRYSENE	<2.0	UG/L
DIBENZO (A,H) ANTHRACENE	<40.	UG/L
FLUORENE	<2.0	UG/L
FLUORANTHENE	<2.0	UG/L
INDENO (1,2,3-CD) PYRENE	<40.	UG/L
NAPHTHALENE	<2.0	UG/L
PHENANTHRENE	<2.0	UG/L
PYRENE	<2.0	UG/L
BUTYL BENZYL PHTHALATE	<2.0	UG/L
2-CHLORONAPHTHALENE	<2.0	UG/L
1,2-DIPHENYLHYDRAZINE	<2.0	UG/L
1,3-DICHLOROBENZENE	<2.0	UG/L
1,4-DICHLOROBENZENE	<20.	UG/L
1,2-DICHLOROBENZENE	<6.0	UG/L
DIMETHYL PHTHALATE	<2.0	UG/L
DIETHYL PHTHALATE	<20.	UG/L
DI-N-OCTYLPHTHALATE	<10.	UG/L
DI-N-BUTYL PHTHALATE	<2.0	UG/L
2,4-DINITROTOLUENE	<5.0	UG/L
2,6-DINITROTOLUENE	<2.0	UG/L
BIS (2-CHLOROETHYL) ETHER	<5.0	UG/L
BIS (2-ETHYL HEXYL) PHTHALATE	<10.	UG/L
4-CHLOROPHENYL PHENYL ETHER	<2.0	UG/L

... continuing Labslip # 09003693, Field # BL-3

4-BROMOPHENYL PHENYL ETHER	<2.0	UG/L
BIS (2-CHLOROETHOXY) METHANE	<2.0	UG/L
BIS (2-CHLOROISOPROPYL) ETHER	<2.0	UG/L
HEXACHLOROBENZENE	<30.	UG/L
HEXACHLOROETHANE	<2.0	UG/L
HEXACHLOROBUTADIENE	<2.0	UG/L
HEXACHLOROCYCLOPENTADIENE	<10.	UG/L
ISOPHORONE	<2.0	UG/L
NITROBENZENE	<2.0	UG/L
N-NITROSODIMETHYLAMINE	<2.0	UG/L
N-NITROSODIPHENYLAMINE	<2.0	UG/L
N-NITROSODI-N-PROPYLAMINE	<2.0	UG/L
1,2,4-TRICHLOROBENZENE	<2.0	UG/L
BENZIDINE	NA	
3,3-DICHLOROBENZIDINE	NA	
PRIORITY POLLUTANTS - BASE NEUTRAL PREP - GCMS	C	

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Organic chemistry (#8 of 17 on 06/27/89, unseen)

Id: Point/Well/..: Field #: Route: SW00
Collection Date: 05/12/89 Time: 00:00 County: 00 (Unknown)
From: AFS ELUTION 3
Description: WASTE TIRES - INORGANIC SAMPLE 84292
To: PAUL KOZIAR
DNR, SW/2 Source: Other
MADISON
Account number: SW023 Collected by: KOZIAR
Date Received: 05/25/89 Labslip #: 09003694 Reported: 06/20/89

ACENAPHTHENE	<2.0	UG/L
ACENAPHTHYLENE	<2.0	UG/L
ANTHRACENE	<2.0	UG/L
BENZO (B&K) FLUORANTHENE	<10.	UG/L
BENZO (A) ANTHRACENE	<5.0	UG/L
BENZO (G,H,I) PERYLENE	<40.	UG/L
BENZO (A) PYRENE	<10.	UG/L
CHRYSENE	<2.0	UG/L
DIBENZO (A,H) ANTHRACENE	<40.	UG/L
FLUORENE	<2.0	UG/L
FLUORANTHENE	<2.0	UG/L
INDENO (1,2,3-CD) PYRENE	<40.	UG/L
NAPHTHALENE	<2.0	UG/L
PHENANTHRENE	<2.0	UG/L
PYRENE	<2.0	UG/L
BUTYL BENZYL PHTHALATE	<2.0	UG/L
2-CHLORONAPHTHALENE	<2.0	UG/L
1,2-DIPHENYLHYDRAZINE	<2.0	UG/L
1,3-DICHLOROBENZENE	<2.0	UG/L
1,4-DICHLOROBENZENE	<20.	UG/L
1,2-DICHLOROBENZENE	<6.0	UG/L
DIMETHYL PHTHALATE	<2.0	UG/L
DIETHYL PHTHALATE	<20.	UG/L
DI-N-OCTYLPHTHALATE	<10.	UG/L
DI-N-BUTYL PHTHALATE	<2.0	UG/L
2,4-DINITROTOLUENE	<5.0	UG/L
2,6-DINITROTOLUENE	<2.0	UG/L
BIS (2-CHLOROETHYL) ETHER	<5.0	UG/L
BIS (2-ETHYL HEXYL) PHTHALATE	<10.	UG/L
4-CHLOROPHENYL PHENYL ETHER	<2.0	UG/L

... continuing Labslip # 09003694

4-BROMOPHENYL PHENYL ETHER	<2.0	UG/L
BIS (2-CHLOROETHOXY) METHANE	<2.0	UG/L
BIS (2-CHLOROISOPROPYL) ETHER	<2.0	UG/L
HEXACHLOROBENZENE	<30.	UG/L
HEXACHLOROETHANE	<2.0	UG/L
HEXACHLOROBUTADIENE	<2.0	UG/L
HEXACHLOROCYCLOPENTADIENE	<10.	UG/L
ISOPHORONE	<2.0	UG/L
NITROBENZENE	<2.0	UG/L
N-NITROSODIMETHYLAMINE	<2.0	UG/L
N-NITROSODIPHENYLAMINE	<2.0	UG/L
N-NITROSODI-N-PROPYLAMINE	<2.0	UG/L
1,2,4-TRICHLOROBENZENE	<2.0	UG/L
BENZIDINE	NA	
3,3-DICHLOROBENZIDINE	NA	
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Organic chemistry (#9 of 17 on 06/27/89, unseen)

Id: Point/Well/..: Field #: D-3 Route: SW00
Collection Date: 05/12/89 Time: 00:00 County: 00 (Unknown)
From: AFS DUPLICATE #3
Description: WASTE TIRES INORGANIC SAMPLE 84295
To: PAUL KOZIAR
DNR, SW/2 Source: Other
MADISON
Account number: SW023 Collected by: KOZIAR
Date Received: 05/25/89 Labslip #: 09003695 Reported: 06/20/89

ACENAPHTHENE	<2.0	UG/L
ACENAPHTHYLENE	<2.0	UG/L
ANTHRACENE	<2.0	UG/L
BENZO (B&K) FLUORANTHENE	<10.	UG/L
BENZO (A) ANTHRACENE	<5.0	UG/L
BENZO (G,H,I) PERYLENE	<40.	UG/L
BENZO (A) PYRENE	<10.	UG/L
CHRYSENE	<2.0	UG/L
DIBENZO (A,H) ANTHRACENE	<40.	UG/L
FLUORENE	<2.0	UG/L
FLUORANTHENE	<2.0	UG/L
INDENO (1,2,3-CD) PYRENE	<40.	UG/L
NAPHTHALENE	<2.0	UG/L
PHENANTHRENE	<2.0	UG/L
PYRENE	<2.0	UG/L
BUTYL BENZYL PHTHALATE	<2.0	UG/L
2-CHLORONAPHTHALENE	<2.0	UG/L
1,2-DIPHENYLHYDRAZINE	<2.0	UG/L
1,3-DICHLOROBENZENE	<2.0	UG/L
1,4-DICHLOROBENZENE	<20.	UG/L
1,2-DICHLOROBENZENE	<6.0	UG/L
DIMETHYL PHTHALATE	<2.0	UG/L
DIETHYL PHTHALATE	<20.	UG/L
DI-N-OCTYLPHTHALATE	<10.	UG/L
DI-N-BUTYL PHTHALATE	<2.0	UG/L
2,4-DINITROTOLUENE	<5.0	UG/L
2,6-DINITROTOLUENE	<2.0	UG/L
BIS (2-CHLOROETHYL) ETHER	<5.0	UG/L
BIS (2-ETHYL HEXYL) PHTHALATE	<10.	UG/L
4-CHLOROPHENYL PHENYL ETHER	<2.0	UG/L

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... continuing Labslip # 09003695,   Field # D-3

4-BROMOPHENYL PHENYL ETHER	<2.0	UG/L
BIS (2-CHLOROETHOXY) METHANE	<2.0	UG/L
BIS (2-CHLOROISOPROPYL) ETHER	<2.0	UG/L
HEXACHLOROBENZENE	<30.	UG/L
HEXACHLOROETHANE	<2.0	UG/L
HEXACHLOROBUTADIENE	<2.0	UG/L
HEXACHLOROCYCLOPENTADIENE	<10.	UG/L
ISOPHORONE	<2.0	UG/L
NITROBENZENE	<2.0	UG/L
N-NITROSODIMETHYLAMINE	<2.0	UG/L
N-NITROSODIPHENYLAMINE	<2.0	UG/L
N-NITROSODI-N-PROPYLAMINE	<2.0	UG/L
1,2,4-TRICHLOROBENZENE	<2.0	UG/L
BENZIDINE	NA	
3,3-DICHLOROBENZIDINE	NA	
PRIORITY POLLUTANTS - BASE NEUTRAL PREP - GCMS	C	

Appendix E:
Scrap Tire Management Council Study Results

The list of TCLP compounds not found in the uncured samples was substantial and included:

TCLP Listed Chemicals Not Found In Uncured Samples

Metals

Silver
Mercury
Cadmium

Volatile Organics

Acrylonitrile
Carbon Tetrachloride
Chloroform
1,1-Dicholorethene
Methylene Chloride
Tetrachloroethylene
1,1,2-Trichloroethane
Vinyl Chloride
Benzene
Chlorobenzene
1,2-Dichloroethane
Isobutanol
1,1,1,2-Tetrachloroethane
1,1,1-Trichloroethane
Trichloroethylene

Semivolatile Organics

Bis(2-chloroethyl)ether
1,2-Dichlorobenzene
2,4-Dinitrotoluene
Hexachlorobutadiene
Nitrobenzene
Pyridine
2,4,6-Trichlorophenol
o,m,p-Cresols
1,4-Dichlorobenzene
Hexachlorobenzene
Hexachloroethane
Pentachlorophenol
2,3,4,6-Tetrachlorophenol
2,4,5-Trichlorophenol

---

* Not detected at or above method detection limits

TCLP Listed Chemicals Not Detected In Unground Samples*

Metals

Silver
Cadmium

Semivolatile Organics

Bis(2-chloroethyl)ether
1,2-Dichlorobenzene
2,4-Dinitrotoluene
Hexachlorobutadiene
Nitrobenzene
Pyridine
2,4,6-Trichlorophenol
o,m,p-Cresols
1,4-Dichlorobenzene
Hexachlorobenzene
Hexachloroethane
Pentachlorophenol
2,3,4,6-Tetrachlorophenol
2,4,5-Trichlorophenol

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* Not detected at or above method detection limits

TCLP Listed Chemicals Not Detected* In Cured Samples, Cont.

Semivolatile Organics

Bis(2-chloroethyl)ether
1,2-Dichlorobenzene
2,4--Dinitrotoluene
Hexachlorobutadiene
Nitrobenzene
Pyridine
2,4,6-Trichlorophenol
o,m,p-Cresols
1,4-Dichlorobenzene
Hexachlorobenzene
Hexachloroethane
Pentachlorophenol
2,3,4,6-Tetrachlorophenol
2,4,5-Trichlorophenol

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* Not detected at or above method detection limits

TCLP Listed Chemicals Not Detected* In Cured Samples

Metals

Silver

Volatile Organics

Acrylonitrile
Benzene
Carbon Tetrachloride
Chlorobenzene
Chloroform
1,1,2,2-Tetrachloroethane
1,1,1-Trichloroethane
Trichloroethylene
1,2--Dichloroethane
1,1-Dicholorethene
Isobutanol
Methylene Chloride
1,1,1,2-Tetrachloroethane
Tetrachloroethylene
1,1,2-Trichloroethane
Vinyl Chloride

Semivolatiles

This list continues following Table 1.

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* Not detected at or above method detection limits

TABLE 1.

TCLP PROTOCOL TEST – POSITIVE RESULTS

UNITS: mg/L

MDL = Method Detection Limits
a,i = TCLP cured

	VOLATILES			SEMI-VOLATILES	METALS						
SAMPLE ID	Carbon Disulfide	Methyl Ethyl Ketone	Toluene	Phenol	Arsenic	Barium	Cadmium	Chromium	Lead	Mercury	Selenium
MDL	0.005	0.1	0.005	0.01	0.001	0.01	0.005	0.01	0.002	0.0002	0.002
Regulatory Level	14.4	7.2	14.4	14.4	5	100	1	5	5	0.2	1
TIRE PRODUCTS											
1a	0.034	*	0.011	0.013	*	0.083	*	0.048	*	0.0002	*
2a	0.035	*	0.007	0.010	*	0.065	*	0.026	0.016	*	*
3a	0.067	0.021	0.050	*	*	0.150	*	0.012	0.009	*	*
4a	0.017	*	0.010	0.022	*	*	*	0.035	0.014	*	*
5a	*	*	0.190	0.046	*	0.570	*	0.037	0.002	0.0004	*
6a	*	*	*	0.045	*	0.590	*	0.025	0.002	*	*
7a	*	*	0.020	*	*	0.021	*	0.047	0.016	*	*
ROOFING PRODUCTS											
8a	0.160	*	0.007	*	*	0.045	*	*	0.014	*	*
BELTS/HOSE											
9a	0.520	*	0.038	1.30	*	0.590	*	*	0.005	*	*
9i	0.032	*	0.006	*	*	0.012	*	*	0.390	*	*
10a	0.790	*	0.240	0.064	0.007	0.012	0.006	*	0.003	*	0.003
MOLDED PRODUCTS											
11a	0.460	*	0.053	*	*	0.039	*	*	*	*	*
12a	0.320	*	0.074	*	*	0.540	*	*	0.007	*	*
13a	0.035	*	*	*	0.003	0.016	*	*	0.006	*	*
SEALANTS											
14a	*	*	*	*	0.004	0.016	*	0.030	0.030	*	*
PRINTING ROLLS											
15a	2.60	7.00	0.016	*	*	*	*	*	0.008	*	*

These compounds were not detected or detected below method detection limits.

TABLE 2.

TCLP PROTOCOL: A COMPARISON OF CURED AND UNCURED SAMPLES

UNITS: mg/L

MDL = METHOD DETECTION LIMIT
a = TCLP (cured)
b = TCLP (uncured)

	VOLATILES					SEMI-VOLATILES	METALS					
Sample ID	Carbon Disulfide	Methyl Ethyl Ketone	1,1,1-Tri Chloroethane	1,1,2,2-Tetra Chloroethane	Toluene	Phenol	Arsenic	Barium	Chromium	Lead	Mercury	Selenium
MDL	0.005	0.1	0.005	0.005	0.005	0.01	0.001	0.01	0.01	0.002	0.0002	0.002
Regulatory Level	14.4	7.2	30	1.3	14.4	14.4	5	100	5	5	0.2	1
						TIRE PRODUCTS						
3a	0.087	0.021	*	*	0.050	*	*	0.150	0.012	0.009	*	*
3b	0.012	*	0.005	*	0.017	*	*	0.072	0.023	0.008	*	*
5a	*	*	*	*	0.190	0.046	*	0.570	*	*	0.0004	*
5b	*	*	*	*	0.120	0.059	0.002	0.036	0.025	0.005	*	*
						ROOFING						
8a	0.100	*	*	*	0.007	*	*	0.045	*	0.014	*	*
8b	0.610	*	*	0.008	0.017	*	0.004	0.064	*	0.010	*	0.009
						BELTS/HOSES						
9a	0.520	*	*	*	0.038	1.30	*	0.590	*	0.005	*	*
9b	0.089	*	*	*	0.150	0.068	0.001	0.069	0.015	*	*	*
						MOLDED PRODUCTS						
13a	0.035	*	*	*	< *	*	0.003	0.018	*	0.006	*	*
13b	0.860	*	*	*	0.022	*	0.005	0.047	0.010	0.010	*	0.003
						SEALANTS						
14a	*	*	*	*	< *	*	0.004	0.018	0.030	0.036	*	*
14b	*	*	*	*	0.012	*	0.002	0.030	*	*	*	*
						PRINTING ROLLS						
15a	2.60	7.0	*	*	0.018	*	*	*	*	0.008	*	*
15b	1.20	2.3	*	*	0.017	0.012	0.001	0.080	*	0.032	*	*

* These compounds were not detected or detected below method detection limits

TABLE 3.

TCLP PROTOCOL TEST
A COMPARISON OF GROUND AND UNGROUND SAMPLES
UNITS: mg/L

MDL = Method Detection Limit
a = TCLP (cured)
c = TCLP (unground, cured)

	SEMI-VOLATILES	METALS					
Sample ID	Phenol	Arsenic	Barium	Chromium	Lead	Mercury	Selenium
MDL	0.01	0.001	0.01	0.01	0.002	0.0002	0.002
Regulatory Level	14.4	5	100	5	5	0.2	1
TIRE PRODUCTS							
3a	•	•	0.150	0.012	0.009	•	•
3c	0.049	•	0.140	•	0.019	•	•
5a	0.046	•	0.570	0.037	•	0.0004	•
5c	0.059	•	0.029	•	•	•	•
ROOFING							
8a	•	•	0.045	•	0.014	•	•
8c	•	•	0.540	0.010	•	•	0.009
BELTS/HOSES •							
9a	1.30	•	0.590	•	0.005	•	•
9c	0.580	•	0.089	•	•	•	•
MOLDED PRODUCTS							
13a	•	0.003	0.018	•	0.006	•	•
13c	•	0.004	0.031	•	0.008	•	0.003
SEALANTS							
14a	•	0.004	0.018	0.030	0.036	•	•
14c	•	•	0.530	•	•	•	•
PRINTING ROLLS							
15a	•	•	•	•	0.008	•	•
15c	•	•	0.600	•	•	•	•

• These compounds were not detected or were detected below method detection limits

TABLE 4.

TCLP AND EP TOX METALS – COMPARING CURED AND UNCURED SAMPLES

UNITS: mg/L

MDL = METHOD DETECTION LIMIT
a = TCLP (cured)
d = EP Tox (cured)
e = EP Tox (uncured)

	METALS					
Sample ID	Arsenic	Barium	Chromium	Lead	Mercury	Selenium
MDL	0.001	0.010	0.01	0.002	0.0002	0.002
Regulatory Level	5	100	5	5	0.2	1
TIRE PRODUCTS						
3a	*	0.150	0.012	0.009	*	*
3d	*	0.073	*	0.016	*	*
3e	*	0.041	*	0.030	*	*
5a	*	0.570	0.037	0.002	0.0004	*
5d	*	*	*	0.005	*	0.002
5e	*	*	*	0.004	*	*
ROOFING						
8a	*	0.045	*	0.014	*	*
8d	*	*	*	0.007	*	*
8e	*	*	*	0.010	*	*
BELTS/HOSES						
9a	*	0.590	*	0.005	*	*
9d	*	*	*	0.003	*	*
9e	*	0.017	*	0.004	*	*
MOLDED PRODUCTS						
13a	0.003	0.018	*	0.006	*	*
13d	*	*	*	0.002	*	*
13e	*	*	*	0.005	*	*
SEALANTS						
14a	0.004	0.018	0.030	0.036	*	*
14d	*	*	*	*	*	*
14e	*	*	0.028	0.005	*	*
PRINTING ROLLS						
15a	*	*	*	0.008	*	*
15d	*	0.019	0.015	0.007	*	*
15e	*	0.013	*	0.037	*	*

* These compounds were not detected or detected below method detection limits.

Appendix F:
Virginia Department of Transportation Final Report on Leachable Metals in Scrap Tires Results

TABLE II--metals leached at pH 4

Time	Avg pH	Zn mg/kg	Fe mg/kg	Ca mg/kg	Mg mg/kg
1 hour	4.10	13.2	5.3	0.8	0.4
2 hours	4.03	18.6	8.5	1.7	0.4
1 day	4.18	25.2	96.1	3.4	0.6
2 days	4.28	15.1	184.5	6.5	0.4
1 week	4.28	102.1	13992	7.9	1.2
2 weeks	4.44	112.0	31622	8.8	1.8
1 month	4.45	127.4	30668	15.1	1.5
2 months	4.67	153.7	30314	24.2	3.3
6 months	4.55	62.5	31344	18.5	3.0
1 year	4.74	124.7	18788	128.4	5.8

Time	Avg pH	Cd ug/kg	Cr ug/kg	Ni ug/kg	Pb ug/kg
1 hour	4.10	1.9	6.3	<20	<20
2 hours	4.03	2.6	<4.0	<20	<20
1 day	4.18	3.5	7.0	48.1	<20
2 days	4.28	nd	nd	nd	nd
1 week	4.28	3.5	<4.0	2116	49.2
2 weeks	4.44	nd	nd	nd	nd
1 month	4.45	<1.2	82.4	2460	<30
2 months	4.67	nd	nd	nd	nd
6 months	4.55	<1.2	12.6	647	<30
1 year	4.74	2.1	152	928	138

Time	Avg pH	Cu ug/kg	Al ug/kg	Ba ug/kg	Ag ug/kg
1 hour	4.10	109	185	87	2.3
2 hours	4.03	188	321	78	2
1 day	4.18	192	23	25	1.5
2 days	4.28	nd	nd	nd	nd
1 week	4.28	328	746	422	2.5
2 weeks	4.44	nd	nd	nd	nd
1 month	4.45	13	177	1262	3.2
2 months	4.67	nd	nd	nd	nd
6 months	4.55	<12	<24	2083	5.2
1 year	4.74	159	491	1537	10

nd = not determined

TABLE II (continued)--metals leached at pH 4

Time	Avg pH	Sn ug/kg	As ug/kg	Hg ug/kg	Se ug/kg
1 hour	4.10	<40	nd	nd	nd
2 hours	4.03	<40	nd	nd	nd
1 day	4.18	<40	nd	nd	nd
2 days	4.28	nd	nd	nd	nd
1 week	4.28	<50	nd	nd	nd
2 weeks	4.44	nd	nd	nd	nd
1 month	4.45	<60	nd	nd	nd
2 months	4.67	nd	nd	nd	nd
6 months	4.55	<60	nd	nd	nd
1 year	4.74	<60	<25	<1	<30

TABLE III--metals leached at pH 7

Time	Avg pH	Zn mg/kg	Fe mg/kg	Ca mg/kg	Mg mg/kg
1 hour	5.99	6.6	11.4	1.4	0.2
2 hours	5.87	14.3	29.2	2.6	0.3
1 day	6.00	14.7	83.1	3.8	0.5
2 days	5.97	6.0	87.4	3.0	0.3
1 week	6.01	4.1	85.7	3.3	0.4
2 weeks	6.02	2.7	79.6	4.1	0.5
1 month	6.00	2.3	91.7	5.1	0.8
2 months	6.15	0.3	103	8.5	1.2
5 months	6.32	0.2	73.8	10.8	1.8
1 year	6.69	0.6	84.3	6.8	1.6

Time	Avg pH	Cd ug/kg	Cr ug/kg	Ni ug/kg	Pb ug/kg
1 hour	5.99	nd	nd	nd	nd
2 hours	5.87	nd	nd	nd	nd
1 day	6.00	27.6	5.3	138	<20
2 days	5.97	nd	nd	nd	nd
1 week	6.01	<1.0	4.6	40	nd
2 weeks	6.02	nd	nd	nd	nd
1 month	6.00	<1.0	<4.0	81	21
2 months	6.15	nd	nd	nd	nd
6 months	6.32	8.2	<4.0	31	<20
1 year	6.69	<1.0	16	35	<20

nd = not determined

TABLE III (continued)--metals leached at pH 7

Time	Avg pH	Cu ug/kg	Al ug/kg	Ba ug/kg	Ag ug/kg
1 hour	5.99	nd	nd	nd	nd
2 hours	5.87	nd	nd	nd	nd
1 day	6.00	146	<20	290	nd
2 days	5.97	nd	nd	nd	nd
1 week	6.01	15.7	269	300	nd
2 weeks	6.02	nd	nd	nd	nd
1 month	6.00	<10	79	339	nd
2 months	6.15	nd	nd	nd	nd
6 months	6.32	<10	<20	776	nd
1 year	6.69	35	213	415	nd

Time	Avg pH	Sn ug/kg	As ug/kg	Hg ug/kg	Se ug/kg
1 hour	5.99	nd	nd	nd	nd
2 hours	5.87	nd	nd	nd	nd
1 day	6.00	<40	nd	nd	nd
2 days	5.97	nd	nd	nd	nd
1 week	6.01	<40	nd	nd	nd
2 weeks	6.02	nd	nd	nd	nd
1 month	6.00	<40	nd	nd	nd
2 months	6.15	nd	nd	nd	nd
6 months	6.32	<40	nd	nd	nd
1 year	6.69	<40	<15	<0.7	<19

TABLE IV--metals leached at pH 8

Time	Avg pH	Zn mg/kg	Fe mg/kg	Ca mg/kg	Mg mg/kg
1 hour	7.98	5.4	1.6	4.2	0.3
2 hours	8.00	6.8	1.3	4.5	0.4
1 day	7.97	10.5	1.4	3.9	0.4
2 days	7.92	8.4	4.9	4.1	0.7
1 week	7.80	2.2	11.5	12.5	1.1
2 weeks	7.84	0.6	131	12.7	1.8
1 month	7.81	<0.1	41.1	15.6	2.0
2 months	7.63	<0.1	134	15.3	1.9
6 months	7.63	0.2	214	16.9	2.4
1 year	7.59	0.6	75.7	21.4	3.1

TABLE IV (continued)--metals leached at pH 8

Time	Avg pH	Cd ug/kg	Cr ug/kg	Ni ug/kg	Pb ug/kg
1 hour	7.98	nd	nd	nd	nd
2 hours	8.00	nd	nd	nd	nd
1 day	7.97	2.6	6.8	39.4	<20
2 days	7.92	nd	nd	nd	nd
1 week	7.80	<1.0	<4.0	94.2	<20
2 weeks	7.84	nd	nd	nd	nd
1 month	7.81	<1.0	<4.0	81.2	<20
2 months	7.63	nd	nd	nd	nd
6 months	7.63	<1.0	4.6	22.0	<20
1 year	7.59	3.3	2.1	111.3	<20

Time	Avg pH	Cu ug/kg	Al ug/kg	Ba ug/kg	Ag ug/kg
1 hour	7.98	<400 *	nd	nd	nd
2 hours	8.00	687 *	nd	nd	nd
1 day	7.97	2582 *	<20	148	61
2 days	7.92	1546 *	nd	nd	nd
1 week	7.80	759 *	1283	211	2.3
2 weeks	7.84	<400 *	nd	nd	nd
1 month	7.81	<10	271	181	2.0
2 months	7.63	nd	nd	nd	nd
6 months	7.63	<10	<20	190	2.2
1 year	7.59	21	122	1073	1.1

Time	Avg pH	Sn ug/kg	As ug/kg	Hg ug/kg	Se ug/kg
1 hour	7.98	nd	nd	nd	nd
2 hours	8.00	nd	nd	nd	nd
1 day	7.97	<40	nd	nd	nd
2 days	7.92	nd	nd	nd	nd
1 week	7.80	<40	nd	nd	nd
2 weeks	7.84	nd	nd	nd	nd
1 month	7.81	<40	nd	nd	nd
2 months	7.63	nd	nd	nd	nd
6 months	7.63	<40	nd	nd	nd
1 year	7.59	<40	<16	<0.8	<20

nd = not determined
* Cu analysis by flame

TABLE V

TCLP Metals

Element	Conc. in extract,ppb	Conc. in tires, ug/Kg
Cd	1.55	4.4
Cr	2.8	7.9
Pb	19.6	55.6
Ag	<1.0	<2.8
Ni	39.7	113
Al	148	420
Cu	83	235
Sn	<25	<71
	Conc. in extract,ppm	Conc. in tires,mg/Kg
Fe	120	341
Zn	10.6	30
Mg	0.108	0.307
Ca	1.00	2.84

Appendix G:
Illinois Department of Energy and Natural Resources Study Results

DTC Laboratories, Inc.

4590 INDUSTRIAL DRIVE
SPRINGFIELD, ILLINOIS 62703
(217) 529-9191

ANALYTICAL REPORT

CLIENT: Il. Department of Energy & Natural Resources
DATE RECEIVED: 3-20-90
SAMPLE DESCRIPTION: Shredded Tires
LOG NO.: 4801-90
REPORT DATE: 4801-90

ITEM		RESULT
Phenol		21.8 ug/g (PPM)
EP TOX Arsenic	<	0.06 mg/l (PPM)
EP TOX Barium		0.02 mg/l (PPM)
EP TOX Cadmium	<	0.01 mg/l (PPM)
EP TOX Chromium	<	0.01 mg/l (PPM)
EP TOX Chromium, Hexavalent	<	0.1 mg/l (PPM)
EP TOX Lead	<	0.05 mg/l (PPM)
EP TOX Mercury	<	0.05 mg/l (PPM)
EP TOX Selenium	<	0.06 mg/l (PPM)
EP TOX Silver	<	0.01 mg/l (PPM)
EP TOX Zinc		0.42 mg/l (PPM)
Arsenic, Total	<	1.76 ug/g (PPM)
Barium, Total	<	0.12 ug/g (PPM)
Cadmium, Total	<	0.12 ug/g (PPM)
Chromium, Total		50.79 ug/g (PPM)
Lead, Total		36.55 ug/g (PPM)
Mercury, Total	<	0.05 ug/g (PPM)
Selenium, Total	<	0.42 ug/g (PPM)
Silver, Total	<	0.18 ug/g (PPM)
Zinc, Total		6640. ug/g (PPM)
Iron, Total		192000. ug/g (PPM)
EP TOX Iron		0.06 mg/l (PPM)

Gerald O. Mack by (WIE)

Gerald O. Mack
Chief Scientist

ANALYTICAL REPORT

Client: Illinois Department of Energy & Natural Resources
Date Received: 3-20-90
Sample Description: Shredded Tires
Log Number: 4801-90
Report Date: 04-23-90

Compound Name (Method 8240)	Detection Limit ug/kg (PPM)	Result ug/kg (PPB)
Chloromethane	10	< 10
Bromomethane	10	< 10
Vinyl Chloride	10	< 10
Chloroethane	10	< 10
Acetone	5	< 5
Carbon Disulfide	100	< 100
1,1-Dichloroethene	5	< 5
1,1-Dichloroethane	5	< 5
trans-1,2-Dichloroethene	5	< 5
Chloroform	5	< 5
1,2-Dichloroethane	5	< 5
2-Butanone	5	< 5
1,1,1-Trichlorethane	100	< 100
Carbon Tetrachloride	5	< 5
Vinyl Acetate	50	< 50
Bromodichloromethane	5	< 5
1,1,2,2-Tetrachloroethane	5	< 5
1,2-Dichloropropane	5	< 5
trans-1,3-Dichloropropene	5	< 5
Trichloroethene	5	< 5
Dibromochloromethane	5	< 5
1,1,2-Trichloroethane	5	< 5
Benzene	5	< 5
cis-1,3-Dichloropropene	5	< 5
2-Chlorethyl Vinyl Ether	10	< 10
Bromoform	5	< 5
2-Hexane	50	< 50
4-Methyl 1-2-pentanone	50	< 50

ANALYTICAL REPORT
(Continued)

Client: Illinois Department of Energy & Natural Resources
Date Received: 3-20-90
Sample Description: Shredded Tires
Log Number: 4801-90
Report Date: 04-23-90

Compound Name (Method 8240)	Detection Limit ug/kg (PPM)	Result ug/kg (PPB)
Toluene	5	< 5
Chlorobenezene	5	< 5
Ethyl Benzene	5	< 5
Styrene	5	< 5
Total Xylenes	5	< 5

Gerald O. Mack

Gerald O. Mack
Chief Scientist

Appendix H:
Tire Pond Sampling Data

Hamden Tire Pond May 12, 1987

Sample Type: Water
Collected By: E.C Labs
Date Received: 5/12/87

Client I.D.:	Pond	NW1	NE2	SW3
Sample No.:	EC-3984	EC-3985	EC-3986	EC-3987
		(mg/L)		
Parameter				
Groundwater Level (Feet)		7.50	10.50	9.65
pH (Units)	8.49	7.30	6.30	6.48
Conductivity (umhos/cm)	2,730	446	1,330	523
Total Dissolved Solids	1,592	284	940	324
Ammonia - N	0.59	0.74	4.47	10.30
Nitrate - N	<0.50	1.50	<0.50	7.50
Nitrite -N	<0.01	<0.01	<0.01	<0.01
Total Organic Nitrogen	<1.00	<1.00	<1.00	<1.00
Sulfate	17.0	53.0	102.0	<1.00
Organic Sulfer	<1.00	<1.00	<1.00	<1.00
Chemical Oxygen Demand	<10.00	<10.00	<10.00	44.40
Cadmium	<0.001	<0.001	<0.001	<0.001
Copper	<0.01	<0.01	<0.01	<0.01
Nickel	<0.005	0.010	0.009	<0.005
Iron	0.26	0.14	2.04	32.73
Zinc	0.03	0.27	0.04	0.10
Pesticides/Herbicides		(ug/L)		
Endrin	<0.02	<0.02	<0.02	<0.02
Lindame	<0.40	<0.40	<0.40	<0.40
Methoxychlor	<10.0	<10.0	<10.0	<10.0
Toxaphene	<0.50	<0.50	<0.50	<0.50
2, 4-D	<10.0	<10.0	<10.0	<10.0
2,4,5-TP Silvex	<1.00	<1.00	<1.00	<1.00

Client I.D.:	Pond	NW1	NE2	SW3
Sample No.:	EC-3984	EC-3985	EC-3986	EC-3987
		(mg/L)		
Parameter				
Method 8010 - Halogenated Volatile Organics				
Benzyl chloride	<0.001	<0.001	<0.001	<0.001
Bis (2-chloroethoxy)methane	<0.001	<0.001	<0.001	<0.001
Bis (2-chloroisopropyl)ether	<0.001	<0.001	<0.001	<0.001
Bromobenzene	<0.001	<0.001	<0.001	<0.001
Bromodichloromethane	<0.001	<0.001	<0.001	<0.001
Bromoform	<0.001	<0.001	<0.001	<0.001
Bromomethane	<0.001	<0.001	<0.001	<0.001
Carbon tetrachloride	<0.001	<0.001	<0.001	<0.001
Chloracetaldehyde	<0.001	<0.001	<0.001	<0.001
Chloral	<0.001	<0.001	<0.001	<0.001
Chloroethane	<0.001	<0.001	<0.001	<0.001
Chloroform	<0.001	<0.001	<0.001	<0.001
1-Chlorohexane	<0.001	<0.001	<0.001	<0.001
2-Chloroethyl vinyl ether	<0.001	<0.001	<0.001	<0.001
Chloromethane	<0.001	<0.001	<0.001	<0.001
Chloromethyl methyl ether	<0.001	<0.001	<0.001	<0.001
Chlorotoluene	<0.001	<0.001	<0.001	<0.001
Dibromochloromethane	<0.001	<0.001	<0.001	<0.001
Dibromomethane	<0.001	<0.001	<0.001	<0.001
Dichlorodifluoromethane	<0.001	<0.001	<0.001	<0.001
1,1-Dichloroethane	<0.001	<0.001	<0.001	<0.001
1,2-Dichloroethane	<0.001	<0.001	<0.001	<0.001
1,1-Dichloroethylene	<0.001	<0.001	<0.001	<0.001
trans-1,2-Dichloroethylene	<0.001	0.002	<0.001	<0.001
Dichloromethane	<0.001	<0.001	<0.001	<0.001
1,2-Dichloropropane	<0.001	0.001	<0.001	<0.001
1,3-Dichloropropylene	<0.001	<0.001	<0.001	<0.001
1,1,2,2-Tetrachloroethane	<0.001	<0.001	<0.001	<0.001
1,1,1,2-Tetrachloroethane	<0.001	<0.001	<0.001	<0.001
Tetrachloroethylene	<0.001	<0.001	<0.001	<0.001
1,1,1-Trichloroethane	<0.001	<0.001	<0.001	<0.001
1,1,2-Trichloroethane	<0.001	<0.001	<0.001	<0.001
Trichloroethylene	<0.001	0.005	<0.001	<0.001
Trichlorofluoromethane	<0.001	<0.001	<0.001	<0.001
Trichloropropane	<0.001	<0.001	<0.001	<0.001
Vinyl chloride	<0.001	<0.001	<0.001	<0.001

Client I.D.:	Pond	NW1	NE2	SW3
Sample No.:	EC-3984	EC-3985	EC-3986	EC-3987
		(mg/L)		
Method 8020 - Aromatic Volatile Organics				
Benzene	<0.001	<0.001	<0.001	<0.001
Chlorobenzene	<0.001	<0.001	<0.001	<0.001
1,2-Dichlorobenzene	<0.001	<0.001	<0.001	<0.001
1,3-Dichlorobenzene	<0.001	<0.001	<0.001	<0.001
1,4-Dichlorobenzene	<0.001	<0.001	<0.001	<0.001
Ethyl benzene	<0.001	<0.001	<0.001	<0.001
Toluene	0.018	<0.001	<0.001	<0.001
Mixed Xylenes	0.036	<0.002	<0.002	<0.002
Polychlorinated Biphenyls:				
PCB-1242	<0.001	<0.001	<0.001	<0.001
PCB-1254	<0.001	<0.001	<0.001	<0.001
PCB-1221	<0.001	<0.001	<0.001	<0.001
PCB-1232	<0.001	<0.001	<0.001	<0.001
PCB-1248	<0.001	<0.001	<0.001	<0.001
PCB-1260	<0.001	<0.001	<0.001	<0.001
PCB-1016	<0.001	<0.001	<0.001	<0.001

Sample Type: Water
Collected By: E.C Labs
Date Received: 8/31/87

Client I.D.:	Pond	NW1	NE2	SW3
Sample No.:	EC-5037	EC-5038	EC-5039	EC-5040
		(mg/L)		
Parameter				
Groundwater Level (Feet)	—	9.1	13.0	10.9
pH (Units)	8.17	6.96	5.95	6.49
Conductivity (umhos/cm)	2,400	415	1,819	544
Total Dissolved Solids	1,746	314	1,210	368
Ammonia - N	0.71	0.55	4.28	11.40
Nitrate - N	<0.50	1.20	<0.50	1.0
Nitrite -N	<0.01	0.02	<0.01	<0.01
Total Organic Nitrogen	<1.0	<1.0	<1.0	<1.0
Sulfate	<1.0	22.0	130.0	<1.0
Organic Sulfer	<1.0	<1.0	<1.0	<1.0
Chemical Oxygen Demand	35.3	13.2	27.3	50.0
Cadmium	<0.001	<0.001	<0.001	<0.001
Copper	<0.01	<0.01	<0.01	<0.01
Nickel	<0.005	<0.005	<0.005	<0.005
Iron	0.38	<0.05	5.32	29.26
Zinc	<0.02	0.04	<0.02	0.03
Pesticides/Herbicides		(ug/L)		
Endrin	<0.02	<0.02	<0.02	<0.02
Lindane	<0.40	<0.40	<0.40	<0.40
Methoxychlor	<10.0	<10.0	<10.0	<10.0
Toxaphene	<0.50	<0.50	<0.50	<0.50
2, 4-D	<10.0	<10.0	<10.0	<10.0
2,4,5-TP Silvex	<1.00	<1.00	<1.00	<1.00

Client I.D.:	Pond	NW1	NE2	SW3
Sample No.:	EC-5037	EC-5038	EC-5039	EC-5040
		(mg/L)		
Parameter				
Method 8010 – Halogenated Volatile Organics				
Benzyl chloride	<0.001	<0.001	<0.001	<0.001
Bis (2-chloroethoxy)methane	<0.001	<0.001	<0.001	<0.001
Bis (2-chloroisopropyl)ether	<0.001	<0.001	<0.001	<0.001
Bromobenzene	<0.001	<0.001	<0.001	<0.001
Bromodichloromethane	<0.001	<0.001	<0.001	<0.001
Bromoform	<0.001	<0.001	<0.001	<0.001
Bromomethane	<0.001	<0.001	<0.001	<0.001
Carbon tetrachloride	<0.001	<0.001	<0.001	<0.001
Chloracetaldehyde	<0.001	<0.001	<0.001	<0.001
Chloral	<0.001	<0.001	<0.001	<0.001
Chloroethane	<0.001	<0.001	<0.001	<0.001
Chloroform	<0.001	<0.001	<0.001	<0.001
1-Chlorohexane	<0.001	<0.001	<0.001	<0.001
2-Chloroethyl vinyl ether	<0.001	<0.001	<0.001	<0.001
Chloromethane	<0.001	<0.001	<0.001	<0.001
Chloromethyl methyl ether	<0.001	<0.001	<0.001	<0.001
Chlorotoluene	<0.001	<0.001	<0.001	<0.001
Dibromochloromethane	<0.001	<0.001	<0.001	<0.001
Dibromomethane	<0.001	<0.001	<0.001	<0.001
Dichlorodifluoromethane	<0.001	<0.001	<0.001	<0.001
1,1-Dichloroethane	<0.001	<0.001	<0.001	<0.001
1,2-Dichloroethane	<0.001	<0.001	<0.001	<0.001
1,1-Dichloroethylene	<0.001	<0.001	<0.001	<0.001
trans-1,2-Dichloroethylene	<0.001	0.002	<0.001	<0.001
Dichloromethane	<0.001	<0.001	<0.001	<0.001
1,2-Dichloropropane	<0.001	0.002	<0.001	<0.001
1,3-Dichloropropylene	<0.001	<0.001	<0.001	<0.001
1,1,2,2-Tetrachloroethane	<0.001	<0.001	<0.001	<0.001
1,1,1,2-Tetrachloroethane	<0.001	<0.001	<0.001	<0.001
Tetrachloroethylene	<0.001	<0.001	<0.001	<0.001
1,1,1-Trichloroethane	<0.001	<0.001	<0.001	<0.001
1,1,2-Trichloroethane	<0.001	<0.001	<0.001	<0.001
Trichloroethylene	<0.001	0.004	<0.001	<0.001
Trichlorofluoromethane	<0.001	<0.001	<0.001	<0.001
Trichloropropane	<0.001	<0.001	<0.001	<0.001
Vinyl chloride	<0.001	<0.001	<0.001	<0.001

Client I.D.:	Pond	NW1	NE2	SW3
Sample No.:	EC-5037	EC-5038	EC-5039	EC-5040
		(mg/L)		
Method 8020 - Aromatic Volatile Organics				
Benzene	<0.001	<0.001*	<0.001	<0.001
Chlorobenzene	<0.001	<0.001	<0.001	<0.001
1,2-Dichlorobenzene	<0.001	<0.001	<0.001	<0.001
1,3-Dichlorobenzene	<0.001	<0.001	<0.001	<0.001
1,4-Dichlorobenzene	<0.001	<0.001	<0.001	<0.001
Ethyl benzene	<0.001	<0.001	<0.001	<0.001
Toluene	<0.001	<0.001	<0.001	<0.001
Xylene	<0.002	<0.002	<0.002	<0.002
Polychlorinated Biphenyls:				
PCB-1242	<0.001	<0.001	<0.001	<0.001
PCB-1254	<0.001	<0.001	<0.001	<0.001
PCB-1221	<0.001	<0.001	<0.001	<0.001
PCB-1232	<0.001	<0.001	<0.001	<0.001
PCB-1248	<0.001	<0.001	<0.001	<0.001
PCB-1260	<0.001	<0.001	<0.001	<0.001
PCB-1016	<0.001	<0.001	<0.001	<0.001

*Trace amount found below detectable limit

Hamden Tire Pond
Report No.: M89-0617

Client I.D.:	NW	NE	SW	Pond
Sample No.:	89-2072	89-2073	89-2074	89-2075
	(Units in mg/L unless noted)			
Parameter				
Groundwater Level (Feet)	8.2	13.2	9.9	
pH (Units)	7.1	4.7	6.4	7.8
Conductivity (umhos/cm)	422	2100	682	2130
Total Dissolved Solids	300	2084	474	1440
Ammonia - N	0.2	3.9	8.0	1.4
Nitrate - N	4.3	1.5	1.4	3.0
Nitrite -N	0.02	<0.01	<0.01	0.06
Total Organic Nitrogen	<1.0	<1.0	<1.0	<1.0
Sulfate	24	1050	<1.0	<1.0
Organic Sulfer	<1.0	<1.0	<1.0	<1.0
Chemical Oxygen Demand	7.5	15.0	76.2	32.1
Cadmium	<0.001	<0.001	<0.001	<0.001
Copper	<0.01	<0.01	<0.01	<0.01
Nickel	<0.005	0.155	<0.005	<0.005
Iron	1.60	11.8	55.2	0.195
Zinc	0.062	0.102	0.024	0.020

PESTICIDES/HERBICIDES:	(Units in ppb)			
Gamma-BHC (Lindane)	<0.40	<0.40	<0.40	<0.40
Endrin	<0.02	<0.02	<0.02	<0.02
Methoxychlor	<10.0	<10.0	<10.0	<10.0
Toxaphene	<0.50	<0.50	<0.50	<0.50
2, 4-D	<1.0	<1.0	<1.0	<1.0
2,4,5-TP Silvex	<1.0	<1.0	<1.0	<1.0

Client I.D.:	NW	NE	SW	Pond
Sample No.:	89-2072	89-2073	89-2074	89-2075
		(Units in ppb)		
Parameter				
METHOD 8010 - HALOGENATED VOLATILE ORGANICS:				
Benzyl Chloride	<1.0	<1.0	<1.0	<1.0
Bis (2-chloroethoxy)-methane	<1.0	<1.0	<1.0	<1.0
Bis (2-chloroisopropyl) ether	<1.0	<1.0	<1.0	<1.0
Bromobenzene	<1.0	<1.0	<1.0	<1.0
Bromodichloromethane	<1.0	<1.0	<1.0	<1.0
Bromoform	<1.0	<1.0	<1.0	<1.0
Bromomethane	<1.0	<1.0	<1.0	<1.0
Carbon Tetrachloride	<1.0	<1.0	<1.0	<1.0
Chloracetaldehyde	<1.0	<1.0	<1.0	<1.0
Chloral	<1.0	<1.0	<1.0	<1.0
Chloroethane	<1.0	<1.0	<1.0	<1.0
Chloroform	<1.0	<1.0	<1.0	<1.0
1-Chlorohexane	<1.0	<1.0	<1.0	<1.0
2-Chloroethyl vinyl ether	<1.0	<1.0	<1.0	<1.0
Chloromethane	<1.0	<1.0	<1.0	<1.0
Chloromethyl methyl ether	<1.0	<1.0	<1.0	<1.0
Chlorotoluene	<1.0	<1.0	<1.0	<1.0
Dibromochloromethane	<1.0	<1.0	<1.0	<1.0
Dibromomethane	<1.0	<1.0	<1.0	<1.0
Dichlorodifluoromethane	<1.0	<1.0	<1.0	<1.0
1,1-Dichloroethane	<1.0	<1.0	<1.0	<1.0
1,2-Dichloroethane	<1.0	<1.0	<1.0	<1.0
1,1-Dichloroethylene	<1.0	<1.0	<1.0	<1.0
trans-1,2-Dichloro-ethylene	2.8	<1.0	<1.0	<1.0
1,2-Dichloropropane	<1.0	<1.0	<1.0	<1.0
trans-1,3-Dichloro-propylene	<1.0	<1.0	<1.0	<1.0
Methylene Chloride	<1.0	<1.0	<1.0	<1.0
1,1,2,2-Tetrachloroethane	<1.0	<1.0	<1.0	<1.0
1,1,1,2-Tetrachloroethane	<1.0	<1.0	<1.0	<1.0
Tetrachloroethylene	<1.0	<1.0	<1.0	<1.0
1,1,1-Trichloroethane	<1.0	<1.0	<1.0	<1.0
1,1,2-Trichloroethane	<1.0	<1.0	<1.0	<1.0
Trichloroethylene	5.4	<1.0	<1.0	<1.0
Trichlorofluoromethane	<1.0	<1.0	<1.0	<1.0
Trichloropropane	<1.0	<1.0	<1.0	<1.0
Vinyl Chloride	<1.0	<1.0	<1.0	<1.0

Client I.D.:	NW	NE	SW	Pond
Sample No.:	89-2072	89-2073	89-2074	89-2075
		(Units in ppb)		
Parameter				
METHOD 8020 - AROMATIC VOLATILE ORGANICS:				
Benzene	<1.0	<1.0	<1.0	<1.0
Chlorobenzene	<1.0	<1.0	<1.0	<1.0
1,2-Dichlorobenzene	<1.0	<1.0	<1.0	<1.0
1,3-Dichlorobenzene	<1.0	<1.0	<1.0	<1.0
1,4-Dichlorobenzene	<1.0	<1.0	<1.0	<1.0
Ethyl benzene	<1.0	<1.0	<1.0	<1.0
Toluene	<1.0	<1.0	<1.0	<1.0
m-Xylene	<1.0	<1.0	<1.0	<1.0
o-Xylene	<1.0	<1.0	<1.0	<1.0
p-Xylene	<1.0	<1.0	<1.0	<1.0

POLYCHLORINATED BIPHENYLS:		(Units in ppb)		
PCB-1016	<1.0	<1.0	<1.0	<1.0
PCB-1221	<1.0	<1.0	<1.0	<1.0
PCB-1232	<1.0	<1.0	<1.0	<1.0
PCB-1242	<1.0	<1.0	<1.0	<1.0
PCB-1248	<1.0	<1.0	<1.0	<1.0
PCB-1254	<1.0	<1.0	<1.0	<1.0
PCB-1260	<1.0	<1.0	<1.0	<1.0

Hamden Tire Pond August 17, 1989

Hamden Tire Pond
Report No.: M89-1087

	Ground Water	Ground Water	Ground Water	Surface Water
Sample Type:	Ground Water	Ground Water	Ground Water	Surface Water
Client I.D.:	MW1	MW2	MW3	Pond
Sample No.:	89-3562	89-3563	89-3564	89-3565
	(Units in mg/L unless noted)			
Parameter				
Groundwater Level (Feet)	7.0	9.7	9.0	-
pH (Units)	7.2	4.5	6.3	8.0
Conductivity (umhos/cm)	425	1808	567	1714
Total Dissolved Solids	342	1692	356	1182
Ammonia - N	0.09	4.0	6.3	0.07
Nitrate - N	2.8	0.69	0.43	1.4
Nitrite -N	<0.01	<0.01	<0.01	<0.01
Total Organic Nitrogen	<1.0	<1.0	<1.0	1.24
Sulfate	45.0	800.0	<1.0	<1.0
Organic Sulfer	<1.0	<1.0	<1.0	<1.0
Chemical Oxygen Demand	7.5	7.4	22.2	37.4
Cadmium	<0.002	<0.002	<0.002	<0.002
Copper	<0.025	<0.025	<0.025	<0.025
Nickel	<0.040	0.673	<0.040	<0.040
Iron	0.197	22.0	16.8	0.052
Zinc	0.038	2.88	0.022	<0.020
Pesticides/Herbicides:	(Units in ug/L)			
Gamma-BHC (Lindane)	<0.40	<0.40	<0.40	<0.40
Endrin	<0.02	<0.02	<0.02	<0.02
Methoxychlor	<10.0	<10.0	<10.0	<10.0
Toxaphene	<0.50	<0.50	<0.50	<0.50
2, 4-D	<1.00	<1.00	<1.00	<1.00
2,4,5-TP Silvex	<1.00	<1.00	<1.00	<1.00

Sample Type:	Ground Water	Ground Water	Ground Water	Surface Water
Client I.D.:	MW1	MW2	MW3	Pond
Sample No.:	89-3562	89-3563	89-3564	89-3565

(Units in mg/L)

Parameter				
METHOD 8010 - HALOGENATED VOLATILE ORGANICS:				
Benzyl Chloride	<0.001	<0.001	<0.001	<0.001
Bis (2-chloroethoxy)-methane	<0.001	<0.001	<0.001	<0.001
Bis (2-chloroisopropyl) ether	<0.001	<0.001	<0.001	<0.001
Bromobenzene	<0.001	<0.001	<0.001	<0.001
Bromodichloromethane	<0.001	<0.001	<0.001	<0.001
Bromoform	<0.001	<0.001	<0.001	<0.001
Bromomethane	<0.001	<0.001	<0.001	<0.001
Carbon Tetrachloride	<0.001	<0.001	<0.001	<0.001
Chloracetaldehyde	<0.001	<0.001	<0.001	<0.001
Chloral	<0.001	<0.001	<0.001	<0.001
Chloroethane	<0.001	<0.001	<0.001	<0.001
Chloroform	<0.001	<0.001	<0.001	<0.001
1-Chlorohexane	<0.001	<0.001	<0.001	<0.001
2-Chloroethyl vinyl ether	<0.001	<0.001	<0.001	<0.001
Chloromethane	<0.001	<0.001	<0.001	<0.001
Chloromethyl methyl ether	<0.001	<0.001	<0.001	<0.001
Chlorotoluene	<0.001	<0.001	<0.001	<0.001
Dibromochloromethane	<0.001	<0.001	<0.001	<0.001
Dibromomethane	<0.001	<0.001	<0.001	<0.001
Dichlorodifluoromethane	<0.001	<0.001	<0.001	<0.001
1,1-Dichloroethane	<0.001	<0.001	<0.001	<0.001
1,2-Dichloroethane	<0.001	<0.001	<0.001	<0.001
1,1-Dichloroethylene	<0.001	<0.001	<0.001	<0.001
trans-1,2-Dichloro-ethylene	0.051	<0.001	<0.001	<0.001
1,2-Dichloropropane	<0.001	<0.001	<0.001	<0.001
trans-1,3-Dichloro-propylene	<0.001	<0.001	<0.001	<0.001
Methylene Chloride	<0.001	<0.001	<0.001	<0.001
1,1,2,2-Tetrachloroethane	<0.001	<0.001	<0.001	<0.001
1,1,1,2-Tetrachloroethane	<0.001	<0.001	<0.001	<0.001
Tetrachloroethylene	0.009	0.002	0.001	<0.001
1,1,1-Trichloroethane	<0.001	<0.001	<0.001	<0.001
1,1,2-Trichloroethane	<0.001	<0.001	<0.001	<0.001
Trichloroethylene	0.343	<0.001	<0.001	<0.001
Trichlorofluoromethane	<0.001	<0.001	<0.001	<0.001
Trichloropropane	<0.001	<0.001	<0.001	<0.001
Vinyl Chloride	<0.001	<0.001	<0.001	<0.001

Sample Type:	Ground Water	Ground Water	Ground Water	Surface Water
Client I.D.:	MW1	MW2	MW3	Pond
Sample No.:	89-3562	89-3563	89-3564	89-3565
		(Units in mg/L)		
Parameter				
METHOD 8020 - AROMATIC VOLATILE ORGANICS:				
Benzene	<0.001	<0.001	<0.001	<0.001
Chlorobenzene	<0.001	<0.001	<0.001	<0.001
1,2-Dichlorobenzene	<0.001	<0.001	<0.001	<0.001
1,3-Dichlorobenzene	<0.001	<0.001	<0.001	<0.001
1,4-Dichlorobenzene	<0.001	<0.001	<0.001	<0.001
Ethyl benzene	<0.001	<0.001	<0.001	<0.001
Toluene	<0.001	<0.001	<0.001	<0.001
m-Xylene	<0.001	<0.001	<0.001	<0.001
o-Xylene	<0.001	<0.001	<0.001	<0.001
p-Xylene	<0.001	<0.001	<0.001	<0.001
POLYCHLORINATED BIPHENYLS:		(Units in mg/L)		
PCB-1016	<0.001	<0.001	<0.001	<0.001
PCB-1221	<0.001	<0.001	<0.001	<0.001
PCB-1232	<0.001	<0.001	<0.001	<0.001
PCB-1242	<0.001	<0.001	<0.001	<0.001
PCB-1248	<0.001	<0.001	<0.001	<0.001
PCB-1254	<0.001	<0.001	<0.001	<0.001
PCB-1260	<0.001	<0.001	<0.001	<0.001

Client I.D.:	Pond	SW	NW	NE
Sample No.:	88-3140	88-3141	88-3142	88-3143
			(mg/L)	
Parameter				
Groundwater Level (Feet)	--	10.4	8.0	14.6
pH (Units)	7.78	6.40	7.10	6.83
Conductivity (umhos/cm)	2050.0	372.0	330.0	951.0
Total Dissolved Solids	1598.0	398.0	312.0	985.0
Ammonia - N	0.38	6.45	0.18	2.06
Nitrate - N	0.50	4.5	2.0	<0.50
Nitrite -N	<0.01	<0.01	<0.01	<0.01
Total Organic Nitrogen	<1.0	<1.0	<1.0	<1.0
Sulfate	7.0	<1.0	32.0	250.0
Organic Sulfer	<1.0	<1.0	<1.0	<1.0
Chemical Oxygen Demand	53.0	55.8	11.3	23.0
Cadmium	<0.001	<0.001	<0.001	<0.001
Copper	<0.01	<0.01	<0.01	<0.01
Nickel	<0.005	<0.005	<0.005	<0.005
Iron	1.83	19.14	<0.05	0.38
Zinc	<0.02	0.04	<0.02	0.03
Pesticides/Herbicides			(ug/L)	
Gamma-BHC (Lindane)	<0.40	<0.40	<0.40	<0.40
Endrin	<0.02	<0.02	<0.02	<0.02
Methoxychlor	<10.0	<10.0	<10.0	<10.0
Toxaphene	<0.50	<0.50	<0.50	<0.50
2, 4-D	<1.00	<1.00	<1.00	<1.00
2,4,5-TP Silvex	<1.00	<1.00	<1.00	<1.00

Client I.D.:	Pond	SW	NW	NE
Sample No.:	88-3140	88-3141	88-3142	88-3143
		(mg/L)		
Parameter				
Method 8010 - Halogenated Volatile Organics				
Benzyl Chloride	<0.001	<0.001	<0.001	<0.001
Bis (2-chloroethoxy)-methane	<0.001	<0.001	<0.001	<0.001
Bis (2-chloroisopropyl) ether	<0.001	<0.001	<0.001	<0.001
Bromobenzene	<0.001	<0.001	<0.001	<0.001
Bromodichloromethane	<0.001	<0.001	<0.001	<0.001
Bromoform	<0.001	<0.001	<0.001	<0.001
Bromomethane	<0.001	<0.001	<0.001	<0.001
Carbon Tetrachloride	<0.001	<0.001	<0.001	<0.001
Chloracetaldehyde	<0.001	<0.001	<0.001	<0.001
Chloral	<0.001	<0.001	<0.001	<0.001
Chloroethane	<0.001	<0.001	<0.001	<0.001
Chloroform	<0.001	<0.001	<0.001	<0.001
1-Chlorohexane	<0.001	<0.001	<0.001	<0.001
2-Chloroethyl vinyl ether	<0.001	<0.001	<0.001	<0.001
Chloromethane	<0.001	<0.001	<0.001	<0.001
Chloromethyl methyl ether	<0.001	<0.001	<0.001	<0.001
Chlorotoluene	<0.001	<0.001	<0.001	<0.001
Dibromochloromethane	<0.001	<0.001	<0.001	<0.001
Dibromomethane	<0.001	<0.001	<0.001	<0.001
Dichlorodifluoromethane	<0.001	<0.001	<0.001	<0.001
1,1-Dichloroethane	<0.001	<0.001	<0.001	<0.001
1,2-Dichloroethane	<0.001	<0.001	<0.001	<0.001
1,1-Dichloroethylene	<0.001	<0.001	<0.001	<0.001
trans-1,2-Dichloro-ethylene	<0.001	<0.001	<0.001	<0.001
1,2-Dichloropropane	<0.001	<0.001	<0.001	<0.001
trans-1,3-Dichloro-propylene	<0.001	<0.001	<0.001	<0.001
Methylene Chloride	<0.001	<0.001	<0.001	<0.001
1,1,2,2-Tetrachloro-ethane	<0.001	<0.001	<0.001	<0.001
1,1,1,2-Tetrachloro-ethane	<0.001	<0.001	<0.001	<0.001
Tetrachloroethylene	<0.001	<0.001	<0.001	<0.001
1,1,1-Trichloroethane	<0.001	<0.001	<0.001	<0.001
1,1,2-Trichloroethane	<0.001	<0.001	<0.001	<0.001
Trichloroethylene	<0.001	<0.001	<0.001	<0.001
Trichlorofluoromethane	<0.001	<0.001	<0.001	<0.001
Trichloropropane	<0.001	<0.001	<0.001	<0.001
Vinyl Chloride	<0.001	<0.001	<0.001	<0.001

Client I.D.:	Pond	SW	NW	NE
Sample No.:	88-3140	88-3141	88-3142	88-3143
		(mg/L)		
Parameter				
Method 8020 - Aromatic Volatile Organics				
Benzene	<0.001	<0.001	<0.001	<0.001
Chlorobenzene	<0.001	<0.001	<0.001	<0.001
1,2-Dichlorobenzene	<0.001	<0.001	<0.001	<0.001
1,3-Dichlorobenzene	<0.001	<0.001	<0.001	<0.001
1,4-Dichlorobenzene	<0.001	<0.001	<0.001	<0.001
Ethyl benzene	<0.001	<0.001	<0.001	<0.001
Toluene	<0.001	0.003	0.001	<0.001
Xylene	<0.002	<0.002	<0.002	<0.002
Polychlorinated Biphenyls:				
PCB-1016	<0.001	<0.001	<0.001	<0.001
PCB-1221	<0.001	<0.001	<0.001	<0.001
PCB-1232	<0.001	<0.001	<0.001	<0.001
PCB-1242	<0.001	<0.001	<0.001	<0.001
PCB-1248	<0.001	<0.001	<0.001	<0.001
PCB-1254	<0.001	<0.001	<0.001	<0.001
PCB-1260	<0.001	<0.001	<0.001	<0.001

Appendix I:
Tire Water Toxicity Study Results

The Acute Lethality to Rainbow Trout of Water Contaminated by an Automobile Tire

By: Scott Abernethy
January 1994

Table 1. *Summary of the aquatic toxicity tests conditions.*

Test species	trout	*D. magna*	minnow	*C. dubia*
Exposure, hrs.	96	48	96	48
Life stage	fry	neonates	fry	neonates
Wet weight/age	0.7-4.3 g	< 24 hours	0.2-0.4 g	< 24 hours
Test vessel	20 L plastic bucket	50 mL glass vial	250 mL beaker	30 mL plastic cup
Solution volume	20 litres	50 mL	200 mL	15 mL
Loading	10 fish	3 neonates	3 fish	5 neonates
Replicates	none	4	2	2
Temperature, °C	13 to 17	18 to 22	21 to 23	18 to 22
Aeration	yes	no	no	no
Food	none	none	brine shrimp once daily	YCT once at start of the test

Table 2. *The experimental design.*

Tire water batch #	Toxicity test #	Test species or sample treatment	Sample age days
	LC50 tests of four species		
1	1a	rainbow trout	< 5 hours old
	1b	*D. magna*	< 5 hours old
2	2a	rainbow trout	< 5 hours old
	2b	*C. dubia*	< 5 hours old
	2c	fathead minnow	< 5 hours old
	LT50 tests of rainbow trout		
2	2a	none, initial test	< 5 hours old
	3a	none, baseline test	2
	3b	pH 3	2
	3c	pH 11	2
	3d	EDTA	2
	3e	$Na_2S_2O_3$	2
	4	stored, 15°C, dark	7
3	5	none, initial test	< 5 hours old
	6a	none, baseline test	1
	6b	pH 6	1
	6c	pH 7	1
	6d	pH 8	1
	6e	activated carbon	1
3	7a	stored, 15°C, dark	7
	7b	stored, 20°C, dark	7
	7c	stored, 20°C,light	7

Table 3. *Cumulative percent mortality in the dilution series tests.*

Concentration	Tire water batch #1		Tire water batch #2	
% vol/vol	24 hours	96 hours	24 hours	96 hours
100	100	100	90	100
65	70	100	0	90
40	0	70	0	0
30	0	40	0	0
20	0	0	0	0
10	0	0	0	0
0 (control)	0	0	0	0
LC50	58	34	83	52
Confidence limits	49 to 68	29 to 40	73 to 93	49 to 56

Table 4. *LT50s of the single concentration trout tests.*

Sample treatment (toxicity test#)	LT50 (hours)	95 % confidence limits
initial (2a)	17	not calculated
baseline (3a)	23	17 to 28
pH 3 (3b)	25	20 to 29
pH 11 (3c)	25	22 to 30
EDTA (3d)	23	17 to 28
$Na_2S_2O_3$ (3e)	21	15 to 25
stored,15°C,dark (4)	35	27 to 43
initial (5)	18	11 to 22
baseline (6a)	20	14 to 24
pH 6 (6b)	16	not calculated
pH 7 (6c)	18	2 to 22
pH 8 (6d)	18	3 to 22
activated carbon (6e)	nonlethal	not calculated
stored,15°C,dark (7a)	21	18 to 25
stored,20°C, dark (7b)	20	18 to 22
stored,20°C,light (7c)	26	23 to 30

Table 5. *GC-MS results: the numbers of compounds identified, classified or unknown. The numbers in parentheses refer to the numbers of compounds in the control water samples. 2a and 2b are separate samples collected four days apart.*

Compound category	Tire water batch #			
	1	2a	2b	3
Identified	9 (2)	13 (4)	16 (1)	11 (5)
Classified	10 (4)	4 (0)	9 (0)	10 (3)
Unknown	15 (0)	11 (1)	24 (1)	41 (8)
Total	34 (6)	28 (5)	49 (2)	62 (16)

APPENDIX 1

THE CHEMICAL ANALYSES OF TIRE WATERS AND CONTROL WATERS

Water concentrations are mg/L. The nitrogen compounds as N. Carbon = dissolved carbon as C. UNF = unfiltered, R = reactive, T = total. ND = not detected. For nondetectable parameters, the detection limits were: ammonium = 0.05; nitrite = 0.015; copper = 0.0019; nickel = 0.004; lead = 0.008; zinc = 0.007; cadmium = 0.0002; chromium = 0.002.

Chemical parameter	Tire water batch #		Control water batch #	
	2	3	2	3
General water quality				
hardness, T, as $CaCO_3$	152	147	151	147
calcium, UNF,R	45	44	45	44
magnesium, UNF,R	10	9	10	9
sodium, UNF,R	14	14	14	14
potassium, UNF,R	1.7	1.7	1.7	1.7
alkalinity, T, as $CaCO_3$	99	98	98	99
fluoride, UNF,R	1.2	1.2	1.2	1.2
chloride, UNF,R	28	28	27	29
sulphate, UNF,R	32	33	31	33
carbon, organic	3	2	2	2
carbon, inorganic	20	22	18	23
Nitrogen compounds				
nitrogen, Kjeld., UNF,R,T	0.25	0.40	ND	0.30
ammonium, fraction R,T	ND	0.40	ND	0.25
nitrates, fraction R,T	0.45	0.45	0.45	0.45
nitrite, fraction R	ND	0.030	ND	0.035
Inorganic metals (UNF,T)				
copper	0.002	ND	0.003	0.0022
nickel	ND	ND	ND	ND
lead	ND	ND	ND	ND
zinc	0.025	0.023	ND	ND
iron	0.06	0.03	0.04	0.07
cadmium	ND	ND	ND	ND
chromium	ND	ND	ND	ND

APPENDIX 2

TARGET ANALYTES AND DETECTION LIMITS

(None were found in the tire water)

Gasoline and solvents, ug/L

1,2-dichloroethylene	2	m-, p-xylenes	2
1,1-dichloroethane	2	bromoform	2
chloroform	2	1,4-dichlorobenzene	2
1,1,1-trichloroethane	2	1,3-dichlorobenzene	2
carbon tetrachloride	2	1,2-dichlorobenzene	2
benzene	2	$BCl_2CH + C_2Cl_3H$	2
1,2-dichloropropane	2	$C_2CL_4 + ClBCH_2$	2
toluene	2	o-xylene	2
1,1,2-trichlorethane	2	1,1,2,2-tetrachloroethane	2
chlorobenzene	2	gasoline	1
ethylbenzene	2	fuel distillate	1

Pesticides, ug/L

ametryne	0.05	difenoxuton	2
atrazine	0.05	diuron	2
prometryne	0.05	fluometuron	2
atrazone	0.05	linuron	2
metolachlor	0.5	metoxuron	2
diethyl simazine	0.5	monolinuron	2
chlorbromuron	2	monuron	2
chlortoluron	2	neburon	2
siduron	2		

APPENDIX 2

TARGET ANALYTES AND DETECTION LIMITS
(None were found in the tire waters)

Organochlorines, ng/L

hexachloroethane	1	alpha-BHC	1
1,3,5-trichlorobenzene	5	beta-BHC	1
1,2,4-trichlorobenzene	5	gamma-BHC	4
hexachlorobutadiene	1	a-chlordane	2
1,2,3-trichlorobenzene	5	g-chlordane	2
2,4,5-trichlorotoluene	5	oxychlordane	2
2,3,6-trichlorotoluene	5	op-DDT	5
1,2,3,5-tetrachlorobenzene	1	pp-DDD	5
1,2,4,5-tetrachlorobenzene	1	pp-DDT	5
2,6,alpha-trichlorotoluene	5	methoxychlor	5
1,2,3,4-tetrachlorobenzene	1	heptachlorepoxide	1
pentachlorobenzene	1	endosulfan I	2
PCB, total	20	dieldrin	2
hexachlorobenzene	1	endrin	5
heptachlor	1	endosulfan II	5
aldrin	1	endosulfan sulphate	5
pp-DDE	1	octachlorostyrene	1
mirex	5	toxaphene	500

Acid extractables, ug/L

phenol	0.2	2,4,5-trichlorophenol	0.2
2,4-dimethylphenol	2	2,3,4-trichlorophenol	0.2
p-chloro-m-cresol	0.2	2,3,5,6-tetrachlorophenol	0.2
2,4-dichlorophenol	0.2	2,3,4,5-tetrachlorophenol	0.2
4-nitrophenol	0.5	pentachlorophenol	0.2
2,3,4,6-tetrachlorophenol	0.2	2,6-dichlorophenol	0.2
2,4-dinitrophenol	20	m-cresol	0.2
4,6-dinitro-o-cresol	10	o-cresol	0.2
2-chlorophenol	0.2	p-cresol	0.2
2,4,6-trichlorophenol	0.2	2,3,5-trichlorophenol	0.2

APPENDIX 2

TARGET ANALYTES AND DETECTION LIMITS

(None were found in the tire water)

Polynuclear aromatic hydrocarbons, ng/L

phenanthrene	10	perylene	10
anthracene	1	benzo(k)fluoranthene	1
fluoranthene	20	benzo(a)pyrene	5
pyrene	20	benzo(g,h,i)perylene	20
benz(a)anthracene	20	dibenz(a,h)anthracene	10
chrysene	50	indeno(1,2,3-c,d)pyrene	20
dimethyl benz(a)anthracene	5	benzo(b)chrysene	2
benzo(e)pyrene	50	coronene	10
benzo(b)fluoranthene	10		

Base-neutral extractables, ug/L

diphenyl ether	0.2	bis(2-chloroethoxy) methane	0.2
bis-2-ethylhexylphthalate	1	naphthalene	0.2
di-n-octylphthalate	0.2	acenaphthylene	0.2
benzo(k)fluoranthene	0.2	2,6-dinitrotoluene	0.5
benzo(a)pyrene	0.2	acenaphthene	0.2
indeno(1,2,3-cd)pyrene	0.5	4-chlorophenyl phenyl ether	0.2
diphenylamine	2	2,4-dinitrotoluene	0.5
3,3-dichlorobenzidine	1	fluorene	0.2
bis(2-chloroethyl)ether	0.5	n-nitrosodiphenylamine	2
indole	0.2	4-bromophenyl phenyl ether	0.2
dibenzo(a,h)anthracene	0.5	phenanthrene	0.2
benzo(g,h,i)perylene	0.2	anthracene	0.2
bis(2-chloroisopropyl)ether	0.2	di-n-butylphthalate	0.2
fluoranthene	0.2	1-methylnaphthalene	0.5
pyrene	0.2	2-chloronaphthalene	0.2
butylbenzylphthalate	0.5	2-methylnaphthalene	0.2
benzo(a)anthracene	0.2	5-nitroacenaphthene	1
chrysene	0.2	benzo(b)fluoranthene	0.2
camphene	0.5	biphenyl	0.2
n-nitrosodi-n-propylamine	0.5	perylene	0.5
1-chloronaphthalene	0.2		

APPENDIX 3

THE COMPOUNDS IDENTIFIED AS MEMBERS OF CERTAIN CHEMICAL CLASSES

The numbers in parentheses refer to the numbers of compounds detected in the same chemical class.

Tire water batch #			
1	2a	2b	3
a methyl-aniline	a methyl-aniline	a methyl-aniline	a methyl-aniline
a nitrogen compound	a nitrogen compound (2)	an amine (2)	a dimethyl-aniline
a C_9 alkylphenol	a phenol	a methyl diphenyl-amine	a methyl diphenyl-amine
a chloro-dimethyl phenol		a C_{10} alkylphenol	a C_4-alkyl pyridine
a phenol (2)		a chloro-dimethyl phenol	a nitrophenol
a chlorine compound		a C_3 alkyl-benzene	a chloro-dimethyl phenol
an alcohol or ether (3)		a carboxylic acid	a methyl phenyl-ethylphenol
		a carboxylic acid ester	a dihydro-indenone + phenol
			a carboxylic acid (2)

APPENDIX 4

THE IDENTIFIED COMPOUNDS AND CONCENTRATIONS (UG/L) IN THE TIRE WATERS

Compound name	CAS #	Tire water batch #			
		1	2a	2b	3
aniline	62-53-3	3	0.3	0.9	0.5
2-methyl-N-phenyl-aniline	1205-39-6	1	1		
N-phenyl-aniline	122-39-4			0.5	0.5
N,N-diphenyl-1,4-benzenediamine	74-31-7			0.4	
[1,1-biphenyl]-2-amine	90-41-5		0.8		
N,N-dibutyl formamide	761-65-9			0.2	
diphenyl formamide	607-0-1			1	
N-phenyl-formamide	103-70-8			0.5	0.3
N,N-diphenyl-hydrazinecarboxamide	603-51-0	0.8			
phenoxazine	135-67-1		5		
benzothiazole	95-16-9	9	1	10	9
2-(methylthio)-benzothiazole	615-22-5		0.4		0.3
2(3H)-benzothiazolone	934-34-9	4	0.1	4	
4-(2-benzothiazolylthio)-morpholine	102-77-2	6	2	5	3
4-acetyl morpholine	1696-20-4		0.7		
2,5-cyclohexadiene-1,4-dione	106-51-4				0.3
1,4-cyclohexanedione	637-88-7	0.3	0.5	0.7	
2,3-dihydro-1H-inden-1-one	83-33-0			0.2	
4-methyl-2-pentanone	108-10-1			1	
1-methyl-2-pyrrolidinone	872-50-4				0.2
4-(1-methyl-1-phenylethyl)-phenol	599-64-4	0.1	0.6	0.8	0.6
4-(phenylamino)-phenol	122-37-2				8
dinitro propyl phenol	1420-07-1			0.6	
2,6-bis(1,1-dimethylethyl)-4-ethyl phenol	4130-42-1		0.7		

Compound name	CAS #	Tire water batch #			
		1	2a	2b	3
2-chloroethanol phosphate	115-96-8			0.2	
9H-fluoren-9-ol	1689-64-1				0.3
α,α-dimethyl benzenemethanol	617-94-7	0.3	0.3	0.4	

Appendix J:
Identification of Tire Leachate Toxicants Study Results

Identification of Tire Leachate Toxicants and a Risk Assessment of Water Quality Effects Using Tire Reefs in Canals

By: S.M. Nelson, G. Mueller, D.C. Hemphill

May 1993

Table 1. Physico-chemical parameters of toxicity test waters.

Parameter	Tire leachate	Lake Mead dilution water
Dissolved oxygen (mg/L)	6.1	6.1
pH	8.36	8.60
Conductivity (μS/cm)	1128	1070
Total alkalinity (mg/L)	110	108
Total hardness (mg/L)	328	309

Table 2. Results of TIE tests.

Manipulation	24-hr LC_{50} (%) and 95% confidence limits	
	C. dubia	Fathead Minnow
Baseline toxicity test (this test repeated twice for *C. dubia*)	21.0 (15.9-27.7) 20.3 (17.0-24.2)	> 100
pH 3 Adjustment	30.8 (24.0-39.4)	> 100
pH 11 Adjustment	35.4 (24.9-50.2)	> 100
Aeration	17.7 (confidence limits not reliable)	--
Filtration	23.3 (17.2-31.6)	> 100
SPE	61.6 (48.0-78.9)	> 100
Eluted SPE	> 100	> 100
Other Tests	**Results (% survival in 100% concentration)**	
EDTA	100	--
sodium thiosulfate	20	--

Confirmation that zinc was the primary toxicant was obtained by adding zinc to control water through the addition of zinc chloride and then performing an additional toxicity test using *C. dubia*. The nominal value of 750 μg/L zinc in the 100% concentration was confirmed through chemistry analysis that indicated zinc was present in duplicate samples at 88 and 91% of the nominal value.

Table 3. Chemistry results from TIE tests.

Parameter	Type of water			
	Lake Mead dilution water	Deionized water blank	Tire leachate-duplicate 1	Tire leachate-duplicate 2
Zn (μg/L)	8.7	<4.0	751	755
Cd (μg/L)	0.2	<0.1	0.6	0.6
Cu (μg/L)	<5.0	<5.0	6.7	5.7
Pb (μg/L)	<1.0	<1.0	6.7	6.7
Ni (μg/L)	<10.0	<10.0	<10.0	<10.0
Ca (mg/L)	71.2	--	74.7	--
Mg (mg/L)	31.2	--	31.6	--
Na (mg/L)	98.3	--	102	--
K (mg/L)	5.35	--	5.93	--
CO_3 (mg/L)	<0.00	--	<0.00	--
HCO_3 (mg/L)	136	--	143	--
SO_4 (mg/L)	266	--	277	--
Cl (mg/L)	113	--	115	--

The 24-hr LC_{50} calculated from this test was 147.1 μg/L zinc (95% C.I. 131.7-164.3 μg/L zinc). It is of interest to note that our 24-hr LC_{50} value is lower than the 48-hr LC_{50} (255 μg/L zinc) reported by Carlson et al. (1986) for C. dubia exposed to zinc in softer water (hardness of 90 mg/L). EPA (1987) presents hardness as being most important in determining zinc toxicity and according to this scenario our LC_{50}, at a hardness of 300 mg/L, should be much higher. It is possible, however, that pH may be as important as hardness in determining toxicity, with increased pH leading to increased zinc toxicity. This has been demonstrated with fishes (Mount 1966, Everall et al. 1989) and our data is at least suggestive that this may be the case with C. dubia. In addition, our low alkalinity relative to hardness differs from many stream waters (3:1 ratio hardness:alkalinity vs. the average 1.3:1 ratio observed in river waters of North America (Livingstone 1963)) and it is possible that this may cause increased toxicity. With the use of C. dubia as a standard toxicity test organism, it is unfortunate that the relationship of hardness, alkalinity, and pH on zinc toxicity to C. dubia has not been described.

The TU_a calculated for the original leachate test was 4.9 and our zinc bioassay indicated that zinc could be held accountable for 5.1 TU_a of the leachate. The closeness of these values suggests that most of the leachate toxicity is from zinc.

Table 4. List of organic compounds tested for in tire leachate water. None of these compounds were detected at a detection limit of 1.0 μg/L.

Acenaphthene
Acenaphthylene
Acetophenone
Aldrin
Aniline
Anthracene
4-Aminobiphenyl
Aroclor-1016
Aroclor-1221
Aroclor-1232
Aroclor-1242
Aroclor-1248
Aroclor-1254
Aroclor-1260
Benzidine
Benzoic Acid
Benzo(a)anthracene
Benzo(b)fluoranthene
Benzo(k)fluoranthene
Benzo(g,h,i)perylene
Benzo(a)pyrene
Benzyl alcohol
α-BHC
B-BHC
σ-BHC
BHC (Lindane)
Bis(2-chloroethoxy)methane
Bis(2-chloroethyl)ether
Bix(2-ethylhexyl)phthalate
4-Bromophenyl phenyl ether
Butyl benzyl phthalate
Chlorodane
4-Chloroaniline
1-Chloronaphthalene
2-Chloronaphthalene
4-Chloro-3-methylphenol
2-Chlorophenol
4-Chlorophenyl phenyl ether
Chrysene
4,4'-DDD
4,4'-DDE
4,4'-DDT
Dibenz(a,j)acridine
Dibenz(a,h)anthracene
Dibenzofuran
Di-n-butylphthalate
1,3-Dichlorobenzene
1,4-Dichlorobenzene
1,2-Dichlorobenzene
3,3-Dichlorobenzidine
2,4-Dichlorphenol
2,6-Dichlorophenol
Dieldrin
Diethylphthalate
p-Dimethylaminoazobenzene
7,12-Dimethylbenz(a)anthracene
α-,α-Dimethylphenethylamine
2,4-Dimethylphenol
Dimethylphthalate
4,6-Dinitro-1-methylphenol
2,4-Dinitrophenol
2,4-Dinitrotoluene
2,6-Dinitrotoluene
Diphenylamine
1,2-Diphenylhydrazadine
Di-n-octylphthalate
Endosulfan I
Endosulfan II
Endosulfan Sulfate
Endrin
Endrin aldehyde
Endrin ketone
Ethyl methanesulfonate
Fluoranthene
Fluorene
Heptachlor
Heptachlor epoxide
Hexachlorobenzene
Hexachlorobutadiene
Hexachlorocyclopentadiene
Hexachloraethane
Indeno (1,2,3-cd)pyrene
Isophorene
Methoxychlor
3-Methylcholanthrene
Methyl methanesulfonate
2-Methylnaphthalene
2-Methylphenol (o-cresol)
4-Methylphenol (p-cresol)
Napthalene
1-Napthylamine
2-Napthylamine
2-Nitroaniline
3-Nitroaniline
4-Nitroaniline
Nitrobenzene
2-Nitrophenol
4-Nitrophenol
N-Nitroso-di-n-butylamine
N-Nitrosodimethylamine
N-Nitrosodiphenylamine
N-Nitrosodipropylamine
N-Nitrosopiperidine
Pentachlorobenzene
Pentachloronitrobenzene
Pentachlorophenol
Phenacetin
Phenanthrene
Phenol
2-Picoline
Pronamide
Pyrene
1,2,4,5-tetrachlorobenzene
2,3,4,6-Tetrachlorphenol
1,2,4-Trichlorobenzene
2,3,5-Trichlorophenol
2,4,6-Trichlorophenol
Toxaphene

Appendix K:
Legend of Symbols for USDA Soil Survey Maps
Penobscot County, Maine

U. S. Department of Agriculture
Soil Conservation Service

Penobscot County, Maine

SOIL LEGEND

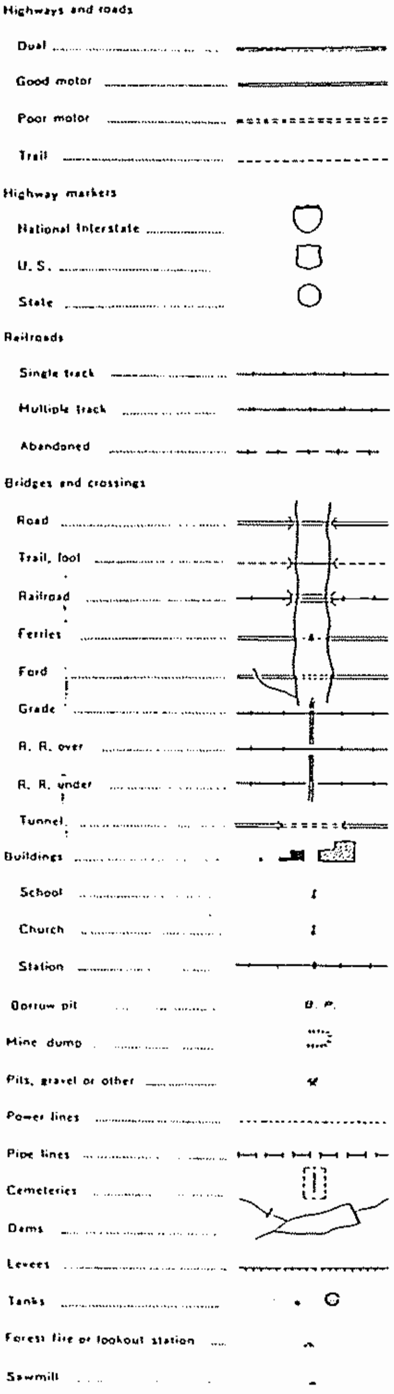
The first capital letter is the initial one of the soil name. A second capital letter, A, B, C, D, or E, shows the slope. Symbols without a slope letter are those of nearly level soils, such as Limerick silt loam, or of land types, such as Rock outcrop, which have a considerable range of slope. A final number 2, in the symbol, shows that the soil is eroded.

SYMBOL	NAME
AaB	Adams loamy sand, 0 to 8 percent slopes
AaC	Adams loamy sand, 8 to 15 percent slopes
AaE	Adams loamy sand, 15 to 45 percent slopes
AgA	Allagash fine sandy loam, 0 to 2 percent slopes
AgB	Allagash fine sandy loam, 2 to 8 percent slopes
AgC	Allagash fine sandy loam, 8 to 15 percent slopes
AgD	Allagash fine sandy loam, 15 to 25 percent slopes
BaA	Bangor silt loam, 0 to 2 percent slopes
BaB	Bangor silt loam, 2 to 8 percent slopes
BaC	Bangor silt loam, 8 to 15 percent slopes
BaD	Bangor silt loam, 15 to 25 percent slopes
BmB	Bangor silt loam, moderately deep, 2 to 8 percent slopes
BmC	Bangor silt loam, moderately deep, 8 to 15 percent slopes
BmD	Bangor silt loam, moderately deep, 15 to 25 percent slopes
BnB	Bangor very stony silt loam, 0 to 8 percent slopes
BnC	Bangor very stony silt loam, 8 to 15 percent slopes
BnD	Bangor very stony silt loam, 15 to 25 percent slopes
BoA	Biddeford silt loam, 0 to 3 percent slopes
BrA	Burnham silt loam, 0 to 3 percent slopes
BuA	Buxton silt loam, 0 to 2 percent slopes
BuB	Buxton silt loam, 2 to 8 percent slopes
BuC	Buxton silt loam, 8 to 15 percent slopes
BxB	Buxton, Scantic, and Biddeford stony silt loams, 0 to 8 percent slopes
CaC	Canaan extremely rocky sandy loam, 5 to 15 percent slopes
CaE	Canaan extremely rocky sandy loam, 15 to 45 percent slopes
CcB	Colton cobbly sandy loam, dark materials, 0 to 8 percent slopes
CcC	Colton cobbly sandy loam, dark materials, 8 to 15 percent slopes
CcD	Colton cobbly sandy loam, dark materials, 15 to 25 percent slopes
CcE	Colton cobbly sandy loam, dark materials, 25 to 45 percent slopes
CnA	Colton gravelly sandy loam, dark materials, 0 to 2 percent slopes
CnB	Colton gravelly sandy loam, dark materials, 2 to 8 percent slopes
CnC	Colton gravelly sandy loam, dark materials, 8 to 15 percent slopes
CnD	Colton gravelly sandy loam, dark materials, 15 to 25 percent slopes
CnE	Colton gravelly sandy loam, dark materials, 25 to 45 percent slopes
CsA	Colton loamy fine sand, dark materials, 0 to 2 percent slopes
CsB	Colton loamy fine sand, dark materials, 2 to 8 percent slopes
CsC	Colton loamy fine sand, dark materials, 8 to 15 percent slopes
CsD	Colton loamy fine sand, dark materials, 15 to 25 percent slopes
DaA	Daigle silt loam, 0 to 2 percent slopes
DaB	Daigle silt loam, 2 to 8 percent slopes
DaC	Daigle silt loam, 8 to 15 percent slopes
DgA	Daigle stony silt loam, 0 to 2 percent slopes
DgB	Daigle stony silt loam, 2 to 8 percent slopes
DgC	Daigle stony silt loam, 8 to 15 percent slopes
DxA	Dixmont silt loam, 0 to 2 percent slopes
DxB	Dixmont silt loam, 2 to 8 percent slopes
DxC	Dixmont silt loam, 8 to 15 percent slopes
DyA	Dixmont very stony silt loam, 0 to 2 percent slopes
DyB	Dixmont very stony silt loam, 2 to 8 percent slopes
DyC	Dixmont very stony silt loam, 8 to 15 percent slopes
EmB	Elmwood fine sandy loam, 0 to 8 percent slopes
Ha	Hadley silt loam
HbB	Hermon sandy loam, 2 to 8 percent slopes
HbC	Hermon sandy loam, 8 to 15 percent slopes
HdB	Hermon sandy loam, moderately deep, 2 to 8 percent slopes
HdC	Hermon sandy loam, moderately deep, 8 to 15 percent slopes
HeB	Hermon very stony sandy loam, 2 to 8 percent slopes
HeC	Hermon very stony sandy loam, 8 to 15 percent slopes
HeE	Hermon very stony sandy loam, 15 to 45 percent slopes
HhC	Hermon extremely stony sandy loam, 5 to 15 percent slopes
HoB	Howland gravelly loam, 0 to 8 percent slopes
HoC	Howland gravelly loam, 8 to 15 percent slopes
HvB	Howland very stony loam, 0 to 8 percent slopes
HvC	Howland very stony loam, 8 to 15 percent slopes
HvD	Howland very stony loam, 15 to 25 percent slopes
Lk	Limerick silt loam
MaB	Machias fine sandy loam, 0 to 8 percent slopes
MbB	Madawaska very fine sandy loam, 0 to 8 percent slopes
Md	Made land
McA	Melrose fine sandy loam, 0 to 2 percent slopes
McB	Melrose fine sandy loam, 2 to 8 percent slopes
McC	Melrose fine sandy loam, 8 to 15 percent slopes
Mn	Mixed alluvial land
MoB	Monarda silt loam, 0 to 8 percent slopes
MrB	Monarda and Burnham very stony silt loams, 0 to 8 percent slopes
MsC	Monarda and Burnham extremely stony silt loams, 0 to 15 percent slopes
Mu	Muck
On	Ondawa fine sandy loam
Pa	Peat and muck
Pc	Peat, coarsely fibrous
Pf	Peat, moderately fibrous
PgB	Plaisted gravelly loam, 2 to 8 percent slopes
PgC	Plaisted gravelly loam, 8 to 15 percent slopes
PgD	Plaisted gravelly loam, 15 to 25 percent slopes
PgE	Plaisted gravelly loam, 25 to 45 percent slopes
PhB	Perham silt loam, 0 to 8 percent slopes
PhC	Perham silt loam, 8 to 15 percent slopes
PmB	Perham stony silt loam, 0 to 8 percent slopes
PmC	Perham stony silt loam, 8 to 15 percent slopes
PrC	Plaisted very stony loam, 5 to 15 percent slopes
PrE	Plaisted very stony loam, 15 to 45 percent slopes
Ps	Peat, sphagnum
PxC	Plaisted extremely stony loam, 5 to 15 percent slopes
Pr	Podunk fine sandy loam
RaB	Red Hook and Atherton silt loams, 0 to 8 percent slopes
RdB	Red Hook and Atherton fine sandy loams, 0 to 8 percent slopes
Rv	Riverwash
RkC	Rockland, Canaan material, sloping
RkD	Rockland, Canaan material, strongly sloping
RmC	Rockland, Thorndike material, sloping
RmD	Rockland, Thorndike material, strongly sloping
Ro	Rock outcrop
Sa	Saco silt loam
ScB	Scantic silt loam, 0 to 8 percent slopes
SeA	Stetson fine sandy loam, 0 to 2 percent slopes
SeB	Stetson fine sandy loam, 2 to 8 percent slopes
SeC	Stetson fine sandy loam, 8 to 15 percent slopes
SeD	Stetson fine sandy loam, 15 to 25 percent slopes
SfC	Stetson Suffield complex, 0 to 15 percent slopes
SfE	Stetson Suffield complex, 15 to 45 percent slopes
ShD	Stony land, Hermon material, strongly sloping
SoD	Stony land, Plaisted material, strongly sloping
SuA	Suffield silt loam, 0 to 2 percent slopes
SuB	Suffield silt loam, 2 to 8 percent slopes
SuC	Suffield silt loam, 8 to 15 percent slopes
SuC2	Suffield silt loam, 8 to 15 percent slopes, eroded
SuD	Suffield silt loam, 15 to 25 percent slopes
SuD2	Suffield silt loam, 15 to 25 percent slopes, eroded
SuE	Suffield silt loam, 25 to 45 percent slopes
SvA	Suffield very fine sandy loam, 0 to 2 percent slopes
SvB	Suffield very fine sandy loam, 2 to 8 percent slopes
SvC	Suffield very fine sandy loam, 8 to 15 percent slopes
SvD	Suffield very fine sandy loam, 15 to 25 percent slopes
ThB	Thorndike shaly silt loam, 2 to 8 percent slopes
ThC	Thorndike shaly silt loam, 8 to 15 percent slopes
ThD	Thorndike shaly silt loam, 15 to 25 percent slopes
ThE	Thorndike shaly silt loam, 25 to 45 percent slopes
TkB	Thorndike very rocky silt loam, 2 to 8 percent slopes
TkC	Thorndike very rocky silt loam, 8 to 15 percent slopes
TvB	Thorndike very stony silt loam, 2 to 8 percent slopes
TvC	Thorndike very stony silt loam, 8 to 15 percent slopes
TvD	Thorndike very stony silt loam, 15 to 35 percent slopes
Wn	Winooski silt loam

Soil map constructed 1962 by Cartographic Division, Soil Conservation Service, USDA, from 1942, 1947 and 1950 aerial photographs. Controlled mosaic based on Maine plane coordinate system, east zone, transverse Mercator projection. 1927 North American datum.

CONVENTIONAL SIGNS

WORKS AND STRUCTURES



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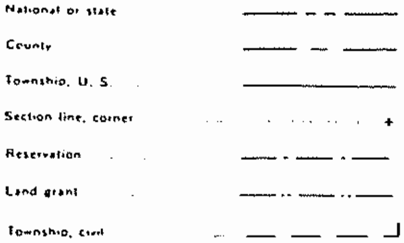
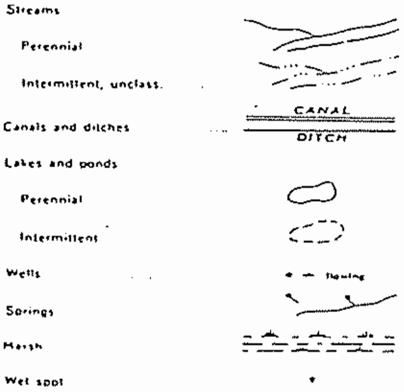
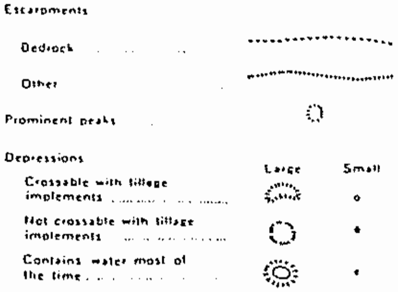


DRAINAGE



RELIEF



MAINE AGRICULTURAL EXPERIMENT STATION

SOIL SURVEY DATA

Soil boundary and symbol	Dx
Gravel	∴
Stones, very stony	°⁰00
Rock outcrops	▾ ▾
Chert fragments	△ △
Clay spot	※
Sand spot	∵
Gumbo or scabby spot	♦
Made land	≂
Severely eroded spot	≑
Blowout, wind erosion	◡
Gullies	∿∿∿∿

Appendix L:
Application for Use of University Forest Land for Research Puposes

Application Form for Activities, Uses, or Developments on the University Forest
University of Maine at Orono

1. Description of proposed activity / use

The University of Maine Civil Engineering Department proposes to study the environmental impacts of using tire chips below the groundwater table using small scale field trials. The study is funded by the Maine Department of Transportation (MDOT). Three sites with differing soils types will be used. The soil types are peat, clay, and till. The clay and till sites are located on University Forest land. The peat site is on private property. At each site a trench 2 to 4 feet wide by 10 to 15 feet long and 6 to 7 feet deep would be dug perpendicular to the direction of the groundwater flow. The trench would be filled with tire chips with the goal of having at least 4 feet of tire chips below the groundwater table. In the field trials, between five and ten groundwater monitoring wells would be installed at each site. Initial groundwater samples will be collected and analyzed before the tire chip installation. After the installation of the tire chips, the groundwater quality will be monitored quarterly. The field trial will last for 2 to 3 years. At the end of the field trial the tire chips and groundwater monitoring wells will be removed and the sites will be restored to their natural condition.

2. Objectives of the activity / use

The objective of this study is to determine the potential impacts on water quality due to using tire chips on highway projects as lightweight fill or thermal insulation in applications where the tire chips will be below the groundwater table. The results will be used by the Maine Department of

Environmental Protection (MDEP) and MDOT in making decisions about the feasibility of using tire chips below the groundwater table.

3. **Nature of the activity:** Research

4. **Amount of land involved:** Approximately one-eighth of an acre at each site

5. **Location of the activity (on University Forest map)** **Compartment:** C
Block: G-7, G-8 } clay site
F
F-6, F-7 } fill site

6. **Who will benefit from the activity / use?**

A major benefit to the State of Maine of using tire chips as lightweight fill or thermal insulation on highway projects would be the use of a waste product. It is estimated that there are 30 to 60 million tires currently stockpiled in Maine and an additional 1 million waste tires are generated annually in Maine. Since landfill space is limited and very valuable, tires are most often stored in open piles above ground. Because of their shape, tires allow water to pool inside them. Stockpiled tires become an excellent breeding ground for mosquitoes and small vermin. Therefore tire piles are dangerous in that they can harbor disease carriers. Tire piles also create a fire hazard. Tire fires generate noxious black smoke and oil. Tire pile fires are generally very difficult to extinguish. If water is used to fight the fire, the fire fighting water becomes contaminated and is a threat to groundwater. Tire piles are also ugly and unnatural scars on Maine's landscape.

The citizens of Maine will benefit from the activity whether the feasibility of using tire chips below the groundwater table is confirmed or disconfirmed. In the event that tire chips are found to have unacceptable adverse impacts on groundwater quality, the benefit will be that Maine's environment would be protected by limiting the use of tire chips to above the groundwater table applications. In the event that the impact of tire chips on groundwater quality is minimal or negligible the benefits will be better, longer lasting, more easily traveled roads and an attractive use for a rapidly accumulating waste product.

7. What is the amount and source of funding for this project?

$40,000 MDOT

8. What is the time frame associated with this use?

2 to 3 years

9. Will this use make long term or permanent changes on the site or affect its availability for other uses?

At the end of the study the tire chips will be dug up and removed and the trenches will be backfilled with the soil that was originally excavated from them. The area will be seeded with grass seed and covered with hay mulch. In addition, the monitoring wells will be removed.

During the two to three year time frame of the study the area immediately surrounding the trenches would not be available for other uses.

10. Who will be responsible for developing and coordinating the proposed activity / use?

Dana N. Humphrey, Associate Professor, Civil Engineering
Lisa A. Downs, Graduate Student, Civil Engineering

11. Will any follow-up or long term work be required for the activity / use?

No, at the end of the two to three years the project will be closed out as described above.

Approved
9/22/93
Charles J. [illegible]
Forest Supt.

Appendix M:
Letter to Doug Schmidt: Landowner
(Peat Site)

UNIVERSITY OF MAINE

Department of Civil and Environmental Engineering

5711 Boardman Hall
Orono ME 04469-5711
207 581-2171
Fax 207 581-1215

17 September 1993

Mr. Doug Schmidt
Levenseller Road
Holden, Maine 04429

Dear Mr. Schmidt:

Thank you for agreeing to allow me to use your land in Bangor, Maine adjacent to the Veazie Railroad easement and the Bangor Bog as a site for my research project. I am sending this letter to summarize my intended use of your land as part of my research.

The University of Maine Department of Civil Engineering proposes to study the environmental impacts of using tire chips below the groundwater table using small scale field trials. The study is funded by the Maine Department of Transportation (MDOT). Three sites with differing soil types will be used. The site on your property is the peat site. A trench approximately 2 to 4 feet wide, 10 to 15 feet long and 5 feet deep will be dug and filled with tire chips. Between 5 and 10 groundwater monitoring wells will be installed. Initial groundwater samples will be taken before the tire chips are installed. After the tire chips are installed, groundwater quality will be monitored quarterly.

The objective of this study is to determine the potential impacts on water quality due to using tire chips on highway projects as lightweight fill or thermal insulation in applications where the tire chips will be below the groundwater table. The results will be used by the Maine Department of Environmental Protection (MDEP) and MDOT in making decisions about the feasibility of using tire chips below the groundwater table.

A major benefit of using tire chips as lightweight fill or thermal insulation on highway projects would be the use of a waste product. It is estimated that there are 30 to 60 million tires currently stockpiled in Maine. In addition, 1 million waste tires are generated in Maine each year.

During the 2 to 3 year time frame of the study the area immediately surrounding the trench would not be available for other uses. At the end of the study the tire chips will be dug up and removed and the trenches will be backfilled with the soil that was originally excavated from them. The area will be seeded with grass seed and covered with hay mulch. In addition, the monitoring wells will be removed.

If you have any questions concerning this project or my use of your land please don't hesitate to call me at 581-1444. My advisor for the field portion of my research is Dana Humphrey. Dana can be reached at 581-2176. I will contact you periodically to keep you informed of our progress.

Sincerely,

Lisa Downs

Lisa A. Downs
Research Assistant
Civil Engineering

Dana N. Humphrey

Dana N. Humphrey, Ph.D., P.E.
Associate Professor
Civil Engineering