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AN EVALUATION OF THE IMPACTS OF HIGHWAY DEICERS ON PESHASTIN CREEK

by

David Yonge and Nathaniel Marcoe
Department of Civil and Environmental Engineering
Washington State University
Pullman, Washington 99163

Washington State Transportation Center (TRAC)
Department of Civil and Environmental Engineering
Washington State University
Pullman, WA 99164-2910

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Edward Molash

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David Yonge and Nathaniel Marcoe

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Washington State Transportation Center (TRAC)
CEE Department; Sloan Hall, Room 101
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16. ABSTRACT

The effects of the highway deicing activities on the Peshastin Creek watershed were studied over a 6-month period from December 1999 to May 2000. Three threatened and/or endangered species: steelhead (*Oncorhynchus tshawytscha*), Chinook salmon (*Oncorhynchus mykiss*) and bull trout (*Salvelinus confluentus*) inhabit the stream and, therefore, a study of the effects of deicing activities was warranted. Five reaches along Peshastin Creek and its tributaries were selected for the collection of weekly grab samples and three of these reaches were outfitted with continuous monitoring equipment. Water quality tests, Microtox® toxicity tests, benthic macro invertebrate enumeration and streambed substrate sieve analyses were used to evaluate the influence of deicing activities (application of traction sand and IceBAN, a liquid deicer) on Peshastin Creek. Chloride exhibited signs of preferential elution and was also found to be significantly higher in concentration in areas adjacent to the US Highway 97. The maximum recorded chloride concentration in Peshastin Creek was 3.3 and 2.7 mg/L at reach 2 and Reach 4, respectively. The non-impacted reaches of Peshastin yielded an average chloride concentration of 0.62 mg/L. Heavy metal concentrations (soluble and total) were much lower than the US EPA recommended limits. The benthic macro invertebrate study, although qualitative in nature, suggested that the deicing activities did not adversely impact the three fish food organisms that were quantified. Streambed substrate analyses indicated that the traction sand used in deicing activities had no measurable negative impact on known spawning locations. The physical, chemical, and biological parameters evaluated in this study indicate that deicing activities along SR 97 had no measurable negative impact on Peshastin Creek.

17. KEY WORDS

Highway deicing, stream impact, deicer toxicity, highway sanding

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EXECUTIVE SUMMARY

With the passage of the Endangered Species Act of 1973, government agencies must insure that any action they take is not “likely to jeopardize the continued existence… or result in the destruction or adverse modification of critical habitat proposed to be designated to such species” (ESA, 1973). Therefore, when deicing activities have the potential to impact the habitat of endangered aquatic species, concerns about water quality, sedimentation and the biological diversity in the stream must be addressed. This research report presents data that was collected to enable an evaluation of the impact of traction sand and IceBAN on Peshastin Creek; a stream located along SR 97 on the eastern slope of the Cascade Mountains in Washington. Three general indices were used to evaluate impact.

1. Water chemistry
2. Streambed sediment
3. Macro invertebrate number
4. Toxicity of deicers

Values within the impacted reach of Peshastin Creek were compared to those obtained in a background (non-impacted) section. No observed degradation in water quality, streambed sediment quality or macro invertebrate numbers were observed. Using chloride as an indicator of IceBAN introduction into the stream, a maximum in-stream IceBAN concentration was found to be 11.2 mg/L in Peshastin Creek. Using a measured ultimate carbonaceous BOD (CBODU) for IceBAN of 67,147 mg/L, the in-stream CBODU was estimated to be 0.54 mg/L with a BOD_5 of 0.04 mg/L; these values are below the commonly accepted BOD method detection limit of 1 to 2 mg/L. The streambed sediment particle size distribution in the impacted section of the creek was found to be similar to that in the non-impacted reach, indicating that no measurable detrimental impact from sanding operations was apparent. This may not be the case in lower velocity streams, and care should be taken when applying traction sand in sensitive areas. Although the macro invertebrate enumeration yielded qualitative data, there was no decrease in numbers between the background and impacted sections of Peshastin Creek. In fact, there was a statistically significant increase in two of the three species enumerated. The Microtox® bioassay procedure indicated that IceBAN had a toxic response (EC_{50}) at a concentration of 4850 mg/L, similar to calcium-magnesium acetate (CMA) which showed an EC_{50} of 4700 mg/L. The IceBAN EC_{50} was significantly less than the maximum estimated in-stream concentration of 11.2 mg/L.

INTRODUCTION

Chemical deicers and abrasives have been used extensively throughout the Northern United States to provide safety during wintertime travel. In the 1960s, the widespread use of rock salt in some areas led to detrimental effects to the environment that were recorded as aquifer contamination, vegetation destruction and/or soil degradation (Schraufnagel, 1967). More recent studies have focused on the impacts on surface waters. Through the 1970s and 1980s, the effects of deicers on aquatic species such as fish and benthic macro invertebrates were studied (Hawkins and Judd, 1972; Molles, 1980; Hoffman et al., 1981). In the late 1980s and 1990s, the environmental impacts of “new” deicers such as calcium magnesium acetate (CMA) were explored (McFarland and O’Reilly, 1992). Recently, Novotney et al. (1999) created a comprehensive guide to minimizing the impacts of deicing activities on the environment.

Although studies show that deicing activities can negatively impact areas adjacent to highways, less information is available regarding surface water impacts. With the passage of the Endangered Species Act of 1973, government agencies must insure that any action they take is not “likely to jeopardize the continued existence… or result in the destruction or adverse modification of critical habitat proposed to be designated to such species” (ESA, 1973). Therefore, when deicing activities have the potential to impact the habitat of endangered aquatic species, concerns about water quality, sedimentation and the biological diversity in the stream must be addressed. This research report presents data that was collected to enable an evaluation of the impact of traction sand and IceBAN on Peshastin Creek; a stream located along SR 97 on the eastern slope of the Cascade Mountains in Washington.

REVIEW OF LITERATURE

The primary function of a chemical deicer is to melt ice and snow on the roadway by lowering the freezing point of the snow-salt mixture. Abrasives aid travel on snow-covered roads by increasing the traction between the ice and an automobile’s tires. Historically, the application of abrasives was the only method used to increase driver safety. By the 1960s, most of the highway departments in the US adopted a ‘bare pavement’ policy, which requires a highway department to keep a roadway free from ice and snow buildup whenever possible. Following the implementations of this policy, the use of chemical deicers increased significantly (Novotny et al., 1999; U.S. EPA, 1971; U.S. EPA, 1973).

The primary chemical deicers in use today are sodium chloride, calcium chloride, magnesium chloride and calcium magnesium acetate (CMA). Other chemicals such as anti-caking agents and proprietary corrosion inhibitors are mixed in small proportions (< 5%) with some of these deicers. Granular deicers, such as rock salt, which is approximately 95 percent sodium chloride, are usually mixed with abrasives and spread out with a sanding truck. Calcium chloride, magnesium chloride and CMA are often used in a liquid form and can be sprayed onto problem areas (Novotny et al., 1999).

Pollutant Accumulation

Pollutants accumulate in snow banks from atmospheric deposition, deicing chemicals, additives and abrasives and the emissions and corrosion from vehicles. As snowflakes fall to the ground, they collect atmospheric pollutants such as sulfate and nitrate. After the snow collects on a roadway, other pollutants such as deicers, heavy metals and hydrocarbons collect in the snow pack. This accumulation coupled with repeated plowing operations throughout the winter creates snow piles adjacent to the roadway that can contain relatively high contaminant concentrations (e.g., 3,851 to 12,005 mg/L for chloride) (Colbeck, 1981; Novotny et al., 1999).

The pollutants can migrate to the nearby aquatic habitats via periodic melt events. These melt events can be either chemically induced or temperature induced, and when dealing with roads, the melt events are usually induced by both factors. Oberts (1994) describes the snowmelt associated with deicing as having three separate predictable stages. The first stage is known as pavement melt and is usually chemically induced, but may also be a result of solar radiation on the paved areas. This melt can take place several times a season and is characterized by relatively high pollutant concentrations and low flows. The second stage following pavement melt is termed roadside melt. This melt involves the more gradual melting of the snow piles adjacent to the pavement. Roadside melt can be both chemically induced due to the deposition of deicers in the snow piles by plowing activities and temperature induced by solar radiation. Relatively moderate pollutant levels and higher flows characterize this melt. Pervious area melt, the final stage, refers to the snow melt that usually takes place greater than three meters away from the roads and is characterized by relatively low concentrations of constituents of concern. Usually, some fraction of the meltwater from these pervious areas will infiltrate into the soil and the remaining fraction will contribute to surface runoff.

Preferential Elution

In the pollutant loaded snow piles adjacent to the roads, where roadside melt occurs, a snowmelt enrichment phenomenon takes place. During the winter season, snowflakes in the snowpack begin to change to create larger round ice granules. As this happens, the specific surface area of the snow decreases and the grain boundaries begin to migrate. The pollutants tend to become segregated from the snow crystals during freeze thaw cycles, and are not incorporated into the crystalline lattice during re-crystallization. Ions and other impurities concentrate on the surface of these snow grains. As temperatures increase, a ‘wetted front’ propagates downward into the snowpack and collects the pollutants from the surfaces of the snow grains. When this wetted front reaches the snow-soil interface, it is characterized by high concentrations of soluble pollutants, relative to the original concentration in the snow piles. The initial 20-30% of meltwater from such a snowpack may remove 40-80% of the pollutants that are retained in the snowpack. This process of snowmelt enrichment has been well documented (Johannsenn and Henriksen, 1978; Colbeck, 1981; Hibberd, 1984; Morris and Thomas, 1985; Brimblecombe et al., 1987). All of the solutes contained in roadside snow piles are not removed at the same rate, and therefore the enrichment is not the same for all pollutants. Studies indicate an anion elution sequence of $SO_4^{2-} > NO_3^- > Cl^-$, and a cation sequence of $K^+ > Ca^{2+} > Mg^{2+} > Na^+$ (Novotny et al., 1999). Therefore, the term ‘preferential elution’ is most often used to describe this phenomenon today (Brimblecombe et al., 1987; Oberts, 1994; Novotny et al., 1999).

Infiltration and Runoff

Snowmelt infiltration into the soil occurs at the snow-soil interface and usually continues until the soil becomes saturated. Infiltration can vary from 0 to 100 percent depending upon the degree of saturation of the soil at freeze-up. In certain cases, infiltration can drop to zero percent if the soil was totally saturated upon freeze-up. This creates an impermeable layer at the snow-soil interface and causes virtually all of the melt water to travel down gradient into nearby receiving waters, if present (Colbeck, 1981; Oberts, 1994). Runoff resulting from this phenomenon would result in direct deicer input into the receiving streams and yield a "worst case" scenario regarding potential environmental impact.

Environmental Impacts

Deicing activities have the potential to create three types of impacts: chemical, biological and physical. These impacts are interrelated (e.g., a change in the water chemistry can be toxic to fish and/or fish food organisms). Therefore, the impacts of some of the major pollutants (chloride, acidity, cyanide from anti-caking additives, heavy metals, and abrasives) will be discussed in the following sections.

Chloride

Chemical deicers that enter receiving streams can change the chemical composition of the water. Since chloride salts make up the majority of the chemical deicers used today, the potential for chloride contamination can be significant. Studies indicate that the acute toxicity of chlorides for benthic macro invertebrates ranged from 2,165 mg/L to greater than 3,000 mg/L (Novotny et al., 1999). Sodium chloride was found to be acutely toxic to mature trout at a concentration of greater than 25,000 mg/L and acutely toxic to newly hatched trout at a concentration of 5,000 mg/L where there was 100 percent mortality in 24 hours in both cases (Hanes et al., 1970). Therefore, the US Environmental Protection Agency (EPA) has developed the National Recommended Water Quality Criteria (henceforth referred to as Criteria) for chloride in freshwater. The concentrations are 860 mg/L for the Criteria Maximum Concentration (CMC) and 230 mg/L for the Criteria Continuous Concentration (CCC).

Typical chloride concentrations in unpolluted river waters range from below detection to 15 mg/L (Hanes et al., 1970). In some cases, in-stream chloride concentrations can be relatively high due to snowmelt runoff. The chloride concentrations in streams in Milwaukee, Wisconsin that are adjacent to heavily salted roadways have been shown to range from 200 mg/L to 2,730 mg/L (U.S. EPA, 1973). However, there is very little published evidence where deicer-laden runoff has exceeded either the CMC or CCC for chloride. For example, thpical spring thaw events in the central Sierra Nevada Mountains resulted in maximum in-stream chloride concentrations that range from 70 to 500 mg/L (Hoffman et al., 1981; Henry et al., 1991).

Acidity

Acid forming ions such as nitrate and sulfate can create an acidic pulse of meltwater that may have a detrimental effect on water quality and aquatic life in poorly buffered streams. The pH was shown to drop from 7.5 to 4.5 in a New Jersey stream during a melt event. These short-term pH depressions can cause a high mortality rate in newly hatched fish (Stansley and Cooper, 1990). This pH depression could be significant for fish species that spawn in the early spring. However, contaminated meltwater containing deicers, sediment, and other pollutants can actually add buffer capacity to the system, which would resist significant pH change. Consequently, highly contaminated melt events from highways typically do not produce a pH depression (Novotny et al., 1999).

Additives

Chemical deicers are often amended with additives, which act as anticaking agents or corrosion inhibitors. Anticaking agents are usually added to granular sodium chloride. The most common anticaking agents are ferric ferrocyanide (Prussian blue) and sodium ferrocyanide (yellow prussiate of soda or YPS). They serve to keep the granules from becoming a hard, unusable mass of salt, and are usually added to rock salt in the amount of 50 to 250 ppm (mg/kg). These chemicals alone are considered nontoxic, but research shows that they can release free cyanide through photolysis (Schraufnagel, 1967). Although these anticaking agents are still used in some parts of the country, their use has diminished significantly since the 1960s (U.S. EPA, 1971).

Heavy metals

Heavy metals such as copper, lead and zinc exist in several forms including particulate and dissolved, and inorganically and organically complexed (bound). The bioavailability and toxicity will vary with the form of the metal. Free ionic metals are generally the most bioavailable and, therefore, the most toxic forms. In many systems however, only a small fraction of the total metals concentration exists in this form. The rest of the metals are usually present in particulate or strongly complexed (organic) forms. These metals are normally considered to be non-bioavailable and nontoxic but with a change in chemical conditions they can dissociate and become bioavailable (Paulson and Amy, 1993). In fact, research has shown that cold temperatures and an increase in salinity decrease the partition coefficient (increases free ionic form) for metals. Therefore, in the winter months with the presence of sodium chloride, there could be a relatively higher proportion of these heavy metals in the free ionic form (Warren and Zimmerman, 1994; Novotny et al., 1999).

Hardness, however, decreases the toxicity of metals and if the receiving water has a sufficiently high concentration of calcium, and magnesium ions, the toxicity of the heavy metals will decrease. Also, if deicing compounds that produce magnesium and calcium ions in solution are used, they could increase the hardness of the receiving waters and decrease the toxicity of the metals in the stream (Novotny et al., 1999).

Abrasives

The application of abrasives is the most common method for enhancing driver safety on roadways. Sand, the most common abrasive used today, is spread out on snow and ice covered roads to provide traction. This sand, however, can have significant adverse impacts on aquatic systems. Through repeated applications and plowings, large amounts of traction sand are deposited along side the roadways. If this sand enters an aquatic system, it could become a significant source of sediment pollution. Molles (1980) noted in a study 15 km north of Santa Fe New Mexico, that a reduction in individual invertebrate numbers was most likely caused by sedimentation from sanding operations rather than chemical changes from the input of deicers. He also suggested that spring inputs of traction sand could be expected to asphyxiate the eggs of spring spawning trout. Specifically, it has been shown that salmon egg survival is significantly reduced when 10 - 20 percent (by weight) of a streams substrate is composed of sediment less than 0.85 mm in diameter (Reiser and White, 1988; Chapman, 1988). Therefore, depending on the particle size distribution of the traction sand, it could negatively impact the salmon egg viability.

Based on the preceding summary, there is sufficient evidence to suggest potential negative environmental impacts from the deicing activities along United States Highway 97 (Highway 97). Data, however, for the deicers being used and for the location in the northwest is sparse to non-existent. Therefore, a study was conducted from December 1999 to May

2000 to survey the effects of deicing activities on Peshastin Creek, located on the Eastern Slope of the Cascade Mountains in Washington State. The study area centered upon Highway 97and the adjacent receiving waters (Peshastin Creek and its tributaries). The Peshastin Creek drainage was selected because of its close proximity to Highway 97, the existence of the threatened and/or endangered species of steelhead, Chinook salmon and bull trout (*Oncorhynchus tshawytscha*, *Oncorhynchus mykiss* and *Salvelinus confluentus*) that inhabit the stream, and a relatively low stream flow. This report presents the data collected at five sampling locations in Peshastin Creek and its tributaries in an effort to evaluate the impact of deicing activities on SR 97.

EXPERIMENTAL METHODS

Site Location and Description

Several potential monitoring sites were evaluated and Peshastin Creek was selected because of the presence of three threatened and/or endangered fish species, its close proximity to Highway 97, the presence of 'background' reaches and its relatively low stream flow. Five sampling locations were selected: Tronsen, Reach 1, Reach 2, Reach 3 and Reach 4 (Figure 1). The Tronsen site was located on Tronsen Creek approximately 100 m upstream from its confluence with Peshastin Creek. Reach 1, utilized as the background sampling point for Peshastin Creek, was located approximately 100 m upstream from the confluence of Tronsen Creek and Highway 97, with a longitude and latitude of N47°23′44.9″ and W120°39′21.5″. This site was located in the headwaters of Peshastin Creek where no deicing activities took place. Reach 2 was located approximately 1.5 km downstream from the confluence of Tronsen and Peshastin Creeks and had a longitude and latitude of N47°24′34.7″ and W120°39′31.1″. Reach 3 was located on Ingalls Creek approximately 300 m upstream from its confluence with Peshastin Creek and had a longitude and latitude of N47°27′50.8″ and W120°39′59.6″. Ingalls Creek is the largest tributary of Peshastin Creek and is a very pristine stream because it flows out of a wilderness area that does not contain roads. Reach 4, at a longitude and latitude of N47°31′03.4″ and W120°37′32.7″, was most downstream sampling location on Peshastin Creek, and was in close proximity to known salmon redds.

Continuous Water Quality Monitoring

An automatic Sigma 960 stream flow meter and data collector was placed at Reaches 2, 3 and 4, resulting in 3 continuous monitoring stations. Each station was set up to record conductivity, pH, stream stage, water temperature, and precipitation. Automatic samplers were also set up that could trigger a sampling event based on percent change in conductivity. In addition, weekly grab samples were collected at each of the five sampling sites to gain information regarding the temporal and spatial variations in water quality. The samples were collected in 1000 mL Nalgene bottles as per Standard Methods, paced in ice and and shipped to the laboratory for subsequent analysis. The average time between sample collection and analysis was approximately 48 hours (*Standard Methods for the Examination of Water and Wastewater*, 1995).

Stream Flow

Stream flow was calculated by using the stage data recorded by the data loggers and stage discharge curves. The stage discharge curves were constructed by gauging the stream with a portable current meter (Marsh-McBirney, Inc. Model 2000) and correlating the discharge to the stream stage data. Reaches 2 and 4 were each gauged on three occasions, Reach 3 was gauged on two occasions and Reaches 1 and Tronsen were each gauged once. Linear regression was then used to define the stage discharge curve. The flow was essentially the same during the two gauging events at Reach 3 and a stage discharge curve was not developed. Instead, Manning's equation, in combination with stream configuration measurements (slope and profile), was used to estimate the flow at Reach 3. The flow at Reach 1 and Tronsen were estimated using the measured flow at Reach 2 and the stream gauging data at Tronsen, Reach 1, and Reach 2 that indicated that flow at Reach 2 results from an approximate 33% contribution from Tronsen Creek and 67% from upper Peshastin Creek (see Appendix A). The five-minute stage readings from the continuous monitoring equipment were averaged over each day that a grab sample was taken and the average daily stage was then used to determine an average daily stream flow.

Water Quality Determination

Standard water quality constituents (alkalinity, turbidity, pH, conductivity and total dissolved solids) and other constituents (chloride and eight metals) were quantified in each weekly grab sample.

Before each of the standard tests were performed, the samples were shaken 20 times and allowed to stand for 30 seconds to permit any large particles to settle. Then, aliquots were taken for each of the tests. Alkalinity and total dissolved solids was determined as per Standard Methods 2320 B and 2540 C, respectively. Turbidity was measured with a Hach 2100AN Turbidimeter as per the operation manual and Standard Methods 2130 B. An Orion 210A pH meter was used to measure the pH as per the Orion users manual and Standard Methods 4500 – H^+ B. A hand-held Control Company Model 06-662-61 automatic temperature compensating conductivity meter was used to measure the conductivity of each sample as per the users manual and Standard Methods 2510 B (*Standard Methods for the Examination of Water and Wastewater*, 1995).

Blanks, consisting of deionized water were run along with each weekly sample set to provide quality control. Three sets of weekly samples were also tested in triplicate to determine the standard error of the procedures.

Ion Determination

A Dionex DX-120 ion chromatograph with an IonPac® AS12A, 4-mm column, along with a 2.7 mM Na_2CO_3 + 0.3 mM $NaHCO_3$ eluent, was used to determine the anion concentrations in the samples. Each sample was filtered through a 0.45 μm filter before being loaded into the sample vials. Standards were prepared as per Standard Methods and three sets of standards were run with each set of aliquots; a set at the beginning and end and a set that was interspersed with the samples to ensure quality control (*Standard Methods for the Examination of Water and Wastewater*, 1995). In addition, blanks consisting of deionized water were run along with each weekly sample set to provide quality control.

Total and soluble metal concentrations were determined for copper, lead, zinc, cadmium, calcium, sodium, magnesium and iron. The sample preparation for both total and soluble metals was per EPA Method 200.7 with the exception of mixing the total metals samples on a wrist-action shaker for 2 hours in order to allow them to equilibrate. The prepared samples were then run on an HP 4500 Series ICPMS with the standards being quantified every 20 samples. Acid blanks consisting of the acid used in preparing the samples were run along with each weekly sample set.

Toxicity Studies

A Microtox® acute toxicity study was performed to determine the acute toxicity of NaCl, $CaCl_2$, IceBAN, and CMA. The test consisted of exposing the Microtox® test organism, the luminescent marine bacteria *Vibrio fischeri*, to dilutions of a known concentration of the sample. A concentration that was lethal to 50% of the population, which was reported as an effective concentration or EC_{50}, could then be calculated. The 90% Sample Concentration Basic Test was performed on 100 mg/L samples of each deicer to determine its specific EC_{50} at 5, 15 and 30 minutes. A comparison was then made to determine the relative toxicity values of the deicers.

The dilution water used in the toxicity testing was a simulated stream water created as per Standard Methods Table 8010:I (*Standard Methods for the Examination of Water and Wastewater*, 1995). The reconstituted fresh water type was chosen to be arithmetically centered between moderately hard water and hard water to best replicate the measured alkalinity of the actual stream water.

Benthic Macro Invertebrate Studies

Benthic macro invertebrates were collected on March 13, 2000 and June 7, 2000 using multiple plate artificial substrate samplers at Reaches 1, 2 and 4. The multiple plate artificial substrate samplers were made of 14 square pieces of water-resistant, tempered hardboard with a total surface area of 0.16 m^2. The collection was performed as per Standard Methods 10500 B and *An Introduction to the Aquatic Insects of North America* (ed. Merritt and Cummins, 1996). During the first sampling period, seven samplers were deployed linearly along a one meter section of the stream bank and allowed to colonize for a period of 13 weeks. During the second sampling period, three clusters of three samplers each were deployed linearly along a one meter section of the stream bank and allowed to colonize for 13 weeks. After collection and preservation with alcohol, the macro invertebrates were then enumerated and sorted by their orders (*Ephemeroptera*, *Plecoptera* and *Trichoptera*). Due to the limited number of sampling periods, the data was considered to be qualitative.

Stream Bed Sediment Studies

Three sediment samples (triplicates) were collected on March 16, 2000 and on June 7, 2000 at four different sampling locations on Peshastin Creek. The first and second sampling locations were in the vicinity of a known salmon spawning location (longitude and latitude of N47°29′04.1″ and W120°39′09.9″). The third location was adjacent to Highway 97 at a longitude and latitude of N47°28′13.8″ and W120°39′27.1″ (refer to Figure 1), and the fourth sampling location was at Reach 1. Each sediment sample was taken from the streambed with a shovel and placed in a plastic 5-gallon bucket. Care was taken to minimize the loss of any fine sediment during collection. A sample of traction sand was also obtained from the sand pile at the Washington State Department of Transportation (WSDOT) maintenance shed on Highway 97.

Sieve analyses were then performed on each sample as per the methods outlined in *Experimental Soil Mechanics* (Bardet, 1989). Ten standard sieves (72.0, 32.0, 26.67, 19.1, 9.51, 6.35, 4.75, 2.0, 0.850, 0.210 mm) were used to produce grain size distributions charts. The triplicate sample data was used to determine mean, standard deviation, and confidence interval for each sampling location.

Deicers

The primary deicer that was being used by WSDOT on Highway 97 was IceBAN. The IceBAN that was used consisted of approximately 37% (wt.) calcium chloride with the remainder consisting of a natural liquid by-product from the wet milling of corn. The product had a dark molasses-like color, a thick consistency (density = 1.4 mg/mL) and had a fermented odor. Granular calcium magnesium acetate (CMA) was also obtained from WSDOT. This product consisted of approximately 91% CMA and 9% insoluble binding material. Reagent grade sodium chloride and calcium chloride were also used in the toxicity tests.

Ultimate Carbonaceous BOD

Since IceBAN is formulated from a corn milling waste product it would be expected to contain significant organic carbon. Consequently, ultimate carbonaceous BOD (CBODU) was determined using an experimental protocol based on Standard Methods, procedure 5210-C using standard 300 mL BOD bottles (*Standard Methods for the Examination of Water and Wastewater*, 1995). This method was modified by collecting samples for nitrate quantification at each dissolved oxygen (DO) reading period that occurred every 7 to 10 days. Samples were prepared at two dilutions and triplicate bottles were used to replicate each dilution. An additional ‘sacrifice’ bottle was added for each triplicate set and was used to replace sample volume lost during each reading period. Each sample set also contained a bottle spiked with a solution of glucose and glutamic acid and triplicate dilution water blanks for quality control. When the DO fell below approximately 2 mg/L in the sample bottles, the contents was re-aerated with purified compressed air passed through a fritted glass air stone.

Oxygen demand exerted during the nitrification of ammonia to nitrate was subtracted from the demand exerted by the biochemical oxidation of organic carbon to enable the generation of CBOD data. The complete nitrification of ammonia to nitrate is described in Equation 1.

$$\mathrm{NH_3} + 2\mathrm{O_2} \rightarrow \mathrm{NO_3^-} + \mathrm{H_3O^+} \qquad (1)$$

It can be seen that 2 moles of oxygen are required per mole of ammonia, forming 1 mole of nitrate. Expressing this relationship on a mass basis we have

$$\frac{2\,\mathrm{mol\,O_2}}{\mathrm{mol\,NO_3^-}} \bullet \frac{32\,{}^{\mathrm{g}}\!/\!_{\mathrm{mol}}}{62\,{}^{\mathrm{g}}\!/\!_{\mathrm{mol}}} = \frac{64}{62} = 1.03\,\frac{gO_2}{gNO_3^-}. \qquad (2)$$

This conversion factor (1.03) was used to calculate the mg of dissolved oxygen consumed by multiplying by the measured nitrate concentration at each dissolved oxygen measurement period. The resulting value was subtracted from the measured oxygen uptake as shown in Equation 3. It should be noted that after re-aeration of a sample, the initial nitrate (N_i) was re-set to that concentration measured during the sampling period just prior to the re-aeration period and the initial DO concentration (DO_i) became the value measured immediately following re-aeration.

$$CBOD = \frac{(DO_i - DO_t) - (N_t - N_i) \bullet 1.03}{P}$$

where
$CBOD =$ carbonaceous BOD (mg/L)
$DO_i =$ initial dissolved oxygen concentration (mg/L) (3)
$DO_t =$ dissolved oxygen concentration at measurement period, t (mg/L)
$N_t =$ nitrate concentration at measurement period, t (mg/L)
$\mathrm{N_i} =$ initial nitrate concentration (mg/L)
$P = \text{dilution factor} = \frac{\text{volume sample}}{300\text{ mL}}$

Ultimate carbonaceous BOD was estimated by using Equation 4, the "standard" first order BOD equation. *Lo* and *k* were used as fitting parameters to minimize the residual sum of squares between the measured and predicted CBOD values through nonlinear regression analysis.

$$BOD = L_0\left(1 - e^{-kt}\right)$$

where (4)
$L_0 =$ ultimate BOD (mg/L)
$k =$ first order rate constant (t^{-1})
$t =$ time

Oxygen demand was monitored throughout the duration of the experiment and the experiment was considered complete when a negligible decrease in DO (≤ 0.15 mg/L) was observed relative to the previous measurement period.

RESULTS AND DISCUSSION

General Trends

Weekly grab samples were used to define constituent concentrations as a function of time while the stage data were used to determine stream flow (Figure 2). The data in Table 1 show the average and the range of values for the constituents of the weekly grab samples. Tronsen Creek exhibited the highest concentrations of general water quality parameters (alkalinity, conductivity, chloride, TDS, and turbidity) while maintaining the lowest stream flow (0.12 – 1.22 m^3/s). Constituent concentrations were found to be the lowest in the background reaches (1 and 3), which are not adjacent to Highway 97. Intermediate concentrations were observed in Reaches 2 and 4, a result of the dilution from Upper Peshastin Creek (Reach 1) and Ingalls Creek (Reach 3).

The data in Figure 3 presents the chloride concentration from the Tronsen, Reach 1 and Reach 2 sampling locations, along with the stream flow at Tronsen. It can be seen that the chloride concentrations at the Tronsen location are significantly greater than at Reach 1 (the Peshastin background sample location). This difference is of interest since Tronsen Creek receives meltwater from Highway 97 and Reach 1 is not influenced by highway runoff. It is reasonable to conclude, therefore, that chloride from highway runoff, likely a result of deicing activities, exist at detectable levels.

Evidence of preferential elution can be observed in Figures 3 and 4. It can be seen that the maximum concentration in chloride occurs prior to the maximum flow. In fact, chloride concentration at Reach 4 increases significantly prior to any measurable increase in flow (from the period of January 23 through February 26). These data indicate that meltwater containing chloride is the first to migrate to the stream, suggesting that the snow piles along the roadway were beginning to melt and contribute constituents at the earliest stages of the spring melt.. The chloride concentrations peaked prior to the flow peak and begin to decrease as flow increases. These trends were not observed in the background reaches. The data for Reach 1 (Figure 3) indicates that the chloride concentration remains relatively constant (between 0.6 and 0.8 mg/L) from January 17, 2000 to February 26, 2000. As the stream flow increases, the chloride concentration decreased to approximately 0.5 mg/L, a result of dilution from the melting snow pack in the background reach.

Conductivity and alkalinity responded in a similar fashion, but the TDS concentrations varied with no apparent trend and presented no clear trends over the study period. The pH values ranged from approximately 7 to 8 for all of the reaches.

Estimation of In-Stream IceBAN Concentration

Maximum in-stream IceBAN concentrations were estimated at Reach 2 and Reach 4 by assuming that any increase in chloride concentration above a "natural" background level was due to the chloride present in the IceBAN formulation (0.24 mg Cl^-/mg IceBAN). The background or "naturally occurring" chloride concentration in Peshastin Creek was assumed to be similar to the concentration in Reach 1 (non-impacted reach of Peshastin Creek) that was shown to remain relatively constant over the entire study period (Figure 3), yielding an average concentration of 0.62 mg/L. The maximum observed chloride concentration at Reach 2 was observed to be 3.3 mg/L and 2.7 mg/L at Reach 4 on 3/6/00. The IceBAN concentration at Reach 2 and Reach 4 was estimated using the following approach.

$$C_{IB} = \frac{C_{R2} - C_{BG}}{F_{Cl^-}}$$

where

C_{IB} = IceBAN concentration (mg/L) (5)

C_{R2} = chloride concentration at reach 2 (mg/L)

C_{BG} = background chloride concentration (mg/L)

F_{Cl^-} = fraction chloride in IceBAN (0.24 mg/mg).

Application of this equation results in an in-stream IceBAN concentration on March 6, 2000 of 11.2 mg/L and 8.7 mg/L for Reach 2 and Reach 4, respectively. It should be noted that this approach assumes:

1. IceBAN is the only source of chloride above background concentrations.
2. All components of IceBAN are transmitted to the stream in a conservative manner (i.e., no retention of the non-chloride fraction of IceBAN as the meltwater migrates toward the stream.

These assumptions result in a conservative estimate of the likely in-stream IceBAN concentration as there may be other sources of chloride other than IceBAN and some retention of other IceBAN constituents would be expected as the meltwater travels toward Peshastin Creek.

Estimation of IceBAN Input per km of Highway

Input of IceBAN per km of stream was estimated by performing a chloride mass balance around the drainage from Reach 2 to Reach 4. Measured flow and chloride concentrations at Reach 2, 3, and 4 were used to solve for a source term 'S' that described chloride mass input per unit time into this reach of Peshastin Creek. Chloride mass was converted to IceBAN mass by dividing by the conversion, 0.24 mg Cl^-/mg IceBAN. Steady state was assumed, yielding the following result.

$$0 = Q_{R2}C_{R2} + Q_{R3}C_{R3} + S - Q_{R4}C_{R4}$$

where

$$\begin{aligned}
&Q_R = \text{flow at reach 2, 3 or 4 (cms)} && (6)\\
&C_R = \text{chloride concentration at reach 2, 3 or 4 (cms)}\\
&S = \text{ chloride source term that represents mass per time of chloride entering}\\
&\text{the stream between reach 2 and 4 (mass per time)}
\end{aligned}$$

The highest chloride input occurred on March 6, 2000. Applying flow and concentration data for this time period and solving for S yields:

$$\begin{aligned}
&S = Q_{R4}C_{R4} - Q_{R2}C_{R2} - Q_{R3}C_{R3}\\
&S = \left(2.33cms(2.7mg/L) - 1.22cms(3.3mg/L) - 0.76cms(0.8mg/L)\right)1000L/m^3 \qquad (7)\\
&S = 1650mg/s = 5.9kg/hr
\end{aligned}$$

Approximate highway distance between Reach 2 and 4 was 12.8 km. Therefore, the chloride mass input rate per km (M_{IB}) is 0.46 kg/km•hr (M_{IB} = S/12.8 km) during the highest recorded chloride concentration period (March 6, 2000). If we assume that the IceBAN is conserved during transport to the stream, its' mass input rate can be determined by dividing M_{IB} by F_{Cl-} yielding 1.9 kg/km•hr.

Toxicity

The data in Table 2 summarizes the Microtox® acute toxicity for IceBAN, CMA, sodium chloride and calcium chloride. These toxicity values are also compared to species toxicity data (Table 2). According to the toxicity values, IceBAN has approximately the same EC_{50} as CMA (4850 mg/L and 4700 mg/L, respectively). However, the toxicity of IceBAN on a species such as *Oncorhynchus mykiss* (rainbow trout) has not been determined. Nevertheless, the estimated in-stream IceBAN concentration would needed to be approximately 433 to 557 greater than the highest observed value to create an acutely toxic environment for the Microtox® test bacteria, *Vibrio fischeri*.

Since chloride can be toxic at high concentrations, the US EPA has developed National Recommended Water Quality Criteria for Chloride. The CMC for chloride is 860 mg/L and the CCC is 230 mg/L. As noted in Figure 1, Tronsen Creek had the maximum chloride concentration of 8.2 mg/L and the largest average chloride concentration of 5.0 mg/L. Therefore, the maximum concentration of chloride needed to produce chloride toxicity in Tronsen Creek based on CMC is approximately 104 times larger than was found in the stream. The *average* long-term concentration of chloride would have to be approximately 46 times larger to produce a toxic effect. Similarly, the chloride concentration in Peshastin Creek would have to be approximately 260 times greater than the highest recorded concentration of 3.3 mg/L at Reach 2 on March 6, 2000, to exceed the CMC.

Metals

Overall, the metals were found to be at relatively low concentrations. Figure 6 and Tables 3, 4 and 5 summarize the study findings. The data in Table 3 summarizes the average and range of values for the total and soluble heavy metals that were quantified in this study (Copper, Lead, Zinc and Cadmium). Copper and zinc concentrations were generally greater than lead and cadmium. A comparison between the maximum soluble in-stream concentrations and the average soluble in-stream concentration can be found in Table 4. Table 4 also contains the US EPA National Recommended Water Quality Criteria. The CMC corresponds to the maximum soluble in-stream concentration and the CCC corresponds to the average soluble in-stream concentration. The Criteria values are, for the most part, approximately one order of magnitude higher than the corresponding measured in-stream soluble metal concentrations.

The maximum total recoverable copper concentration was recorded on April 4, 2000 as 16.8 μg/L in Tronsen Creek. The corresponding soluble copper concentration was 1.15 μg/L. Figure 6 compares the total and soluble fractions of copper with the stream flow over time and is representative of the trends observed for Zn, Cd, and Pb. The soluble fraction of copper remains reasonably constant relative to the total concentration, which increases significantly with the stream flow. Also, the total heavy metal concentrations were proportional to turbidity, (Figure 5) as would be expected.

Table 5 summarizes the data for the four ‘common’ metals (sodium, calcium, magnesium and iron) that were studied. Calcium, magnesium and sodium exhibited signs of preferential elution (see Figure 7 and Table 5), however no apparent elution order could be determined. Although these common metals are non-toxic at their measured concentrations, the data represented in Figure 7 suggests that the increases in calcium, magnesium and sodium produce a slight increase in soluble zinc and copper. These modest increases in soluble copper and zinc could be the result of cation exchange reactions with calcium, magnesium and sodium. This trend is supported by previous research showing that an increase in salinity could increase the proportion of soluble heavy metals (Warren and Zimmerman, 1994; Novotny et al., 1999). However, there are no apparent influences on the soluble lead and cadmium concentrations. Therefore, it cannot be definitely determined from this data if the calcium, magnesium and sodium concentrations directly influence soluble heavy metal concentrations. Furthermore, due to the very low concentrations of all the metals, a slight increase in their concentrations should not present any toxic effects in Peshastin Creek.

Benthic Macro invertebrates

The data in Figure 8 shows the results from the first sampling of benthic macro invertebrates. The analysis of the benthic macro invertebrates was qualitative in nature due to the relatively small number of samples and the short time frame. The high variability of the data is indicated by the confidence interval bars ($\alpha = 0.05$) in Figure 8. However, the data do not indicate a decrease in invertebrate numbers in areas that receive highway snowmelt runoff relative to the background (Reach 1). Rather, they show that the *Ephemeroptera* and *Tricoptera* numbers are significantly greater ($\alpha = 0.05$) at Reach 2 than Reach 1. All three orders were significantly greater at Reach 4 than Reach 1. Also, the total number of organisms collected increased from 15 to 69 to 80 at Reaches 1, 2 and 3, respectively.

The second sample set consisting of 3 clusters of 3 samplers at each reach produced similar results. The *Ephemeroptera* and the *Plecoptera* orders were significantly higher at Reach 2 than at Reach 1 and all of the orders were significantly higher at Reach 4 than Reach 1. Also, the *Ephemeroptera* numbers were significantly higher at Reach 4 than at Reach 2. The total number of organisms collected at Reaches 1, 2 and 4 was 6, 31 and 108, respectively. The total numbers were smaller at Reaches 1 and 2 during the second sampling because of poor sampler placement at Reach 1 during the second sampling and the fact that one cluster of samplers was lost at Reach 2 during the spring melt event. The data from the second sampling event coincide with the first, indicating no decrease in benthic macro invertebrate numbers in the impacted reach of Peshastin Creek versus the background reach.

Sedimentation

The data in Figure 9 show the average grain size distributions for the three sediment sample locations (see Figure 1), the background reach and the traction sand. The percent mass of the samples that was finer than 0.850 mm was compared to a background sample from Reach 1 and a traction sand sample. The average percentage of the sample finer than 0.850 mm for Sample Locations 1 was 9.2% ± 3.7% where the water depth ranged from 0.40 to 0.58 m and the velocity ranged from 0.46 to 0.74 m/s. The average percent finer than 0.850 mm was 5.6% ± 2.6% for Sample Location 2. The depth at Sample Location 2 ranged from 0.40 to 0.61 m and the velocity ranged from 0.60 to 0.85 m/s. Sample Location 3 was found to have 18.5% ± 3.9% finer than 0.850 mm, with a depth of 0.24 m and a velocity ranging from 0.30 to 0.62 m/s. Sample Location 3 was a low velocity area that had significantly more fine sediment than Sample Locations 1 and 2, which were in the immediate proximity of an area known to contain redds. Reach 1 was assumed to be a background and was found to have 8.2% ± 3.1% of the substrate finer than 0.850 mm. The depth at Reach 1 ranged from 0.12 to 0.18 m and the velocity ranged from 0.09 to 0.59 m/s.

The streambed substrate from Sampling Locations 1 & 2 was found to be within the confidence interval of the background substrate collected from Reach 1. Therefore, the sample locations, with the exception of Location 3, were not found to be significantly different than the background. Furthermore, since the critical percent had been reported to be in the range of 10 - 20 percent (by weight), the sample locations were not found to be impaired by sedimentation based on this criteria (Reiser and White, 1988; Chapman, 1988).

A sample of the traction sand was determined to be 52.4% finer than 0.850 mm. This suggests that the traction sand used in deicing activities could be a significant source of sediment that could inhibit oxygen transfer in redds. However, the sediment samples were visually compared to the traction sand sample and the background sample. All three of the samples were different in color and the influence or presents of the traction sand could not be determined. In addition, there was an approximately 2 hectare land slide approximately 3 kilometers upstream from the sample sites. This area of mass wasting was adjacent to Peshastin Creek and could directly influence the sediment load. Therefore, the impacts of the traction sand could not be determined.

CBODU

The CBODU for IceBAN was estimated by obtaining the values of L_o and k that yielded the best fit of the data using Equation 4 (Figure 10). The value of L_o, (67,147 mg/L) was then used as the best estimate of CBODU. In a like manner the first order reaction rate constant was 0.149 day^{-1}. The rate constants were then used to estimate 5-day carbonaceous BOD in the stream that resulted from the in-stream IceBAN concentration that was calculated in a previous section (“Estimation of In-Stream IceBAN Concentration”, page 15). This calculation was based on application of Equation 4, shown below for reference.

$$BOD = L_0\left(1 - e^{-kt}\right) \tag{4}$$

where

L_0 = ultimate BOD (mg/L)

k = first order rate constant (t^{-1})

t = time

In order to calculate in-stream BOD_5, the reaction rate constant, which was determined at 20 °C, was corrected for ambient stream temperature. This was done by application of Equation 7 (Tchobanoglous and Burton, 1991).

$$k_T = k_{20}\theta^{T-20}$$

where

$$k_T = \text{first order rate constant at any temperature T (degrees C)} \qquad (7)$$

$$k_{20} = \text{first order rate constant at 20 degrees C}$$

$$\theta = \text{constant} = 1.13 \text{ for cold water condidtions}$$

$$T = \text{temperature (degrees C)}$$

The stream temperature on March 6, 2000 averaged 2.2 °C. Substituting the appropriate values into Equation 7 yields a $k_{2.2}$ of 0.0156 day^{-1}. In addition, the CBODU must be estimated in the stream from the calculated IceBAN concentration. The IceBAN concentration was previously estimated to be a maximum of 11.2 mg/L on March 6, 2000. By knowing the density of IceBAN (1.4 g/mL), the in-stream CBODU exerted by IceBAN was estimated in the following way.

$$L_{IS} = \frac{L_0}{\sigma} C_{IB}$$

where

$$L_{IS} = \text{in-stream ultimate CBOD contributed from IceBAN}$$

$$\sigma = \text{density of IceBAN} = 1.4 \text{ g/mL} \qquad (8)$$

$$C_{IB} = \text{in-stream IceBAN concentration}$$

$$L_{IS} = \frac{67147 mg/L}{1400 g/L}\left(\frac{11.2 mg/L}{1000 mg/g}\right) = 0.54 mg \text{ CBODU/L}$$

The BOD_5 is then determined through application of Equation 4 as

$$BOD_5 = 0.54mg/L\left(1 - e^{-0.0156*5}\right) = 0.041mg/L.$$

It can be seen that even under the conservative assumptions made to allow estimations of in-stream IceBAN concentration to be made, the impact on stream BOD would be insignificant.

CONCLUSIONS

The impacts of highway deicers and deicing activities on Peshastin Creek, located on the eastern slope of the Cascade Mountains in Washington, were studied and several conclusions were developed based on the data collected. First, the water chemistry data revealed that measurable increases in in-stream chloride concentration could be detected during melt events. The chloride increase was assumed to be directly proportional to an increase of IceBAN concentration within the stream. Based on this assumption, maximum IceBAN concentrations of 11.2 mg/L and 8.7 mg/L were observed at Reach 2 and Reach 4, respectively, on March 6, 2000. A steady state chloride mass balance between Reach 2 and 4 on Peshastin Creek, using the March 6, 2000 chemical constituent and flow data revealed that up to 1.9 kg of IceBAN enters the stream per km of highway per hour (1.9 kg/km·hr) along that 12.8 km stretch of SR 97. It should be noted that this is a worst-case scenario based on the assumptions that all the increase in chloride concentration above background levels is due to the input of IceBAN and that the IceBAN itself acts as a conservative substance and is not retained in any way during its transport to the stream.

Of course, the most important findings are related to measurable negative impacts of deicing activities (traction sand IceBAN application) on the stream environment. Microtox® toxicity testing revealed that IceBAN has an acute toxicity value (EC_{50}: the effective concentration that kills 50% of the bacteria during the test) of 4850 mg/L, very similar to calcium-magnesium acetate (CMA) which yielded an EC_{50} of 4700 mg/L. The highest estimated concentration of IceBAN in Peshastin Creek was 11.2 mg/L, a factor of 433 times less than the EC_{50} of 4850 mg/L. In addition, the *maximum* observed soluble heavy metal concentrations (Cd, Cu, Pb, and Zn) were found to be less than their National Recommended Water Quality Criteria values by at least an order of magnitude.

A qualitative assessment of the direct impact of deicing activities on Peshastin Creek was provided by enumeration of benthic macro invertebrates in both the background section (Reach 1) and “impacted” section (near Reach 2 and Reach 4). Three organisms were enumerated (Ephemeroptera, Plecoptera, and Trichoptera) and the data indicated no decrease in numbers when compared to the background section. In fact the numbers increased in the “impacted” sections of Peshastin Creek.

Streambed sediment analysis indicated that the traction sand did not have any measurable negative impact on the grain size distribution using the reported criteria that no greater than 10 – 20% of the sediment should be finer than 0.85 mm to protect salmon and steelhead egg survival. Apparently the Peshastin Creek stream velocity is sufficient to transport the finer material in the traction sand downstream and out of known salmon spawning areas.

RECOMMENDATIONS/APPLICATION/IMPLEMENTATION

The database and its interpretation that was afforded by this research have yielded important information with regard to the potential impact of deicing activities on a small stream used by anadromous fish for spawning. Although some of the data (benthic macro invertebrate enumeration) was qualitative, the overall conclusion is that there was no measurable negative impact from deicing practices on SR 97. This suggests that the use of IceBAN, which can be more accurately and effectively applied than sand mixed with NaCl, is an effective strategy that protects the environment and provides safer winter time travel. Although it was not possible to quantify the amount of traction sand that entered Peshastin Creek, visual observations made along the steam bank indicated that a significant mass of this sand has the potential to enter the stream. This did not cause a measurable problem in Peshastin Creek, at least in part due to the relatively high stream velocity. In lower velocity streams, however, application of this traction sand could cause streambed sediment problems since it has a significant percentage of particles less than 0.85 mm. As such, it is recommended that traction sand application be minimized or a traction material with a lower specific gravity be used in sensitive areas.

TABLE 1: Water chemistry results. The **Average** and range of values for each parameter.

Constituent	Tronsen	Reach 1	Reach 2	Reach 3	Reach 4
Alkalinity mg/L $CaCO_3$	**93.0** (66.1 – 110.6)	**70.3** (50.6 – 81.0)	**83.7** (57.6 – 98.4)	**47.2** (35.4 – 55.8)	**79.3** (60.7 – 100.3)
Chloride mg/L	**5.0** (2.6 – 8.2)	**0.6** (0.4 – 0.8)	**1.9** (1.0 – 3.3)	**0.6** (0.1 – 0.8)	**1.4** (0.7 – 2.7)
Conductivity $\mu S/cm^2$	**183** (124 – 226)	**128** (94 – 146)	**157** (109 – 183)	**88** (68 – 103)	**151** (116 – 191)
pH pH units	**7.73** (7.31 – 8.10)	**7.63** (7.21 – 7.99)	**7.66** (7.06 – 7.97)	**7.42** (6.89 – 7.80)	**7.60** (7.08 – 7.91)
TDS mg/L	**115.8** (91.0 – 132.5)	**82.8** (61.0 – 98.0)	**98.8** (72.5 – 114.0)	**53.3** (39.0 – 63.5)	**92.4** (74.5 – 121.0)
Turbidity NTU	**2.6** (0.3 – 18.0)	**1.2** (0.2 – 6.1)	**1.4** (0.2 – 8.1)	**0.6** (0.1 – 2.6)	**3.0** (0.3 – 16.8)

TABLE 2: Microtox® acute toxicity test results & species toxicity data.

Deicer	EC_{50} (15 min) mg/L	Species Toxicity Tests mg/L
IceBAN	4,850	--
CMA	4,700	18,000[a]
NaCl	> 8,000	12,200[b]
$CaCl_2$	> 8,000	> 8,000[c]

[a] Acute static 96 hour LC_{50} (lethal concentration to 50% of the population) for *Oncorhynchus mykiss* (McFarland and O'Reilly, 1992).

[b] Acute static LC_{50} for *Oncorhynchus mykiss* (McFarland and O'Reilly, 1992).

[c] Various species (Novotny et al., 1999).

TABLE 3: Heavy metals concentration results. The **<u>Average</u>** and range of values for each parameter.

Metal	**Tronsen**	**Reach 1**	**Reach 2**	**Reach 3**	**Reach 4**
Copper (Total), μg/L	**<u>3.11</u>** (0.53-16.78)	**<u>2.17</u>** (0.38-13.23)	**<u>2.37</u>** (0.41-10.93)	**<u>0.78</u>** (0.28-2.23)	**<u>1.96</u>** (ND-8.40)
Copper (Soluble), μg/L	**<u>0.70</u>** (0.20-1.27)	**<u>0.46</u>** (ND-0.77)	**<u>0.55</u>** (ND-1.49)	**<u>0.46</u>** (ND-1.22)	**<u>0.55</u>** (ND-1.14)
Lead (Total), μg/L	**<u>0.53</u>** (ND-2.39)	**<u>0.46</u>** (ND-2.19)	**<u>0.36</u>** (ND-2.28)	**<u>0.39</u>** (ND-1.80)	**<u>0.11</u>** (ND-1.52)
Lead (Soluble), μg/L	**<u>0.15</u>** (0.03-0.45)	**<u>0.23</u>** (0.01-0.79)	**<u>0.14</u>** (0.01-0.29)	**<u>0.18</u>** (0.01-0.61)	**<u>0.21</u>** (ND-0.59)
Zinc (Total), μg/L	**<u>2.61</u>** (ND-12.14)	**<u>2.21</u>** (ND-11.39)	**<u>1.36</u>** (ND-7.86)	**<u>0.69</u>** (ND-7.86)	**<u>1.78</u>** (ND-8.18)
Zinc (Soluble), μg/L	**<u>1.38</u>** (ND-8.66)	**<u>1.18</u>** (ND-4.27)	**<u>1.75</u>** (ND-7.54)	**<u>0.82</u>** (ND-3.48)	**<u>1.33</u>** (ND-3.90)
Cadmium (Total), μg/L	**<u>0.01</u>** (ND-0.28)	**<u>0.02</u>** (ND-0.35)	**<u>0.03</u>** (ND-0.23)	**<u>0.01</u>** (ND-0.12)	**<u>0.08</u>** (ND-0.72)
Cadmium (Soluble), μg/L	**<u>0.02</u>** (ND-0.17)	**<u>0.06</u>** (ND-0.35)	**<u>0.03</u>** (ND-0.24)	**<u>0.04</u>** (ND-0.38)	**<u>0.07</u>** (ND-0.35)

TABLE 4: National recommended water quality compliance results. The maximum and average soluble in-stream concentrations and the corresponding US EPA National Recommended Water Quality Criteria.

Metal	**Maximum In-Stream Concentration, µg/L**	**Average[a] In-Stream Concentration, µg/L**	**U.S. EPA Criteria**	
			CMC, µg/L	**CCC, µg/L**
Copper	**1.49**	**0.70**	**13.0**	**9.0**
Lead	**0.79**	**0.23**	**65.0**	**2.5**
Zinc	**8.66**	**1.75**	**120.0**	**120.0**
Cadmium	**0.38**	**0.07**	**4.3**	**2.2**

[a] The maximum average soluble in-stream concentration of the four reaches.

TABLE 5: Metals concentration results. The **Average** and range of values for each parameter.

Metal	Tronsen	Reach 1	Reach 2	Reach 3	Reach 4
Sodium (Total), mg/L	**5.2** (3.9-7.5)	**3.2** (2.1-4.9)	**3.6** (2.0-5.8)	**1.5** (1.1-2.9)	**3.5** (1.9-7.2)
Sodium (Soluble), mg/L	**4.1** (2.9-4.9)	**2.6** (1.5-3.1)	**3.0** (1.8-3.6)	**1.2** (0.8-1.5)	**2.3** (1.6-3.0)
Calcium (Total), mg/L	**28.2** (20.6-43.7)	**19.3** (12.2-28.2)	**22.2** (13.2-33.2)	**7.1** (4.6-12.5)	**19.9** (10.8-35.3)
Calcium (Soluble), mg/L	**23.6** (14.8-28.2)	**16.7** (11.3-19.7)	**19.3** (12.4-22.8)	**6.2** (4.1-7.9)	**13.9** (9.5-19.3)
Magnesium (Total), mg/L	**10.0** (6.6-15.6)	**7.2** (4.7-11.0)	**9.5** (5.8-14.1)	**8.9** (5.8-14.0)	**16.0** (7.9-27.6)
Magnesium (Soluble), mg/L	**8.2** (5.3-10.0)	**6.2** (4.0-7.3)	**8.2** (4.9-10.0)	**7.4** (5.4-8.9)	**11.0** (7.6-13.7)
Iron (Total), μg/L	**482** (15-2960)	**235** (5-1260)	**296** (17-1690)	**119** (ND-718)	**837** (56-4130)
Iron (Soluble), μg/L	**97** (54-132)	**73** (24-142)	**78** (46-130)	**30** (9-66)	**72** (31-155)

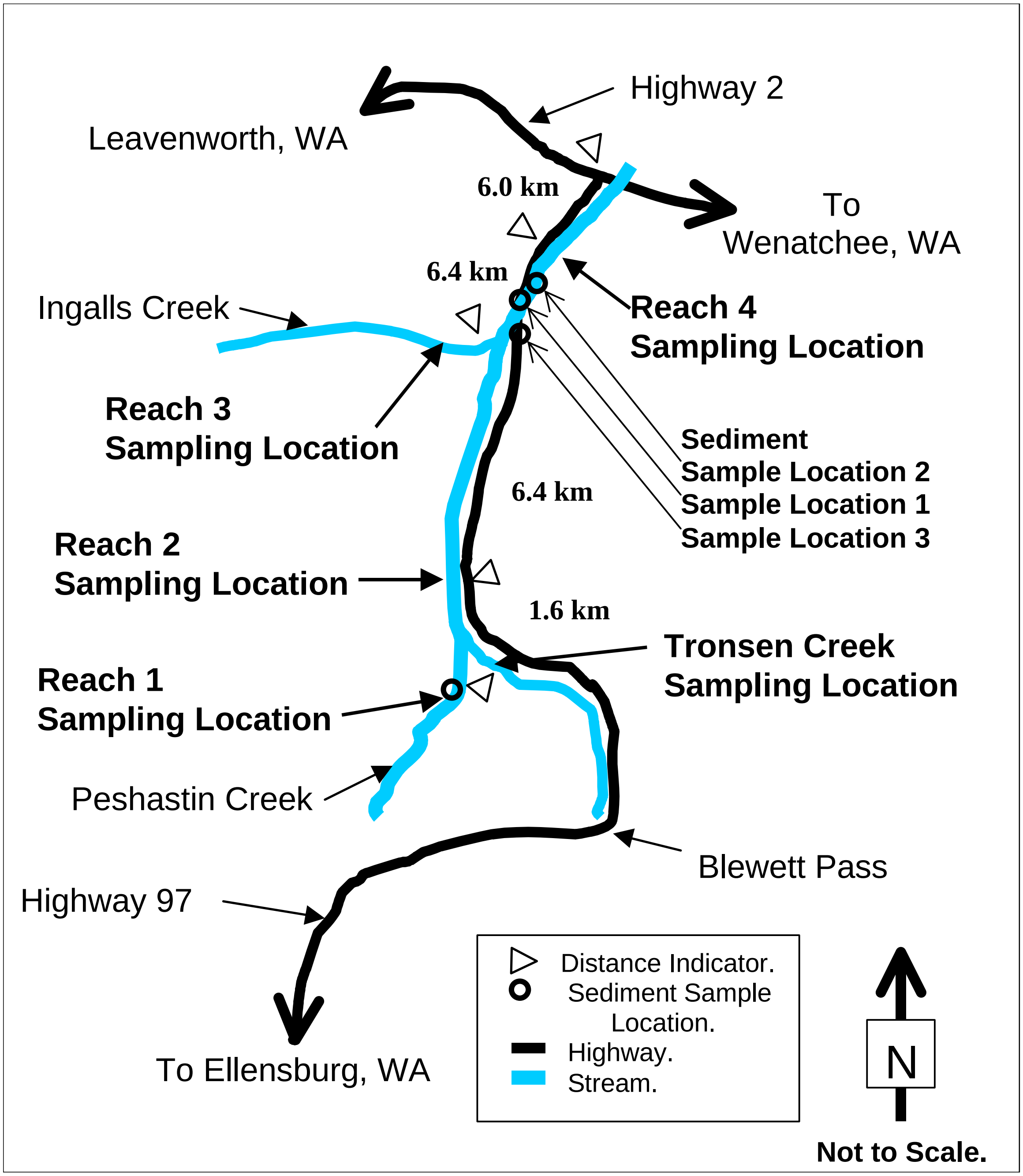

FIGURE 1: Study location, reaches and sediment sampling sites.

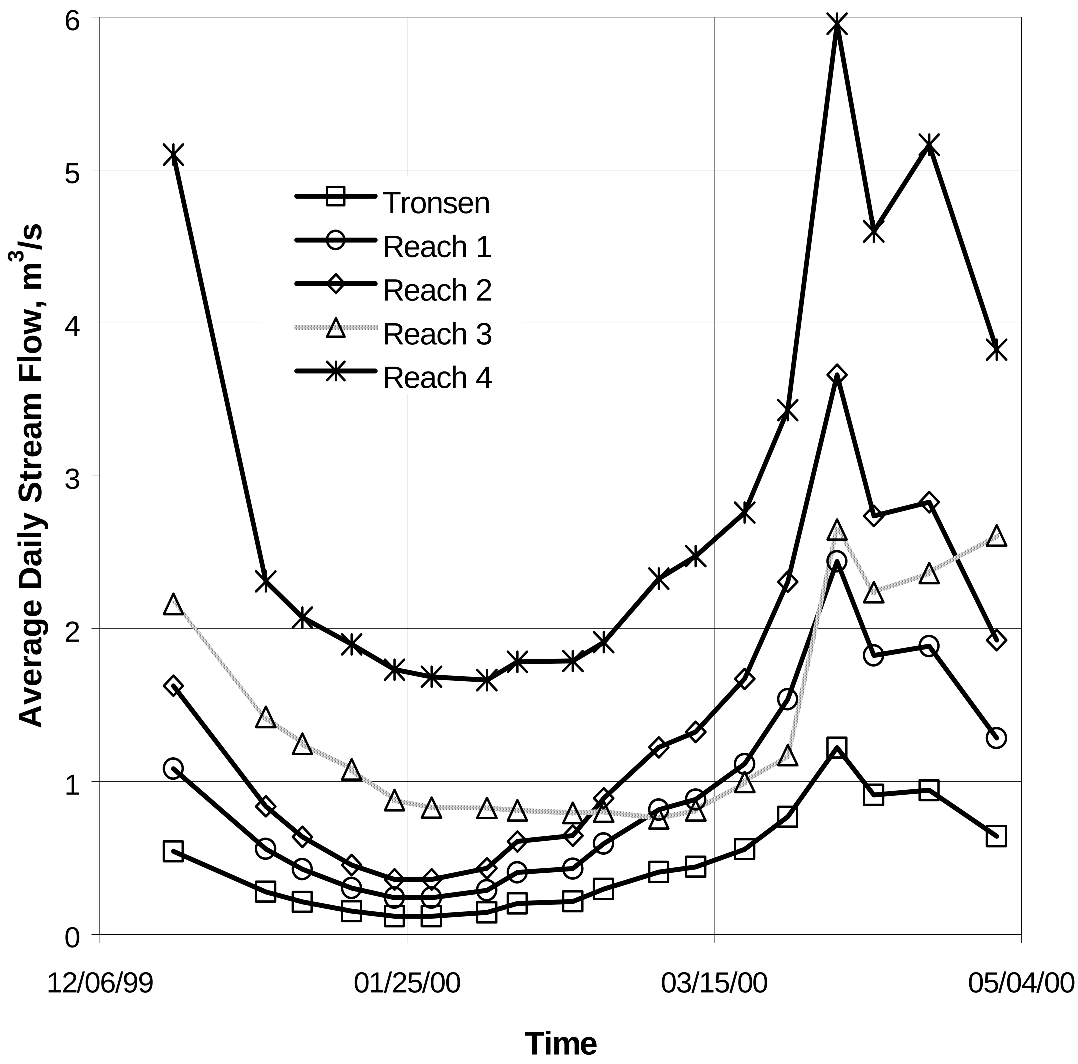

FIGURE 2: Estimated average daily stream flow at each reach.

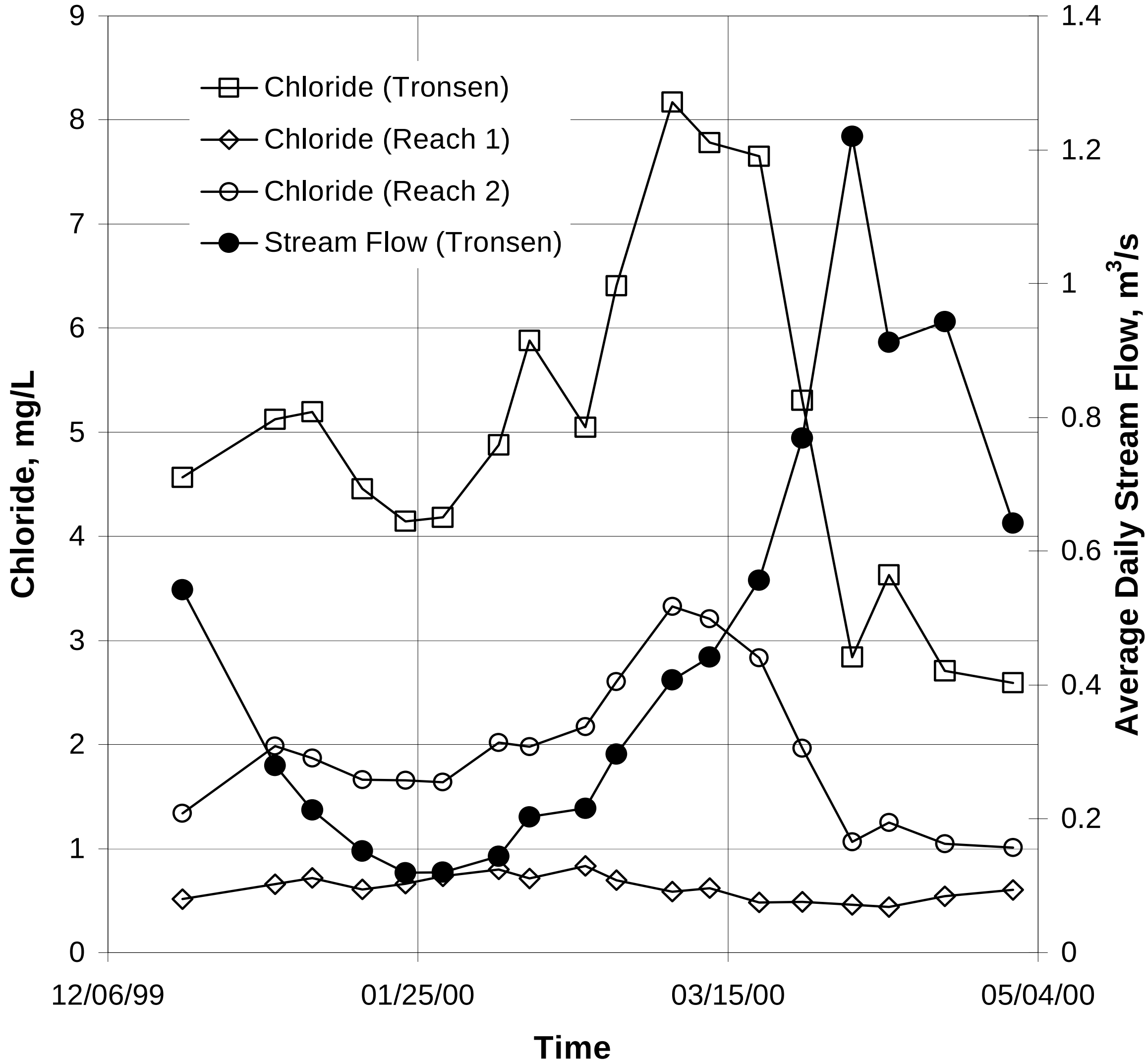

FIGURE 3: Chloride concentration at the Tronsen, Reach 1 (background) and Reach 2 locations. The steam flow is for Tronsen.

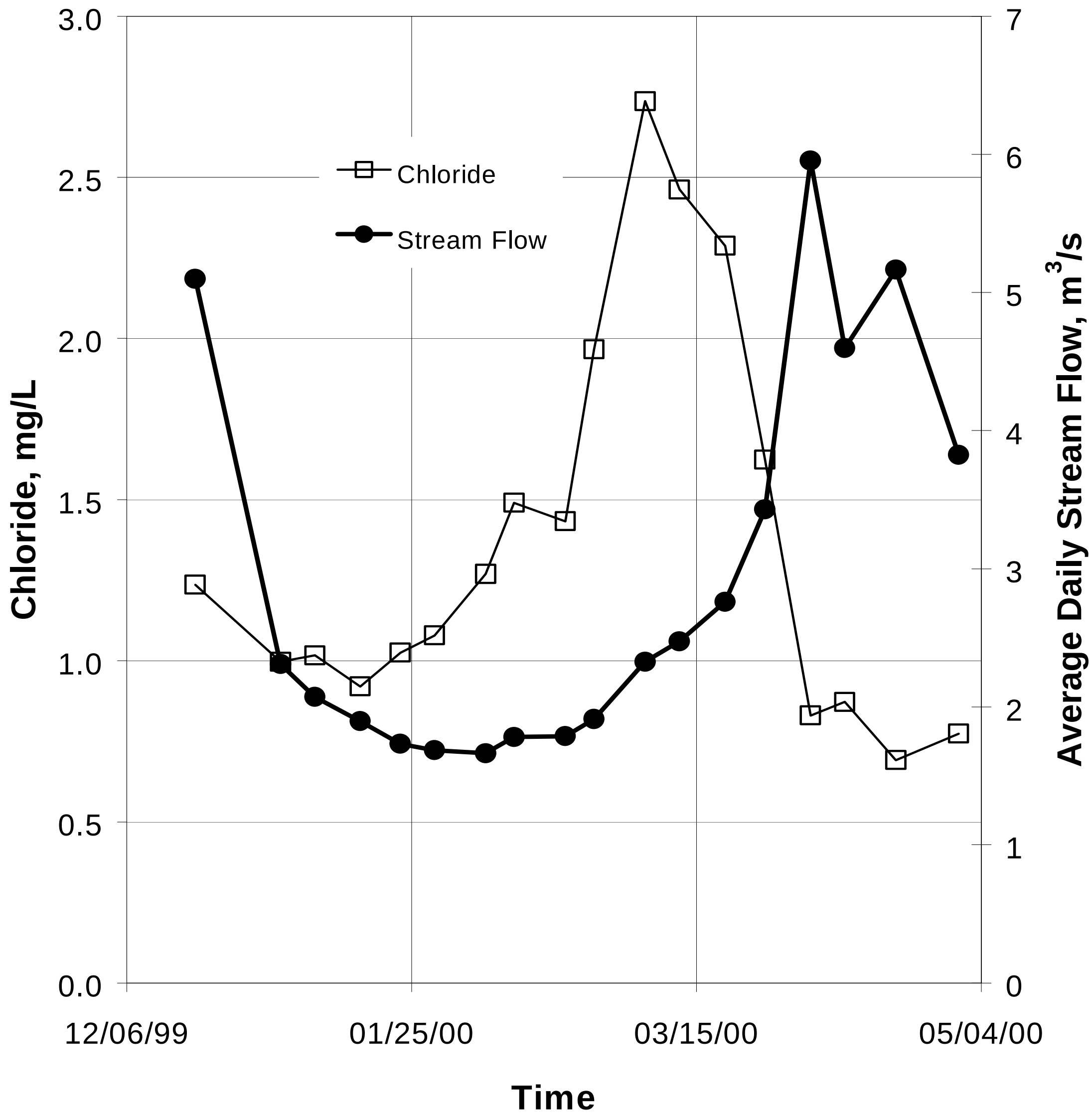

FIGURE 4: Chloride concentration and stream flow versus time for Reach 4.

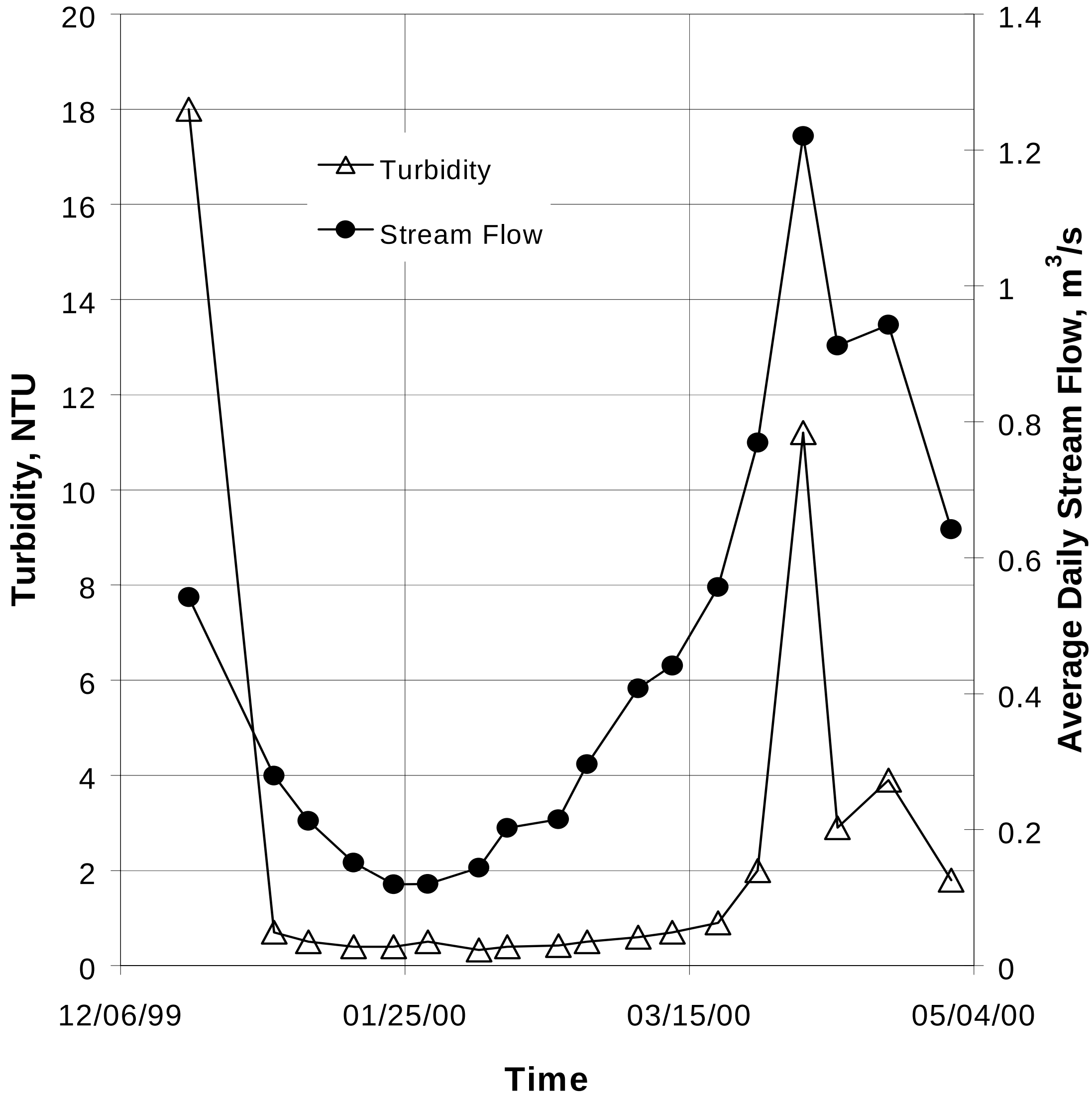

FIGURE 5: Turbidity and stream flow versus time for Tronsen Creek.

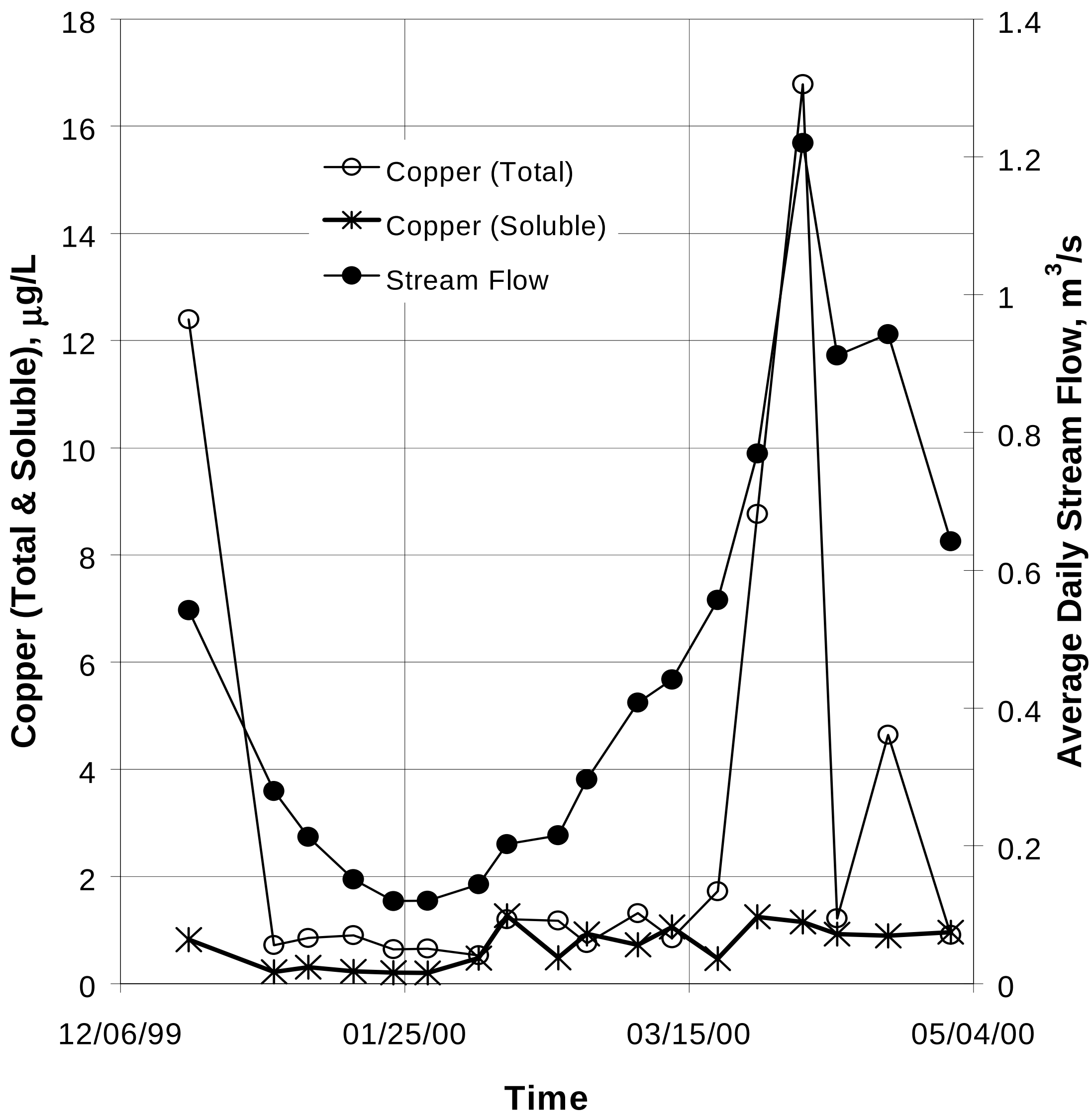

FIGURE 6: Copper (total & soluble) and stream flow versus time for Tronsen Creek.

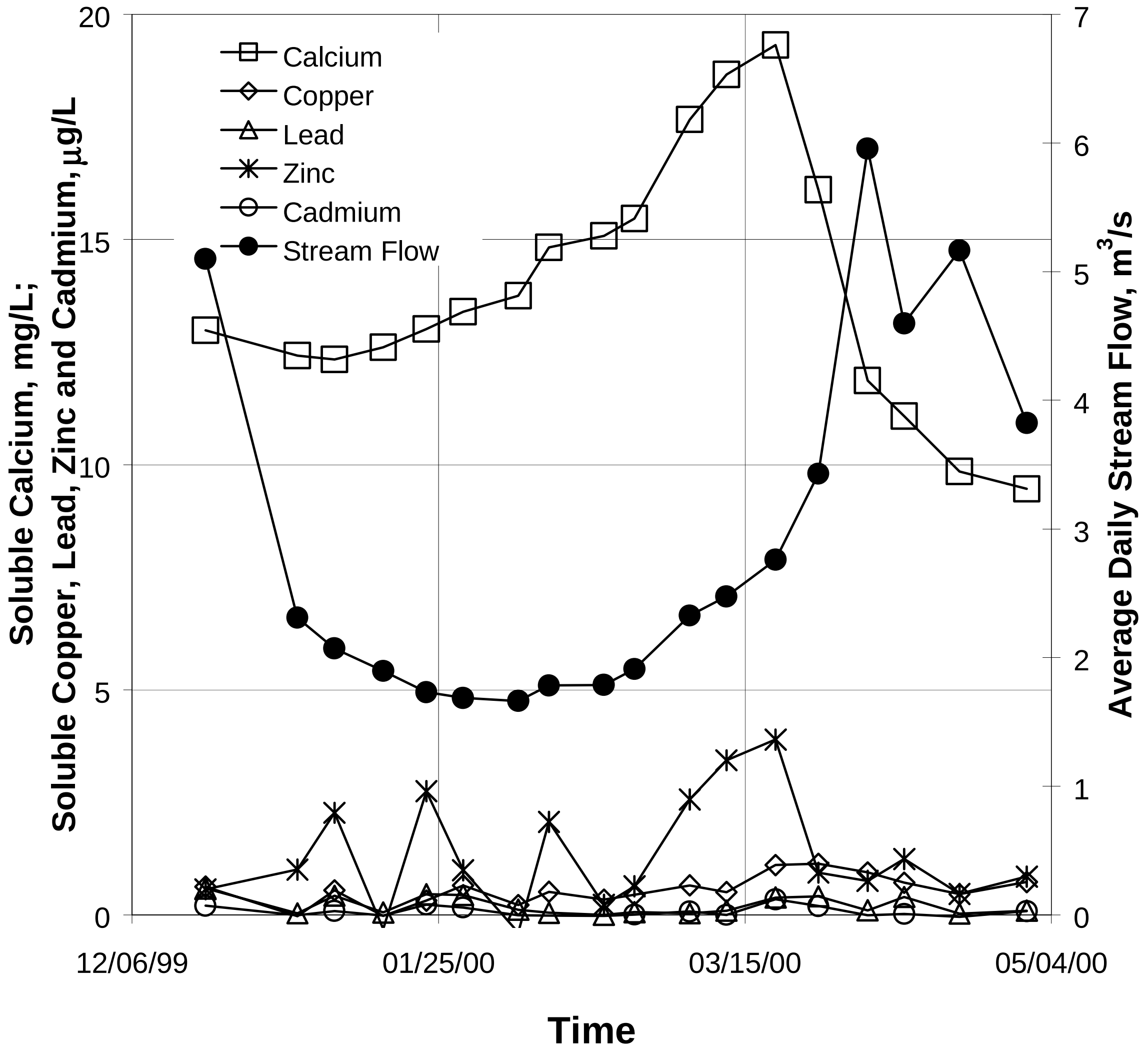

FIGURE 7: Soluble calcium, copper, lead, zinc & cadmium and stream flow versus time for Reach 4.

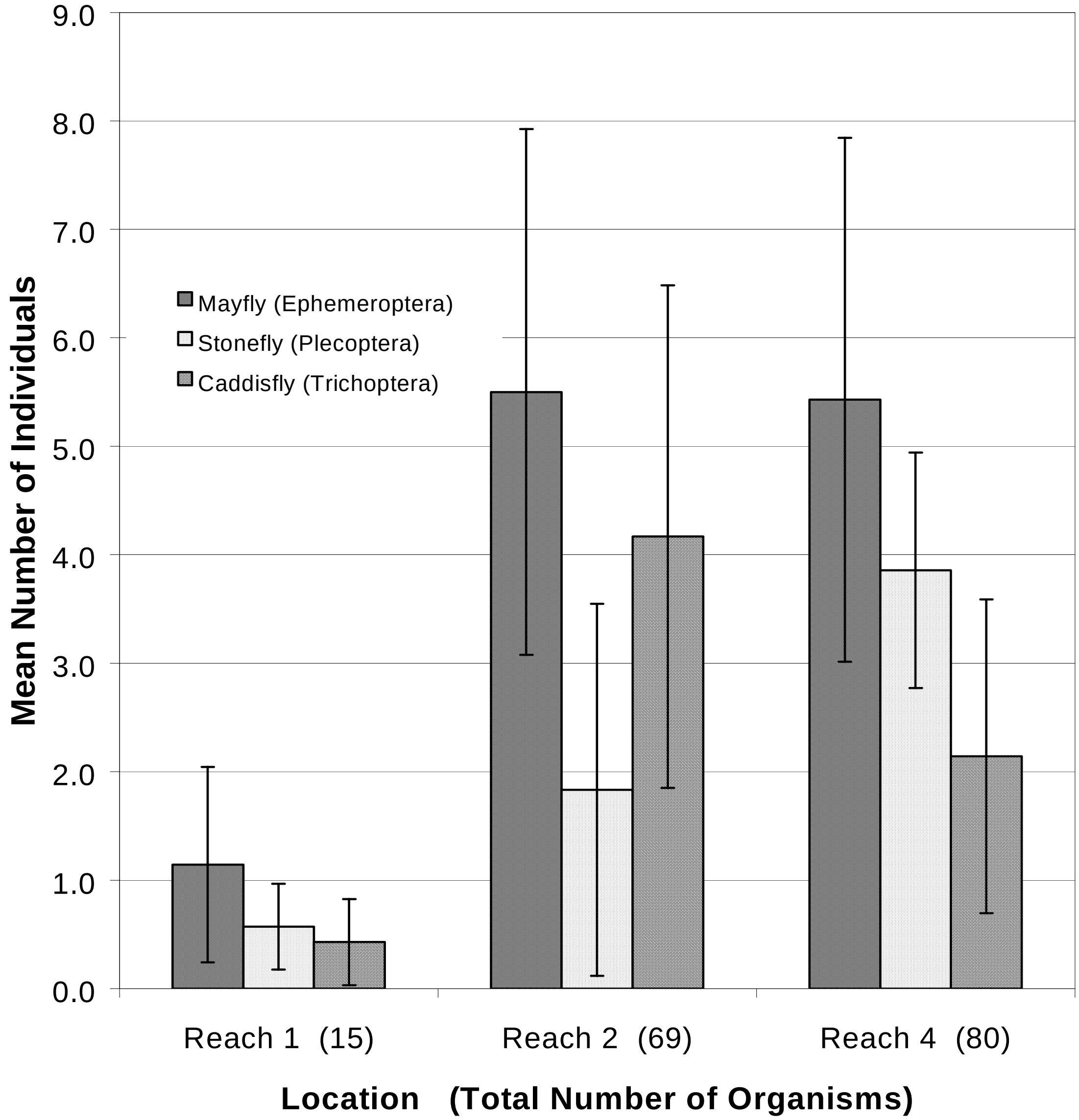

FIGURE 8: Benthic macro invertebrate analysis.

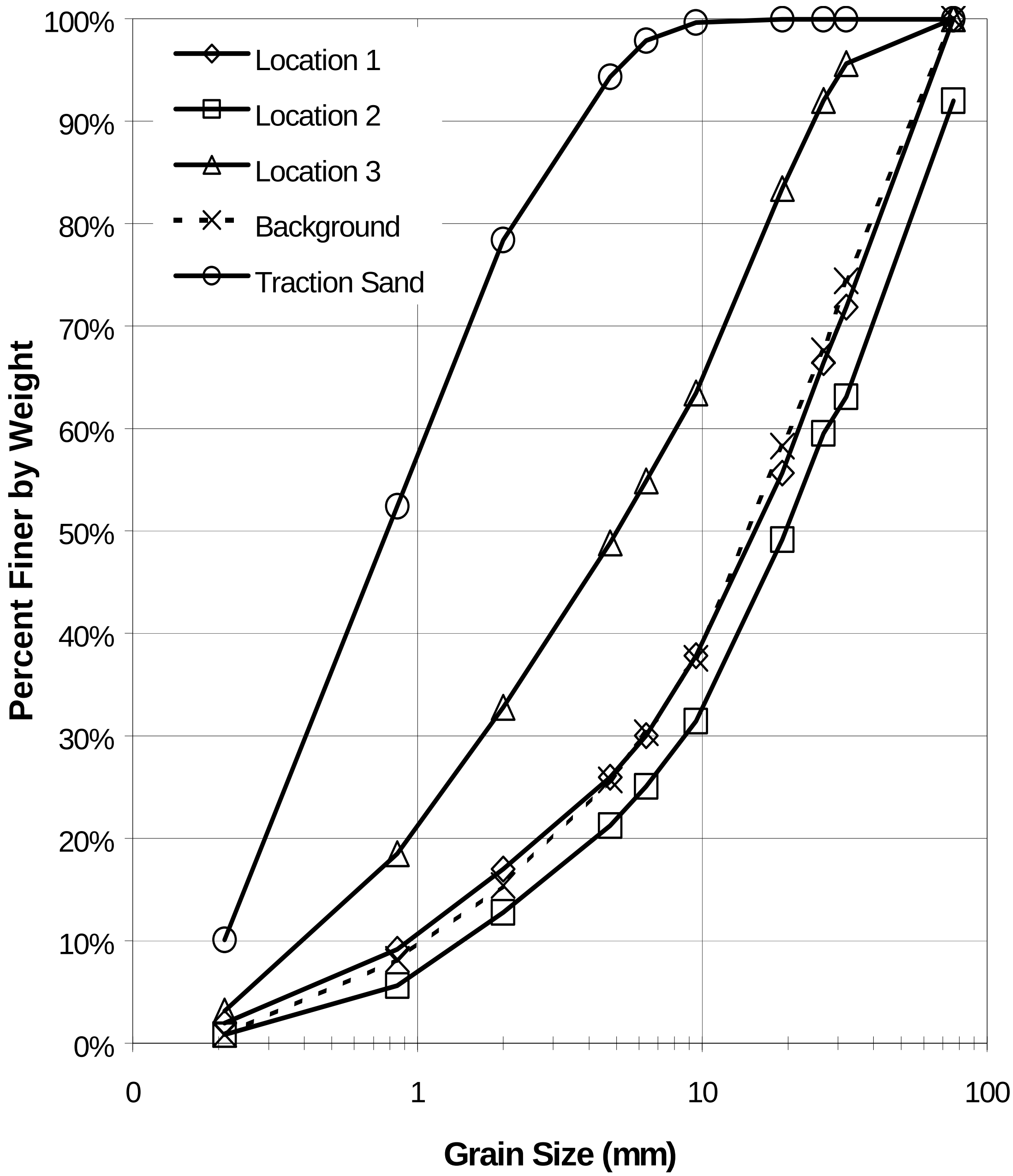

FIGURE 9: Average streambed substrate grain size distribution chart.

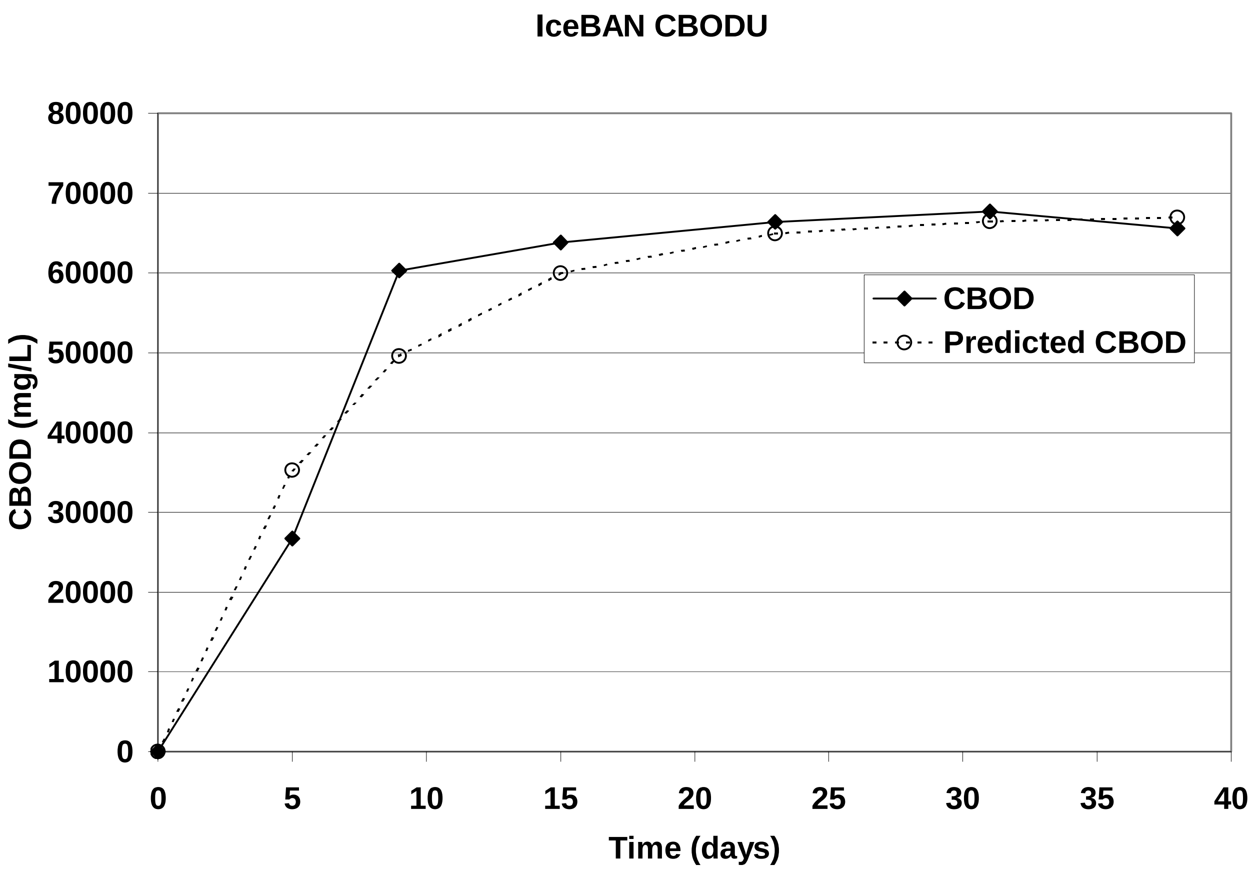

FIGURE 10: Carbonaceous BOD data for IceBAN and the corresponding line of best fit.

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APPENDIX

APPENDIX A

Weekly Sample Data

Appendix A: Alkalinity Data.

This data was generated from the weekly grab samples taken at each reach. .

Alkalinity						
Analyst Name: *Nathaniel Marcoe* Samples: *Weekly Grab Samples.*						
	Alkalinity, mg $CaCO_3$/L					
Date	Tronsen	Reach 1	Reach 2	Reach 3	Reach 4	Blank
12/18/99	80.1	50.6	59.9	38.8	60.7	n/a
01/02/00	93.4	71.1	88.1	44.0	70.1	n/a
01/08/00	92.5	70.5	84.4	43.8	69.1	0.8
01/16/00	93.3	73.4	87.9	46.5	74.3	0.5
01/23/00	98.1	76.9	92.8	49.9	77.2	1.3
01/29/00	99.4	79.1	94.2	52.5	82.2	1.0
02/07/00	101.1 *	79.6	93.7	50.9 *	82.3	0.3
02/12/00	104.0 *	79.6	91.8	49.7 *	83.7	3.3
02/21/00	105.0 *	80.8	96.4	50.5 *	88.6	1.6
02/26/00	106.3	78.3	93.1	50.7	88.2	1.0
03/06/00	110.6	81.0	98.0	52.3	94.3	1.2
03/12/00	109.5	80.7	98.4	52.9	94.7	1.6
03/20/00	103.5	75.0	90.4	55.8	100.3	1.6
03/27/00	94.3	69.9	84.8	48.3	93.1	1.1
04/04/00	69.8	50.7	60.6	35.4	69.1	1.4
04/10/00	76.0	57.8	67.2	41.0	72.6	0.8
04/19/00	66.1	51.7	57.6	41.9	61.8	1.0
04/30/00	71.3	58.4	66.6	44.2	64.8	2.2
* Mean Value						

Appendix A: Chloride Ion Concentration Data.

This data was generated by a Dionix Ion Chromatograph from the weekly grab samples taken at each reach. The values are recorded as mg/L and can also be thought of as ppm.

Chloride Ion Concentrations						
Analyst Name: ***Nathaniel Marcoe*** **Samples:** ***Weekly Grab Samples.***						
	Chloride, mg/L					
Date	Tronsen	Reach 1	Reach 2	Reach 3	Reach 4	Blank
11/11/99	--	0.7	1.5	0.6	1.3	0.1
12/18/99	4.6	0.5	1.3	0.5	1.2	ND
01/02/00	5.1	0.7	2.0	0.6	1.0	ND
01/08/00	5.2	0.7	1.9	0.6	1.0	ND
01/16/00	4.5	0.6	1.7	0.5	0.9	ND
01/23/00	4.1	0.7	1.7	0.6	1.0	ND
01/29/00	4.2	0.7	1.6	0.7	1.1	ND
02/07/00	4.9 *	0.8	2.0	0.7 *	1.3	ND
02/12/00	5.9 *	0.7	2.0	0.8 *	1.5	ND
02/21/00	5.0 *	0.8	2.2	0.8 *	1.4	ND
02/26/00	6.4	0.7	2.6	0.8	2.0	ND
03/06/00	8.2	0.6	3.3	0.8	2.7	ND
03/12/00	7.8	0.6	3.2	0.7	2.5	ND
03/20/00	7.7	0.5	2.8	0.7	2.3	ND
03/27/00	5.3	0.5	2.0	0.7	1.6	ND
04/04/00	2.8	0.5	1.1	0.5	0.8	ND
04/10/00	3.6	0.4	1.3	0.1	0.9	ND
04/19/00	2.7	0.5	1.0	0.4	0.7	ND
04/30/00	2.6	0.6	1.0	0.4	0.8	ND
Average		**0.62**		**0.58**		
* Mean Value						

The shaded data were not used in the calculations.

* Designates the average value of three replicates.

Appendix A: Conductivity Data.

This data was generated in the laboratory from the weekly grab samples taken at each reach. The conductivity was found with a hand held conductivity probe.

Conductivity						
Analyst Name: *Nathaniel Marcoe* **Samples: *Weekly Grab Samples.***						
	Concentration, μS/cm					
Date	Tronsen	Reach 1	Reach 2	Reach 3	Reach 4	Blank
12/18/99	161.7	95.7	116.6	75.0	124.6	n/a
01/02/00	185.3	134.9	169.4	84.5	139.1	0.7
01/08/00	185.6	131.1	162.0	84.2	134.4	0.7
01/16/00	185.4	132.1	164.9	87.4	143.5	0.8
01/23/00	187.4	139.3	170.4	91.1	144.9	0.7
01/29/00	186.5	141.3	170.7	95.9	153.3	0.8
02/07/00	194.0 *	144.7	175.1	93.0 *	153.2	0.8
02/12/00	197.5 *	145.4	169.7	93.2 *	157.8	0.8
02/21/00	198.5 *	146.2	178.7	92.8 *	163.3	0.8
02/26/00	213.0	146.0	177.7	94.0	167.1	0.8
03/06/00	226.0	145.5	183.2	97.6	182.1	0.7
03/12/00	219.0	144.0	182.8	97.3	187.5	0.8
03/20/00	218.0	133.6	171.9	102.5	191.3	0.8
03/27/00	182.6	122.3	151.8	94.3	172.4	0.8
04/04/00	139.2	96.0	115.1	67.7	127.4	0.8
04/10/00	145.8	105.2	123.4	74.7	133.8	0.7
04/19/00	123.8	93.7	108.9	75.3	115.6	0.7
04/30/00	141.8	108.8	127.4	82.7	123.6	0.8
* Mean Value						

Appendix A: pH Data.

This data was generated in the laboratory from the weekly grab samples taken at each reach. The pH was found with a hand held Orion pH probe.

pH						
Analyst Name: *Nathaniel Marcoe* **Samples: *Weekly Grab Samples.***						
	pH Units					
Date	Tronsen	Reach 1	Reach 2	Reach 3	Reach 4	Blank
12/18/99	7.31	7.21	7.06	6.89	7.08	n/a
01/02/00	7.56	7.45	7.53	7.19	7.24	6.48
01/08/00	7.45	7.40	7.50	7.19	7.36	5.18
01/16/00	7.74	7.57	7.58	7.25	7.52	5.30
01/23/00	7.91	7.67	7.62	7.34	7.53	5.37
01/29/00	7.74	7.50	7.54	7.17	7.41	5.02
02/07/00	7.55 *	7.42	7.56	7.30 *	7.49	5.28
02/12/00	7.75 *	7.64	7.69	7.50 *	7.73	5.81
02/21/00	7.72 *	7.64	7.73	7.50 *	7.67	5.62
02/26/00	7.82	7.82	7.80	7.57	7.77	5.41
03/06/00	7.85	7.87	7.91	7.66	7.86	5.53
03/12/00	8.10	7.99	7.97	7.72	7.89	5.34
03/20/00	7.80	7.78	7.91	7.80	7.91	5.84
03/27/00	7.80	7.78	7.82	7.61	7.80	5.01
04/04/00	7.67	7.54	7.57	7.31	7.57	5.27
04/10/00	7.90	7.76	7.77	7.53	7.74	5.09
04/19/00	7.63	7.55	7.58	7.44	7.58	5.08
04/30/00	7.84	7.79	7.79	7.54	7.70	4.95
* Mean						
Max	8.10	7.99	7.97	7.80	7.91	6.48
Min	7.31	7.21	7.06	6.89	7.08	4.95
Average	7.73	7.63	7.66	7.42	7.60	5.39

Appendix A: Stream Stage Data.

Average daily stage values. These values were calculated from a 24 hour period of 5-minute stage readings taken by a Sigma 960.

Stream Stage					
Analyst Name: Nathaniel Marcoe Sample: Weekly Grab Samples					
	Stage, inches				
Date	Tronsen	Reach 1	Reach 2	Reach 3	Reach 4
12/18/99			24.1	23.2	19.0
01/02/00			16.3	16.0	7.4
01/08/00			14.4	14.0	6.4
01/16/00			12.6	12.0	5.7
01/23/00			11.6	9.4	5.0
01/29/00			11.6	8.8	4.8
02/07/00			12.3	8.7	4.7
02/12/00			14.1	8.5	5.2
02/21/00			14.4	8.3	5.2
02/26/00			16.8	8.4	5.8
03/06/00			20.1	7.8	7.5
03/12/00			21.1	8.5	8.1
03/20/00			24.5	11.0	9.3
03/27/00			30.8	13.2	12.0
04/04/00			44.2	27.3	22.5
04/10/00			35.1	23.9	16.9
04/19/00			36.0	25.0	19.2
04/30/00				27.0	13.7

Appendix A: Total Dissolved Solids Data.

This data was generated in the laboratory from the weekly grab samples taken at each reach.

Total Dissolved Solids						
Analyst Name: ***Nathaniel Marcoe*** **Samples:** ***Weekly Grab Samples.***						
	Concentration, mg/L					
Date	Tronsen	Reach 1	Reach 2	Reach 3	Reach 4	Blank
12/18/99	104.0	61.0	72.5	39.0	79.0	n/a
01/02/00	118.0	86.0	98.0	44.0	80.5	n/a
01/08/00	115.5	87.5	103.0	51.5	80.0	-3.5
01/16/00	119.0	92.5	108.0	61.0	94.5	4.5
01/23/00	127.5	89.0	105.5	55.0	87.0	-2.0
01/29/00	121.5	85.5	105.0	50.0	93.5	-2.0
02/07/00	129.5 *	98.0	113.5	62.5 *	91.0	1.0
02/12/00	127.0 *	94.0	107.5	60.0 *	90.5	-12.0
02/21/00	123.2 *	93.5	112.0	54.8 *	104.5	4.0
02/26/00	121.0	81.5	102.0	47.5	93.0	-10.0
03/06/00	126.0	85.0	105.5	53.0	103.0	-9.0
03/12/00	132.5	92.5	114.0	59.0	112.5	-2.0
03/20/00	126.0	86.5	112.0	63.5	121.0	-2.0
03/27/00	111.5	81.5	96.5	59.0	109.5	-4.0
04/04/00	96.5	66.5	81.0	48.0	86.5	1.0
04/10/00	100.5	75.5	85.5	50.0	85.5	3.0
04/19/00	94.0	68.0	77.5	52.0	78.0	6.5
04/30/00	91.0	67.0	78.5	49.5	74.5	-1.0
* Mean Value						

Appendix A: Turbidity Data.

This data was generated in the laboratory from the weekly grab samples taken at each reach. The Turbidity was found with a Hach Turbidimeter.

Turbidity						
Analyst Name: ***Nathaniel Marcoe*** Samples: ***Weekly Grab Samples.***						
	Turbidity, NTU					
Date	Tronsen	Reach 1	Reach 2	Reach 3	Reach 4	Blank
12/18/99	18.0	5.0	6.0	1.0	9.0	0.4
01/02/00	0.7	0.5	0.3	0.2	0.4	0.4
01/08/00	0.5	0.3	0.3	0.2	0.4	0.1
01/16/00	0.4	0.2	0.3	0.2	0.4	0.1
01/23/00	0.4	0.3	0.4	0.3	0.9	0.1
01/29/00	0.5	0.2	0.2	0.2	0.3	0.1
02/07/00	0.3 *	0.2	0.2	0.1 *	0.4	0.1
02/12/00	0.4 *	0.3	0.5	0.2 *	0.5	0.1
02/21/00	0.4 *	0.3	0.3	0.2 *	0.3	0.1
02/26/00	0.5	0.4	0.4	0.2	0.9	0.1
03/06/00	0.6	0.5	0.6	0.2	2.0	0.1
03/12/00	0.7	0.4	0.5	0.3	2.4	0.1
03/20/00	0.9	0.9	0.9	0.5	3.9	0.1
03/27/00	2.0	1.1	1.6	0.5	5.5	0.1
04/04/00	11.2	6.1	8.1	2.6	16.8	0.2
04/10/00	2.9	2.0	2.2	1.5	4.6	0.1
04/19/00	3.9	1.4	2.1	1.4	3.8	0.1
04/30/00	1.8	0.8	0.8	0.8	1.4	0.1
* Mean Value						

Appendix A: Water Temperature Data.

This data was generated in the laboratory from the weekly grab samples taken at each reach. The Turbidity was found with a Hach Turbidimeter.

Water Temperature Data					
Analyst Name: *Nathaniel Marcoe* **Samples: *Weekly Grab Samples.***					
	Water Temperature, °F				
Date	Tronsen	Reach 1	Reach 2	Reach 3	Reach 4
12/18/99	--	--	37.3	36.0	39.2
01/02/00	--	--	33.7	33.1	33.5
01/08/00	--	--	35.0	34.6	35.2
01/16/00	--	--	32.0	32.8	33.7
01/23/00	--	--	32.2	32.9	33.6
01/29/00	--	--	31.5	31.9	32.7
02/07/00	--	--	34.7	35.3	36.4
02/12/00	--	--	34.5	34.4	35.7
02/21/00	--	--	34.1	33.6	34.8
02/26/00	--	--	34.4	33.6	34.6
03/06/00	--	--	35.9	34.8	37.2
03/12/00	--	--	36.4	35.3	37.5
03/20/00	--	--	36.7	35.3	37.9
03/27/00	--	--	38.2	47.2	39.7
04/04/00	--	--	38.9	14.0	40.4
04/10/00	--	--	39.3	14.0	41.2
04/19/00	--	--	40.2	14.9	41.8
04/30/00	--	--	--	38.5	42.9

NOTE:

The shaded data are erroneous due to probe

Appendix A: Stream Flow Calculations (US Standard Units: ft^3/s).

This data was calculated using the stream stage data by the equations in the box labeled Stage Discharge Curves. These curves were generated by gauging the stream .to calculate stream flow and then comparing it to the stage of the stream.

Stream Flow Calculations					
Analyst Name: Nathaniel Marcoe Sample: Weekly Grab Samples					
	Average Daily Flow, cfs				
Date	Tronsen	Reach 1	Reach 2	Reach 3	Reach 4
12/18/99	19.1	38.3	57.4	76.3	180.1
01/02/00	9.9	19.7	29.6	50.2	81.5
01/08/00	7.5	15.0	22.5	44.1	73.2
01/16/00	5.3	10.7	16.0	38.1	67.0
01/23/00	4.2	8.5	12.7	31.0	61.1
01/29/00	4.2	8.5	12.7	29.3	59.5
02/07/00	5.1	10.2	15.3	29.2	58.8
02/12/00	7.2	14.3	21.5	28.6	62.9
02/21/00	7.6	15.2	22.8	28.1	63.1
02/26/00	10.5	20.9	31.4	28.4	67.5
03/06/00	14.4	28.8	43.2	26.8	82.2
03/12/00	15.6	31.2	46.8	28.6	87.4
03/20/00	19.7	39.3	59.0	35.2	97.5
03/27/00	27.2	54.3	81.5	41.4	121.1
04/04/00	43.1	86.2	129.3	93.5	210.3
04/10/00	32.2	64.4	96.6	79.0	162.4
04/19/00	33.3	66.6	99.9	83.4	182.4
04/30/00	22.7 *	45.3 *	68.0 *	92.1	135.1
* Assumed Value					

Stage Discharge Curves:

Reach 4

y=102.23x + 18.492

y= Flow, cfs x= Stage, ft

Reach 3

Mannings Equation (see "Reach 3 Mannings Equation Calculations")

Reach 2

y=42.969x - 28.893

Appendix A: Stream Flow Calculations (Metric Units: m^3/s).

This data was calculated by converting the US Standard units into metric units.

Stream Flow Calculations (Metric)					
Analyst Name: Nathaniel Marcoe Sample: Weekly Grab Samples					
	Average Daily Flow, m^3/s				
Date	Tronsen	Reach 1	Reach 2	Reach 3	Reach 4
12/18/99	0.54	1.08	1.63	2.16	5.10
01/02/00	0.28	0.56	0.84	1.42	2.31
01/08/00	0.21	0.43	0.64	1.25	2.07
01/16/00	0.15	0.30	0.45	1.08	1.90
01/23/00	0.12	0.24	0.36	0.88	1.73
01/29/00	0.12	0.24	0.36	0.83	1.69
02/07/00	0.14	0.29	0.43	0.83	1.66
02/12/00	0.20	0.41	0.61	0.81	1.78
02/21/00	0.22	0.43	0.65	0.80	1.79
02/26/00	0.30	0.59	0.89	0.80	1.91
03/06/00	0.41	0.82	1.22	0.76	2.33
03/12/00	0.44	0.88	1.32	0.81	2.47
03/20/00	0.56	1.11	1.67	1.00	2.76
03/27/00	0.77	1.54	2.31	1.17	3.43
04/04/00	1.22	2.44	3.66	2.65	5.96
04/10/00	0.91	1.82	2.74	2.24	4.60
04/19/00	0.94	1.89	2.83	2.36	5.16
04/30/00	0.64	1.28	1.93	2.61	3.82
* Assumed Value					

Appendix A: Reach 3 Manning's Equation Calculations (US Standard Units: ft^3/s).

This data was calculated for Reach 3 because the stage discharge curve did not span the data set. Therefore, Manning's Equation was used to estimate the stream flow. The channel type was estimated and the dimensions were measured. The slope was taken from a standard USGS 7.5-minute map. The "Area eff" designates the percentage of the area that is being used and the "Area" is the actual area multiplied by that percentage.

Reach 3: Mannings Equation				b =	20	
Q=ϕ/n*A*R^(2/3)*S^(1/2)				z =	2	
Channel Estimation Type:				ϕ =	1.49	
Trapezoidal				n =	0.085	
				Slope =	0.04	
y	t	Area eff	Area, ft^2	P	R	Q, cfs
2.85	31.4	0.35	25.6	32.7	0.78	76.3
2.25	29.0	0.35	19.3	30.1	0.64	50.2
2.08	28.3	0.35	17.6	29.3	0.60	44.1
1.92	27.7	0.35	16.0	28.6	0.56	38.1
1.70	26.8	0.35	14.0	27.6	0.51	31.0
1.65	26.6	0.35	13.4	27.4	0.49	29.3
1.64	26.6	0.35	13.4	27.4	0.49	29.2
1.63	26.5	0.35	13.2	27.3	0.48	28.6
1.61	26.4	0.35	13.1	27.2	0.48	28.1
1.62	26.5	0.35	13.1	27.2	0.48	28.4
1.56	26.3	0.35	12.7	27.0	0.47	26.8
1.63	26.5	0.35	13.2	27.3	0.48	28.6
1.83	27.3	0.35	15.2	28.2	0.54	35.2
2.01	28.1	0.35	16.9	29.0	0.58	41.4
3.19	32.8	0.35	29.5	34.3	0.86	93.5
2.91	31.6	0.35	26.3	33.0	0.80	79.0
3.00	32.0	0.35	27.3	33.4	0.82	83.4
3.17	32.7	0.35	29.2	34.2	0.85	92.1

Appendix A: Metals Concentration Data - Copper.

This data was generated by an ICPMS from the weekly grab samples taken at each reach. The values are recorded as µg/L and can also be thought of as ppb. The numbers under the CMC and CCC are the US EPA National Recommended Water Quality Criteria's Criteria Maximum Concentration and the Criteria Continuous Concentration (µg/L). They correspond to the maximum and continuous in-stream soluble metal concentration.

Copper (Cu)						CMC		CCC		
						13.0		9.0		
	Soluble Copper, µg/L					Total Copper, µg/L				
Date	Tronsen	Reach 1	Reach 2	Reach 3	Reach 4	Tronsen	Reach 1	Reach 2	Reach 3	Reach 4
12/18/99	0.82	0.72	0.61	1.20	0.62	12.40	7.86	1.14	2.00	5.00
01/02/00	0.22	ND	ND	ND	ND	0.72	0.68	0.67	0.50	0.71
01/08/00	0.31	0.13	0.15	0.17	15.60	0.85	0.66	0.41	0.65	0.52
01/16/00	0.23	0.07	0.51	ND	ND	0.90	0.70	0.57	0.39	1.03
01/23/00	0.20	0.13	0.33	0.33	0.32	0.64	1.12	0.61	0.49	0.67
01/29/00	0.20	0.36	0.45	0.58	0.66	0.65	0.38	0.58	0.33	0.73
02/07/00	0.48	0.54	0.34	0.21	0.21	0.53	0.68	0.42	0.36	0.49
02/12/00	1.27	0.61	0.64	0.33	0.51	1.20	0.64	0.76	0.37	0.77
02/21/00	0.48	0.29	0.39	0.27	0.34	1.18	0.80	0.57	0.67	0.76
02/26/00	0.93	0.55	0.48	0.42	0.45	0.75	0.76	1.22	0.62	0.84
03/06/00	0.72	0.35	0.24	0.30	0.65	1.31	1.01	0.43	0.87	0.24
03/12/00	1.06	0.62	0.82	0.74	0.51	0.85	0.79	0.44	0.53	1.05
03/20/00	0.47	0.77	0.44	0.39	1.11	1.73	0.66	0.69	0.28	2.12
03/27/00	1.25	0.74	1.49	0.89	1.14	8.76	4.44	6.68	15.40	8.40
04/04/00	1.15	0.61	0.70	0.60	0.94	16.78	13.23	8.72	1.74	4.05
04/10/00	0.92	0.64	0.89	0.50	0.72	1.22	2.66	7.02	2.23	5.33
04/19/00	0.89	0.59	0.74	0.46	0.46	4.64	1.18	10.93	0.49	2.90
04/30/00	0.96	0.49	0.68	1.22	0.73	0.91	0.83	0.81	0.78	ND
Average	0.70	0.46	0.55	0.46	0.55	3.11	2.17	2.37	0.78	1.96
Min	0.20	ND	ND	ND	ND	0.53	0.38	0.41	0.28	ND
Max	1.27	0.77	1.49	1.22	1.14	16.78	13.23	10.93	2.23	8.40
Not used										

NOTE:

The shaded values were not used in calculations.

The values marked ND are below the detection limits

Appendix A: Metals Concentration Data - Lead.

This data was generated by an ICPMS from the weekly grab samples taken at each reach. The values are recorded as µg/L and can also be thought of as ppb. The numbers under the CMC and CCC are the US EPA National Recommended Water Quality Criteria's Criteria Maximum Concentration and the Criteria Continuous Concentration (µg/L). They correspond to the maximum and continuous in-stream soluble metal concentration.

Lead (Pb)					CMC	CCC				
					65	2.5				
	Soluble Lead, µg/L					Total Lead, µg/L				
Date	Tronsen	Reach 1	Reach 2	Reach 3	Reach 4	Tronsen	Reach 1	Reach 2	Reach 3	Reach 4
12/18/99	0.37	0.40	0.09	0.48	0.59	0.52	ND	ND	ND	6.53
01/02/00	0.13	0.79	0.29	0.01	0.03	0.50	1.12	0.72	0.30	1.52
01/08/00	0.06	0.36	0.01	0.07	0.42	0.56	0.70	0.29	0.54	0.51
01/16/00	0.05	0.13	0.22	0.06	0.06	0.69	2.19	0.46	0.21	0.24
01/23/00	0.16	0.18	0.26	0.24	0.46	0.61	2.19	0.52	1.06	1.19
01/29/00	0.07	0.09	0.16	0.13	0.44	1.46	0.11	0.73	0.17	0.63
02/07/00	0.07	0.18	0.24	0.05	0.11	0.13	0.34	0.83	0.30	0.55
02/12/00	0.13	0.09	0.06	0.03	0.05	0.34	0.20	0.32	1.54	0.19
02/21/00	0.06	0.09	0.02	0.12	0.00	0.23	0.30	0.21	0.31	0.26
02/26/00	0.07	0.12	0.05	0.10	0.06	0.24	0.50	0.32	0.25	0.67
03/06/00	0.16	0.23	0.23	0.16	0.03	1.14	0.93	0.20	0.68	ND
03/12/00	0.20	0.40	0.13	0.61	0.09	0.75	0.76	0.51	0.89	ND
03/20/00	0.07	0.35	0.07	0.08	0.38	0.52	0.52	1.54	0.20	ND
03/27/00	0.03	0.01	0.28	0.22	0.41	ND	ND	2.28	1.80	0.28
04/04/00	0.15	0.15	0.12	0.18	0.10	0.48	1.28	0.47	0.90	1.32
04/10/00	0.28	0.12	0.15	0.35	0.40	0.29	ND	ND	ND	0.49
04/19/00	0.45	0.29	0.07	0.06	0.02	ND	ND	ND	ND	ND
04/30/00	0.12	0.07	0.12	0.21	0.09	2.39	0.69	0.55	0.45	ND
Average	0.15	0.23	0.14	0.18	0.21	0.53	0.46	0.36	0.39	0.11
Min	0.03	0.01	0.01	0.01	0.00	ND	ND	ND	ND	ND
Max	0.45	0.79	0.29	0.61	0.59	2.39	2.19	2.28	1.80	1.52

NOTE:

The shaded values were not used in calculations.

The values marked ND are below the detection limits

Appendix A: Metals Concentration Data - Zinc.

This data was generated by an ICPMS from the weekly grab samples taken at each reach. The values are recorded as μg/L and can also be thought of as ppb. The numbers under the CMC and CCC are the US EPA National Recommended Water Quality Criteria's Criteria Maximum Concentration and the Criteria Continuous Concentration (μg/L). They correspond to the maximum and continuous in-stream soluble metal concentration.

Zinc (Zn)					CMC	CCC				
					120	120				
	Soluble Zinc, μg/L					Total Zinc, μg/L				
Date	Tronsen	Reach 1	Reach 2	Reach 3	Reach 4	Tronsen	Reach 1	Reach 2	Reach 3	Reach 4
12/18/99	8.66	1.37	0.56	3.29	0.57	23.92	22.64	ND	9.28	22.11
01/02/00	3.50	0.79	ND	0.91	1.01	0.25	0.17	0.61	0.46	0.46
01/08/00	ND	ND	ND	28.39	2.27	1.78	0.07	0.16	0.57	1.45
01/16/00	ND	0.24	7.54	ND	ND	0.04	0.65	0.09	0.42	0.86
01/23/00	ND	ND	ND	ND	2.75	0.45	0.35	0.70	ND	2.08
01/29/00	ND	ND	ND	0.08	0.99	0.26	0.55	1.41	0.01	0.49
02/07/00	0.99	3.38	0.11	ND	ND	0.03	3.47	0.17	0.75	0.90
02/12/00	0.54	0.39	7.50	0.41	2.07	0.79	1.31	1.28	1.25	1.92
02/21/00	ND	ND	ND	ND	0.22	0.57	0.23	0.05	ND	0.67
02/26/00	0.31	0.80	ND	0.01	0.63	0.18	1.09	0.72	ND	2.26
03/06/00	1.82	2.36	3.96	2.36	2.57	4.80	4.07	1.17	2.12	1.80
03/12/00	2.91	4.24	7.01	3.48	3.44	1.04	0.75	0.22	1.12	ND
03/20/00	2.29	4.27	1.77	1.53	3.90	0.96	1.18	ND	0.16	ND
03/27/00	1.57	0.17	1.33	0.29	0.94	4.60	21.39	18.60	5.26	6.98
04/04/00	1.38	1.03	0.86	1.93	0.75	7.49	10.55	0.56	2.99	5.18
04/10/00	1.12	0.93	1.37	1.11	1.24	12.14	ND	7.86	ND	8.18
04/19/00	1.47	1.39	1.05	0.28	0.46	10.75	11.39	5.90	ND	0.72
04/30/00	0.43	0.55	0.13	0.50	0.85	ND	1.12	1.20	0.99	ND
Average	1.38	1.18	1.75	0.82	1.33	2.61	2.21	1.36	0.69	1.78
Min	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Max	8.66	4.27	7.54	3.48	3.90	12.14	11.39	7.86	5.26	8.18

NOTE:

The shaded values were not used in calculations.

The values marked ND are below the detection limits

Appendix A: Metals Concentration Data - Cadmium.

This data was generated by an ICPMS from the weekly grab samples taken at each reach. The values are recorded as µg/L and can also be thought of as ppb. The numbers under the CMC and CCC are the US EPA National Recommended Water Quality Criteria's Criteria Maximum Concentration and the Criteria Continuous Concentration (µg/L). They correspond to the maximum and continuous in-stream soluble metal concentration.

Cadmium (Cd)					CMC	CCC				
					4.3	2.2				
	Soluble Cadmium, µg/L					Total Cadmium, µg/L				
Date	Tronsen	Reach 1	Reach 2	Reach 3	Reach 4	Tronsen	Reach 1	Reach 2	Reach 3	Reach 4
12/18/99	0.17	0.32	ND	0.23	0.20	0.28	ND	ND	ND	0.72
01/02/00	0.01	0.12	0.06	ND	ND	0.01	0.02	0.03	ND	0.01
01/08/00	0.03	0.06	ND	ND	0.09	0.00	ND	ND	0.00	0.07
01/16/00	ND	0.05	0.02	ND	ND	ND	0.06	0.00	0.01	0.01
01/23/00	0.04	0.03	0.23	ND	0.23	0.00	0.15	0.05	0.03	0.11
01/29/00	0.03	0.00	0.00	0.00	0.16	0.00	ND	0.02	ND	0.16
02/07/00	ND	0.35	0.00	0.00	ND	ND	0.35	ND	0.02	0.00
02/12/00	0.02	ND	ND	ND	ND	0.05	0.01	0.01	0.03	0.02
02/21/00	ND	0.00	ND	0.00	ND	ND	ND	ND	0.01	0.05
02/26/00	ND	ND	ND	ND	0.01	ND	ND	ND	ND	0.13
03/06/00	0.13	0.05	0.05	0.04	0.07	ND	0.02	0.02	0.12	ND
03/12/00	ND	0.02	ND	0.38	0.00	0.07	ND	0.07	0.11	ND
03/20/00	0.02	0.01	ND	0.00	0.35	0.06	ND	0.09	0.03	ND
03/27/00	ND	ND	0.24	0.09	0.20	ND	0.09	0.10	0.01	0.26
04/04/00	0.04	0.04	0.04	0.02	0.00	ND	0.03	0.00	0.02	ND
04/10/00	ND	ND	0.04	0.04	0.02	ND	ND	0.23	ND	0.36
04/19/00	ND	0.02	ND	ND	ND	ND	ND	0.00	ND	ND
04/30/00	ND	0.03	0.07	ND	0.08	ND	0.06	ND	ND	0.03
Average	0.02	0.06	0.03	0.04	0.07	0.01	0.02	0.03	0.00	0.08
Min	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Max	0.17	0.35	0.24	0.38	0.35	0.28	0.35	0.23	0.12	0.72

NOTE:

The shaded values were not used in calculations.

The values marked ND are below the detection limits

Appendix A: Metals Concentration Data - Sodium.

This data was generated by an ICPMS from the weekly grab samples taken at each reach. The values are recorded as µg/L and can also be thought of as ppb.

Sodium (Na)										
	Soluble Sodium, µg/L					Total Sodium, µg/L				
Date	Tronsen	Reach 1	Reach 2	Reach 3	Reach 4	Tronsen	Reach 1	Reach 2	Reach 3	Reach 4
12/18/99	3,941	2,338	2,810	1,090	2,035	6,552	4,855	4,527	1,875	3,631
01/02/00	4,579	2,895	3,203	1,202	2,034	4,516	2,778	3,302	1,234	1,969
01/08/00	4,720	2,908	3,343	1,450	2,218	4,568	2,835	3,283	1,223	1,923
01/16/00	4,785	2,985	3,484	1,276	2,100	4,432	2,875	3,131	1,216	2,050
01/23/00	4,889	3,092	3,532	1,526	2,293	4,774	2,861	3,292	1,377	1,933
01/29/00	4,855	2,915	3,378	1,406	2,285	4,623	2,954	3,708	1,382	2,195
02/07/00	4,713	3,079	3,562	1,373	2,298	4,460	2,869	3,185	1,338	2,233
02/12/00	4,847	3,071	3,467	1,404	2,528	4,692	2,909	3,421	1,367	2,269
02/21/00	4,457	2,951	3,354	1,314	2,450	4,453	2,941	3,317	1,325	2,450
02/26/00	4,436	2,854	3,301	1,315	2,600	4,318	2,804	3,234	1,393	2,635
03/06/00	3,830	2,492	2,897	1,260	2,707	4,015	2,825	3,188	1,259	6,474
03/12/00	3,840	2,539	2,960	1,312	2,878	4,362	2,861	3,173	1,281	7,229
03/20/00	3,640	2,566	2,870	1,372	2,977	3,862	2,566	2,887	1,289	6,251
03/27/00	3,742	2,196	3,285	1,362	2,773	7,286	4,694	5,837	2,859	5,848
04/04/00	2,867	1,471	1,796	846	1,775	6,059	3,432	4,128	1,763	3,671
04/10/00	3,045	1,759	2,146	867	1,771	6,756	4,259	4,837	1,953	4,308
04/19/00	3,624	1,808	2,026	844	1,562	7,523	3,835	4,829	1,866	3,118
04/30/00	3,462	2,066	2,477	1,001	1,550	6,991	2,130	1,992	1,146	3,052
Average	4,126	2,554	2,994	1,234	2,268	5,235	3,182	3,626	1,508	3,513
Min	2,867	1,471	1,796	844	1,550	3,862	2,130	1,992	1,146	1,923
Max	4,889	3,092	3,562	1,526	2,977	7,523	4,855	5,837	2,859	7,229

NOTE:

The shaded values were not used in calculations.

The values marked ND are below the detection

Appendix A: Metals Concentration Data - Calcium.

This data was generated by an ICPMS from the weekly grab samples taken at each reach. The values are recorded as µg/L and can also be thought of as ppb.

Calcium (Ca)

	Soluble Calcium, µg/L					Total Calcium, µg/L				
Date	Tronsen	Reach 1	Reach 2	Reach 3	Reach 4	Tronsen	Reach 1	Reach 2	Reach 3	Reach 4
12/18/99	22,163	13,303	15,483	5,059	12,983	43,720	27,569	27,644	8,706	24,092
01/02/00	25,263	17,893	20,543	6,001	12,423	23,983	17,303	20,603	5,880	12,213
01/08/00	24,933	18,073	20,523	6,217	12,333	24,033	17,803	20,163	6,109	11,863
01/16/00	25,023	18,453	20,983	6,462	12,603	23,993	17,823	19,913	6,118	12,363
01/23/00	25,143	18,813	22,083	6,483	13,013	24,683	18,103	21,073	6,528	11,853
01/29/00	26,443	18,883	21,513	7,210	13,393	25,083	18,173	22,453	6,960	13,253
02/07/00	26,256	19,103	22,113	6,877	13,753	25,123	18,313	20,463	6,296	12,983
02/12/00	27,268	19,653	22,543	6,905	14,823	20,554	13,944	18,858	5,067	10,798
02/21/00	25,373	18,393	21,533	6,499	15,083	25,569	18,333	21,383	6,376	14,703
02/26/00	26,153	18,633	21,233	6,488	15,463	25,743	18,403	21,633	6,679	15,673
03/06/00	28,193	18,357	22,148	6,834	17,667	23,603	15,914	19,369	6,035	34,498
03/12/00	27,717	18,520	22,790	7,203	18,662	24,563	16,096	19,331	5,985	35,267
03/20/00	26,549	17,856	21,532	7,895	19,317	27,291	17,935	21,632	7,625	33,588
03/27/00	22,569	15,668	18,831	6,541	16,108	41,078	28,171	33,244	12,482	31,357
04/04/00	16,770	11,292	13,567	4,129	11,872	33,529	23,987	25,780	8,269	23,606
04/10/00	17,854	12,829	13,867	4,896	11,079	33,658	25,008	28,145	9,710	21,898
04/19/00	14,777	11,486	12,448	4,428	9,845	30,687	22,480	25,488	9,074	19,253
04/30/00	16,057	13,178	13,783	4,768	9,458	30,878	12,150	13,168	4,622	18,172
Average	23,583	16,688	19,306	6,161	13,882	28,209	19,306	22,241	7,140	19,857
Min	14,777	11,292	12,448	4,129	9,458	20,554	12,150	13,168	4,622	10,798
Max	28,193	19,653	22,790	7,895	19,317	43,720	28,171	33,244	12,482	35,267

NOTE:

The shaded values were not used in calculations.

The values marked ND are below the detection

Appendix A: Metals Concentration Data - Magnesium.

This data was generated by an ICPMS from the weekly grab samples taken at each reach. The values are recorded as µg/L and can also be thought of as ppb.

Magnesium (Mg)										
	Soluble Magnesium, µg/L					Total Magnesium, µg/L				
Date	Tronsen	Reach 1	Reach 2	Reach 3	Reach 4	Tronsen	Reach 1	Reach 2	Reach 3	Reach 4
12/18/99	7,461	4,483	5,912	6,774	8,514	13,130	8,949	11,198	11,914	19,435
01/02/00	8,671	6,633	8,451	7,435	10,796	8,454	6,231	8,764	7,345	10,436
01/08/00	8,460	6,532	8,725	7,731	10,686	8,307	6,621	8,993	7,415	10,616
01/16/00	8,721	6,970	9,226	7,843	11,286	8,258	6,719	9,014	7,348	11,236
01/23/00	8,957	7,157	9,819	7,575	11,716	8,952	6,856	9,422	8,093	10,376
01/29/00	8,994	7,182	9,760	8,416	12,186	8,729	7,306	10,506	8,273	11,796
02/07/00	9,180	7,217	10,016	8,046	12,056	8,623	6,763	8,849	7,777	11,526
02/12/00	9,568	7,171	9,465	8,032	12,266	6,594	4,773	6,786	5,790	7,924
02/21/00	8,835	6,792	9,151	7,455	11,916	8,931	6,920	9,017	7,476	11,756
02/26/00	9,270	6,815	9,122	7,399	11,606	9,131	6,782	8,983	7,595	11,676
03/06/00	10,020	7,009	9,184	7,844	13,087	9,053	6,561	8,763	7,511	27,561
03/12/00	9,916	7,323	9,962	8,242	13,609	9,782	7,053	9,002	7,341	27,163
03/20/00	9,517	6,999	9,252	8,876	13,731	10,081	6,998	9,322	8,721	24,025
03/27/00	7,700	5,646	7,692	7,056	10,744	15,562	11,045	14,141	13,945	22,597
04/04/00	5,433	3,994	4,909	5,446	8,066	12,484	8,293	10,558	10,054	19,683
04/10/00	6,088	4,491	6,217	5,792	9,265	12,474	9,861	11,677	12,296	17,930
04/19/00	5,318	3,981	4,958	6,134	7,574	10,918	7,486	10,328	14,012	16,201
04/30/00	5,774	4,725	6,499	7,301	9,432	10,394	4,735	5,795	6,693	16,178
Average	8,216	6,173	8,240	7,411	11,030	9,992	7,219	9,506	8,867	16,006
Min	5,318	3,981	4,909	5,446	7,574	6,594	4,735	5,795	5,790	7,924
Max	10,020	7,323	10,016	8,876	13,731	15,562	11,045	14,141	14,012	27,561

NOTE:

The shaded values were not used in calculations.

The values marked ND are below the detection

Appendix A: Metals Concentration Data - Iron.

This data was generated by an ICPMS from the weekly grab samples taken at each reach. The values are recorded as µg/L and can also be thought of as ppb.

Iron (Fe)										
	Soluble Iron, µg/L					Total Iron, µg/L				
Date	Tronsen	Reach 1	Reach 2	Reach 3	Reach 4	Tronsen	Reach 1	Reach 2	Reach 3	Reach 4
12/18/99	121	142	130	29	102	1,633	1,102	1,216	718	4,133
01/02/00	100	64	79	24	48	109	91	88	31	64
01/08/00	91	67	77	23	50	114	78	85	35	66
01/16/00	94	70	80	22	46	135	71	92	28	56
01/23/00	97	73	82	20	56	101	67	89	27	100
01/29/00	102	69	78	27	50	100	72	105	32	58
02/07/00	97	67	81	25	50	97	64	76	21	81
02/12/00	99	69	84	25	53	ND	ND	ND	ND	ND
02/21/00	82	60	71	19	48	96	71	72	24	84
02/26/00	95	61	73	19	51	92	63	76	24	76
03/06/00	101	69	57	48	110	15	5	52	ND	587
03/12/00	85	60	54	52	86	71	51	23	ND	621
03/20/00	70	63	76	48	75	103	79	78	39	915
03/27/00	102	127	88	66	155	510	245	330	66	1,371
04/04/00	128	99	129	9	154	2,961	1,263	1,689	470	3,953
04/10/00	93	79	62	35	69	719	310	429	268	1,023
04/19/00	132	43	58	29	59	953	326	507	267	825
04/30/00	54	24	46	23	31	385	41	17	26	219
Average	97	73	78	30	72	482	235	296	119	837
Min	54	24	46	9	31	15	5	17	ND	56
Max	132	142	130	66	155	2,961	1,263	1,689	718	4,133

NOTE:

The shaded values were not used in calculations.

The values marked ND are below the detection

APPENDIX B

Calculations & Procedures

Appendix B: Microtox calculations.

Microtox® Toxicity data and calculations. Shaded data not used in calculations.

Microtox® Toxicity Tests								
Analyst: *Nathaniel Marcoe*								
Deicer	Date	Concentration	$EC50_{15}$ (%)	EC50 mg/L	95% CI Range (%)		95% CI Range (mg/L)	
IceBAN	1/18/00	2754.5	72	1,982	36	143	995	3,947
IceBAN	6/30/00	1000	164	1,639	124	216	1,242	2,162
IceBAN	7/3/00	3000	85	2,538	73	98	2,183	2,951
IceBAN	7/11/00	8000	63	5,071	61	65	4,916	5,231
IceBAN	7/19/00	8000	58	4,631	56	60	4,455	4,814
CMA	7/4/00	3000	89	2,682	47	170	1,410	5,098
CMA	7/11/00	8000	59	4,749	40	88	3,222	7,000
CMA	7/19/00	8000	58	4,660	21	165	1,648	13,181
NaCl	7/11/00	8000	--	> 8,000				
$CaCl_2$	7/11/00	8000	--	> 8,000		Not used:		

Deicer	EC50-15min
IceBAN	4,851
CMA	4,705
NaCl	>8,000
$CaCl_2$	>8,000

Phenol Standards		EC_{50}5 mg/L	
STD	1/17/00	17.6	OK
STD	6/29/00	23.7	OK
STD	7/10/00	15.97	OK

Range = 13-26 mg/L

Species			LC_{50}
Oncorhynchus mykiss	(Rainbow Trout)	CMA	17,500
Acute Static 96h		CMA	18,700
		CMA	> 1,000
		NaCl	12,200

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Appendix B: Benthic macro invertebrate data and calculations.

Benthic macro invertebrate data and confidence interval calculations.

First Benthic Macro invertebrate Sampling 03/13/00

Reach 1	May fly	Stone fly	Caddis fly	Reach 2	Mayfly	Stone fly	Caddis fly	Reach 4	Mayfly	Stone fly	Caddis fly
# 1	2	1	1	# 1	4	6	9	# 1	10	6	0
# 2	0	0	0	# 2	12	3	3	# 2	0	5	3
# 3	2	1	1	# 3	---	---	---	# 3	4	5	5
# 4	0	0	1	# 4	5	1	3	# 4	4	3	4
# 5	0	0	0	# 5	5	0	1	# 5	7	2	0
# 6	1	1	0	# 6	3	1	2	# 6	8	3	1
# 7	3	1	0	# 7	4	0	7	# 7	5	3	2

	Mayfly		Stonefly		Caddisfly		Totals
Reach	Mean	CI	Mean	CI	Mean	CI	Total organisms
Reach 1	1.1	0.9	0.6	0.4	0.4	0.4	15
Reach 2	5.5	2.4	1.8	1.7	4.2	2.3	69
Reach 4	5.4	2.4	3.9	1.1	2.1	1.4	80

Second Benthic Macro invertebrate Sampling 06/07/00

Reach 1	Mayfly	Stone fly	Caddis fly	Reach 2	Mayfly	Stone fly	Caddis fly	Reach 4	Mayfly	Stone fly	Caddis fly
# 1	0	0	0	# 1	19	6	1	# 1	17	4	6
# 2	2	2	0	# 2	2	2	1	# 2	28	8	7
# 3	1	0	1	# 3	---	---	---	# 3	30	4	4

	Mayfly		Stonefly		Caddisfly		Totals
Reach	Mean	CI	Mean	CI	Mean	CI	Total organisms
Reach 1	1.0	0.7	0.7	0.9	0.3	0.4	6
Reach 2	10.5	8.9	4.0	2.1	1.0	---	31
Reach 4	25.0	5.2	5.3	1.7	5.7	1.1	108

Appendix B: IceBAN data & calculations.

The IceBAN data and calculations including chloride concentration, calcium chloride concentration and metals concentrations.

Sample = 100 mg IceBAN / L	
Sample	Chloride Conc. mg/L
IceBAN 03/13/00 A	23.57
IceBAN 03/13/00 B	23.62
IceBAN 03/13/00 C	23.69
IceBAN 03/13/00 D	23.54
IceBAN 03/13/00 E	23.47
Average	23.58
Variance	0.006
Std.Dev.	0.081
CI	0.081

% Cl^- in IceBAN = 23.58%

%$CaCl_2$ in IceBAN = 36.9%

Metals Concentrations (Measured and Calculated)

Metal	Concentrations in 100mg/L Solution.	
	Soluble, μg/L	Total, μg/L
Cu	0.22	0.36
Pb	0.15	1.43
Zn	1.91	ND
Cd	ND	ND
Na	275	621
Ca	9,572	19,181
Mg	106	192
Fe	16	20

Metal	Calculated Concentrations in Pure IceBAN	
	Soluble, mg/L	Total, mg/L
Cu	3.014	4.932
Pb	2.055	19.589
Zn	26.164	--
Cd	--	--
Na	3,767	8,506
Ca	131,123	262,753
Mg	1,452	2,630
Fe	219.2	274.0

Appendix B: Acid digestion procedures.

The acid digestion process from US EPA Method 200.7, *Determination of Metals and Ttrace Elements in Water and Wastes by Inductively Coupled Plasma – Atomic Emission Spectrometry*, Section 11.2.

1. Transfer 100 mL (±1 mL) aliquot from a well mixed, acid preserved sample to a 250 ml Griffin Beaker.
2. Add 2 mL of (1+1) nitric acid and 1.0 mL of (1+1) hydrochloric acid to the beaker.
3. Place the beaker on a hotplate set at ~85°C and cover with a ribbed watch glass.
4. Reduce the volume in the beaker to ~ 20 mL, then cover the lip of the beaker with a watch glass.
5. Reflux the sample for 30 minutes.
6. Allow to cool and pour contents into syringe (filter apparatus).
7. Make volume to 50 mL with reagent grade water.
8. Filter into 60 mL Nalgene bottle and shake.
9. Keep sample stored at 4°C until used.

APPENDIX C

Sediment Data

Appendix C: Sieve analysis data.

Sieve analysis data.

Sieve Analysis				
Sample: 1-1				
Analyst Name:		***Nathaniel Marcoe***		
Test Date:		***May 12, 2000***		
Sample Description:		***Peshastin Creek stream bed***		
Sample Mass =		**2867.8**	***grams***	
US Sieve Number	Sieve Opening (mm)	Wt. Retained (g)	Wt. Passing (g)	% Finer
3 in	76.2	0.0	2867.3	100.0%
$1^1/_4$ in	32.0	1593.9	1273.4	44.4%
1 in	26.7	115.4	1158.0	40.4%
3/4 in	19.1	308.1	849.9	29.6%
3/8 in	9.51	225.0	624.9	21.8%
1/4 in	6.35	95.8	529.1	18.4%
# 4	4.75	59.1	470.0	16.4%
# 10	2.00	144.0	326.0	11.4%
# 20	0.850	168.3	157.7	5.5%
# 70	0.210	134.6	23.1	0.8%
	Pan	23.1	0	0.0%
Total Measured Mass:		2867.3	grams	
% Error =		0.017%		
Acceptable Error =		0.042%		

Appendix C: Sieve analysis data.

Sieve analysis data.

Sieve Analysis				
Sample: 1-2				
Analyst Name:		***Nathaniel Marcoe***		
Test Date:		***May 16, 2000***		
Sample Description:		***Peshastin Creek stream bed.***		
Sample Mass =		**3454.9**	***grams***	
US Sieve Number	Sieve Opening (mm)	Wt. Retained (g)	Wt. Passing (g)	% Finer
3 in	76.2	0.0	3454.7	100.0%
$1^1/_4$ in	32.0	1491.4	1963.3	56.8%
1 in	26.7	278.4	1684.9	48.8%
3/4 in	19.1	423.2	1261.7	36.5%
3/8 in	9.51	388.9	872.8	25.3%
1/4 in	6.35	130.1	742.7	21.5%
# 4	4.75	69.1	673.6	19.5%
# 10	2.00	181.3	492.3	14.2%
# 20	0.850	240.0	252.3	7.3%
# 70	0.210	214.8	37.5	1.1%
	Pan	37.5	0	0.0%
Total Measured Mass:		3454.7	grams	
% Error =		0.006%		
Acceptable Error =		0.035%		

Appendix C: Sieve analysis data.

Sieve analysis data.

Sieve Analysis				
Sample: 1-3				
Analyst Name:		***Nathaniel Marcoe***		
Test Date:		***May 17, 2000***		
Sample Description:		***Peshastin Creek stream bed.***		
Sample Mass =		**3308.8**	***grams***	
US Sieve Number	Sieve Opening (mm)	Wt. Retained (g)	Wt. Passing (g)	% Finer
3 in	76.2	0.0	3309.6	100.0%
$1^1/_4$ in	32.0	293.4	3016.2	91.2%
1 in	26.7	177.4	2838.8	85.8%
3/4 in	19.1	429.0	2409.8	72.8%
3/8 in	9.51	667.1	1742.7	52.7%
1/4 in	6.35	337.1	1405.6	42.5%
# 4	4.75	180.9	1224.7	37.0%
# 10	2.00	323.2	901.5	27.2%
# 20	0.850	290.3	611.2	18.5%
# 70	0.210	438.1	173.1	5.2%
	Pan	173.1	0	0.0%
Total Measured Mass:		3309.6	grams	
% Error =		0.023%		
Acceptable Error =		0.036%		

Appendix C: Sieve analysis data.

Sieve analysis data.

Sieve Analysis				
Sample: 1-1b				
Analyst Name:	***Nathaniel Marcoe***			
Test Date:	***June 13, 2000***			
Sample Description:	***Peshastin Creek stream bed 06.07.00***			
Sample Mass =	**3915.2**	***grams***		
US Sieve Number	Sieve Opening (mm)	Wt. Retained (g)	Wt. Passing (g)	% Finer
3 in	76.2	0.0	3915.7	100.0%
$1^1/_4$ in	32.0	1017.9	2897.8	74.0%
1 in	26.7	140.1	2757.7	70.4%
3/4 in	19.1	230.4	2527.3	64.6%
3/8 in	9.51	896.2	1631.1	41.7%
1/4 in	6.35	432.9	1198.2	30.6%
# 4	4.75	204.4	993.8	25.4%
# 10	2.00	403.4	590.4	15.1%
# 20	0.850	288.1	302.3	7.7%
# 70	0.210	234.0	68.3	1.7%
	Pan	68.3	0	0.0%
Total Measured Mass:	3915.7	grams		
% Error =	0.013%			
Acceptable Error =	0.031%			

Appendix C: Sieve analysis data.

Sieve analysis data.

Sieve Analysis				
Sample: 1-2b				
Analyst Name:	***Nathaniel Marcoe***			
Test Date:	***June 14, 2000***			
Sample Description:	***Peshastin Creek stream bed.***			
Sample Mass =	**6351.8**	***grams***		
US Sieve Number	Sieve Opening (mm)	Wt. Retained (g)	Wt. Passing (g)	% Finer
3 in	76.2	0.0	6352.4	100.0%
$1^1/_4$ in	32.0	965.7	5386.7	84.8%
1 in	26.7	421.4	4965.3	78.2%
3/4 in	19.1	524.3	4441.0	69.9%
3/8 in	9.51	1390.4	3050.6	48.0%
1/4 in	6.35	726.5	2324.1	36.6%
# 4	4.75	363.8	1960.3	30.9%
# 10	2.00	861.9	1098.4	17.3%
# 20	0.850	600.6	497.8	7.8%
# 70	0.210	403.9	93.9	1.5%
	Pan	93.9	0	0.0%
Total Measured Mass:		6352.4	grams	
% Error =		0.009%		
Acceptable Error =		0.019%		

Appendix C: Sieve analysis data.

Sieve analysis data.

Sieve Analysis				
Sample: 1-3b				
Analyst Name:		***Nathaniel Marcoe***		
Test Date:		***June 14, 2000***		
Sample Description:		***Peshastin Creek stream bed.***		
Sample Mass =		**4061.3**	***grams***	
US Sieve Number	Sieve Opening (mm)	Wt. Retained (g)	Wt. Passing (g)	% Finer
3 in	76.2	0.0	4062.5	100.0%
$1^1/_4$ in	32.0	818.1	3244.4	79.9%
1 in	26.7	197.8	3046.6	75.0%
3/4 in	19.1	589.8	2456.8	60.5%
3/8 in	9.51	934.3	1522.5	37.5%
1/4 in	6.35	280.1	1242.4	30.6%
# 4	4.75	163.6	1078.7	26.6%
# 10	2.00	391.2	687.5	16.9%
# 20	0.850	357.5	330.0	8.1%
# 70	0.210	268.7	61.3	1.5%
	Pan	61.3	0	0.0%
Total Measured Mass:		4062.5	grams	
% Error =		0.028%		
Acceptable Error =		0.030%		

Appendix C: Sieve analysis data.

Sieve analysis data.

Sieve Analysis				
Sample: 2-1				
Analyst Name:		***Nathaniel Marcoe***		
Test Date:		***May 19, 2000***		
Sample Description:		***Peshastin Creek stream bed***		
Sample Mass =		**4755.6**	***grams***	
US Sieve Number	Sieve Opening (mm)	Wt. Retained (g)	Wt. Passing (g)	% Finer
3 in	76.2	0.0	4756.6	100.0%
$1^{1}/_{4}$ in	32.0	536.0	4220.6	88.8%
1 in	26.7	37.7	4182.9	88.0%
3/4 in	19.1	430.2	3752.7	78.9%
3/8 in	9.51	1397.1	2355.6	49.5%
1/4 in	6.35	414.8	1940.8	40.8%
# 4	4.75	277.0	1663.8	35.0%
# 10	2.00	642.6	1021.2	21.5%
# 20	0.850	601.6	419.6	8.8%
# 70	0.210	378.8	40.8	0.9%
	Pan	40.8	0	0.0%
Total Measured Mass:		4756.6	grams	
% Error =		0.022%		
Acceptable Error =		0.025%		

Appendix C: Sieve analysis data.

Sieve analysis data.

Sieve Analysis				
Sample: 2-2				
Analyst Name:		***Nathaniel Marcoe***		
Test Date:		***May 22, 2000***		
Sample Description:		***Peshastin Creek stream bed.***		
Sample Mass =		**2437.5**	***grams***	
US Sieve Number	Sieve Opening (mm)	Wt. Retained (g)	Wt. Passing (g)	% Finer
3 in	76.2	0.0	2438.2	100.0%
$1^1/_4$ in	32.0	1465.5	972.7	39.9%
1 in	26.7	190.9	781.8	32.1%
3/4 in	19.1	184.1	597.7	24.5%
3/8 in	9.51	212.2	385.5	15.8%
1/4 in	6.35	51.2	334.3	13.7%
# 4	4.75	34.4	300.0	12.3%
# 10	2.00	98.9	201.1	8.3%
# 20	0.850	114.6	86.6	3.6%
# 70	0.210	73.7	12.8	0.5%
	Pan	12.8	0	0.0%
Total Measured Mass:		2438.2	grams	
% Error =		0.030%		
Acceptable Error =		0.049%		

Appendix C: Sieve analysis data.

Sieve analysis data.

Sieve Analysis				
Sample: 2-3				
Analyst Name:		***Nathaniel Marcoe***		
Test Date:		***May 23, 2000***		
Sample Description:		***Peshastin Creek stream bed.***		
Sample Mass =		**2710.1**	***grams***	
US Sieve Number	Sieve Opening (mm)	Wt. Retained (g)	Wt. Passing (g)	% Finer
3 in	76.2	0.0	2710.3	100.0%
$1^1/_4$ in	32.0	1096.2	1614.1	59.6%
1 in	26.7	94.2	1519.9	56.1%
3/4 in	19.1	453.8	1066.1	39.3%
3/8 in	9.51	502.4	563.7	20.8%
1/4 in	6.35	130.2	433.5	16.0%
# 4	4.75	78.6	354.9	13.1%
# 10	2.00	167.9	187.0	6.9%
# 20	0.850	115.5	71.5	2.6%
# 70	0.210	64.3	7.2	0.3%
	Pan	7.2	0	0.0%
Total Measured Mass:		2710.3	grams	
% Error =		0.007%		
Acceptable Error =		0.044%		

Appendix C: Sieve analysis data.

Sieve analysis data.

Sieve Analysis				
Sample: 2-1b				
Analyst Name:		*Nathaniel Marcoe*		
Test Date:		*June 20, 2000*		
Sample Description:		*Peshastin Creek stream bed*		
Sample Mass =		**4192.9**	*grams*	
US Sieve Number	Sieve Opening (mm)	Wt. Retained (g)	Wt. Passing (g)	% Finer
3 in	76.2	0.0	4192.2	100.0%
$1^1/_4$ in	32.0	1024.3	3167.9	75.6%
1 in	26.7	226.6	2941.3	70.1%
3/4 in	19.1	572.1	2369.2	56.5%
3/8 in	9.51	669.8	1699.4	40.5%
1/4 in	6.35	278.8	1420.6	33.9%
# 4	4.75	174.6	1246.0	29.7%
# 10	2.00	435.8	810.2	19.3%
# 20	0.850	390.1	420.1	10.0%
# 70	0.210	337.5	82.6	2.0%
	Pan	82.6	0	0.0%
Total Measured Mass:		4192.2	grams	
% Error =		0.018%		
Acceptable Error =		0.029%		

Appendix C: Sieve analysis data.

Sieve analysis data.

Sieve Analysis				
Sample: 2-2b				
Analyst Name:		***Nathaniel Marcoe***		
Test Date:		***June 20, 2000***		
Sample Description:		***Peshastin Creek stream bed.***		
Sample Mass =		**4312.2**	***grams***	
US Sieve Number	Sieve Opening (mm)	Wt. Retained (g)	Wt. Passing (g)	% Finer
3 in	76.2	1397.2	2915.5	67.6%
$1^1/_4$ in	32.0	901.7	2013.8	46.7%
1 in	26.7	0.0	2013.8	46.7%
3/4 in	19.1	199.3	1814.5	42.1%
3/8 in	9.51	776.8	1037.7	24.1%
1/4 in	6.35	416.2	621.5	14.4%
# 4	4.75	179.3	442.2	10.3%
# 10	2.00	221.3	220.9	5.1%
# 20	0.850	118.3	102.6	2.4%
# 70	0.210	83.9	18.7	0.4%
	Pan	18.7	0	0.0%
Total Measured Mass:		4312.7	grams	
% Error =		0.012%		
Acceptable Error =		0.028%		

Appendix C: Sieve analysis data.

Sieve analysis data.

Sieve Analysis				
Sample: 2-3b				
Analyst Name:		***Nathaniel Marcoe***		
Test Date:		***May 23, 2000***		
Sample Description:		***Peshastin Creek stream bed.***		
Sample Mass =		**4914.7**	***grams***	
US Sieve Number	Sieve Opening (mm)	Wt. Retained (g)	Wt. Passing (g)	% Finer
3 in	76.2	771.2	4143.2	84.3%
$1^1/_4$ in	32.0	801.0	3342.2	68.0%
1 in	26.7	190.8	3151.4	64.1%
3/4 in	19.1	522.3	2629.1	53.5%
3/8 in	9.51	768.4	1860.7	37.9%
1/4 in	6.35	308.4	1552.3	31.6%
# 4	4.75	220.8	1331.5	27.1%
# 10	2.00	571.7	759.8	15.5%
# 20	0.850	443.9	315.9	6.4%
# 70	0.210	272.3	43.6	0.9%
	Pan	43.6	0	0.0%
Total Measured Mass:		4914.4	grams	
% Error =		0.006%		
Acceptable Error =		0.024%		

Appendix C: Sieve analysis data.

Sieve analysis data.

Sieve Analysis				
Sample: 3-1				
Analyst Name:		***Nathaniel Marcoe***		
Test Date:		***May 23, 2000***		
Sample Description:		***Peshastin Creek stream bed***		
Sample Mass =		**3803.3**	***grams***	
US Sieve Number	Sieve Opening (mm)	Wt. Retained (g)	Wt. Passing (g)	% Finer
3 in	76.2	0.0	3802.5	100.0%
$1^1/_4$ in	32.0	349.2	3453.2	90.8%
1 in	26.7	205.4	3247.8	85.4%
3/4 in	19.1	487.9	2759.9	72.6%
3/8 in	9.51	1019.4	1740.5	45.8%
1/4 in	6.35	353.7	1386.8	36.5%
# 4	4.75	193.1	1193.7	31.4%
# 10	2.00	377.2	816.5	21.5%
# 20	0.850	320.0	496.5	13.1%
# 70	0.210	419.1	77.4	2.0%
	Pan	77.4	0	0.0%
Total Measured Mass:		3802.5	grams	
% Error =		0.022%		
Acceptable Error =		0.032%		

Appendix C: Sieve analysis data.

Sieve analysis data.

Sieve Analysis				
Sample: 3-2				
Analyst Name:		***Nathaniel Marcoe***		
Test Date:		***May 24, 2000***		
Sample Description:		***Peshastin Creek stream bed.***		
Sample Mass =		**4460.1**	***grams***	
US Sieve Number	Sieve Opening (mm)	Wt. Retained (g)	Wt. Passing (g)	% Finer
3 in	76.2	0.0	4460.5	100.0%
$1^1/_4$ in	32.0	186.2	4274.3	95.8%
1 in	26.7	49.9	4224.4	94.7%
3/4 in	19.1	235.7	3988.7	89.4%
3/8 in	9.51	960.6	3028.1	67.9%
1/4 in	6.35	421.7	2606.4	58.4%
# 4	4.75	292.4	2314.0	51.9%
# 10	2.00	779.9	1534.1	34.4%
# 20	0.850	578.4	955.7	21.4%
# 70	0.210	728.6	227.1	5.1%
	Pan	227.1	0	0.0%
Total Measured Mass:		4460.5	grams	
% Error =		0.010%		
Acceptable Error =		0.027%		

Appendix C: Sieve analysis data.

Sieve analysis data.

Sieve Analysis				
Sample: 3-3a				
Analyst Name:		*Nathaniel Marcoe*		
Test Date:		*May 24, 2000*		
Sample Description:		*Peshastin Creek stream bed.*		
Sample Mass =		3161.7	*grams*	
US Sieve Number	Sieve Opening (mm)	Wt. Retained (g)	Wt. Passing (g)	% Finer
3 in	76.2	0.0	3162.4	100.0%
$1^1/_4$ in	32.0	43.1	3119.3	98.7%
1 in	26.7	162.8	2956.5	93.5%
3/4 in	19.1	255.3	2701.2	85.4%
3/8 in	9.51	516.2	2185.0	69.1%
1/4 in	6.35	247.4	1937.6	61.3%
# 4	4.75	196.9	1740.7	55.1%
# 10	2.00	593.5	1147.2	36.3%
# 20	0.850	572.8	574.4	18.2%
# 70	0.210	504.8	69.6	2.2%
	Pan	69.6	0	0.0%
Total Measured Mass:		3162.4	grams	
% Error =		0.023%		
Acceptable Error =		0.038%		

Appendix C: Sieve analysis data.

Sieve analysis data.

Sieve Analysis				
Sample: 3-3b				
Analyst Name:		***Nathaniel Marcoe***		
Test Date:		***May 24, 2000***		
Sample Description:		***Peshastin Creek stream bed.***		
Sample Mass =		**2406.1**	***grams***	
US Sieve Number	Sieve Opening (mm)	Wt. Retained (g)	Wt. Passing (g)	% Finer
3 in	76.2	0.0	2407.1	100.0%
$1^{1}/_{4}$ in	32.0	70.1	2337.0	97.1%
1 in	26.7	65.4	2271.6	94.4%
3/4 in	19.1	198.2	2073.4	86.2%
3/8 in	9.51	363.9	1709.5	71.0%
1/4 in	6.35	186.2	1523.3	63.3%
# 4	4.75	150.3	1373.0	57.1%
# 10	2.00	434.7	938.3	39.0%
# 20	0.850	422.7	515.6	21.4%
# 70	0.210	435.5	80.1	3.3%
	Pan	80.1	0	0.0%
Total Measured Mass:		2407.1	grams	
% Error =		0.042%		
Acceptable Error =		0.050%		

Appendix C: Sieve analysis data.

Sieve analysis data.

Sieve Analysis				
Sample: R1-1				
Analyst Name:		***Nathaniel Marcoe***		
Test Date:		***June 15, 2000***		
Sample Description:		***Peshastin Creek stream bed***		
Sample Mass =		**5323.2**	***grams***	
US Sieve Number	Sieve Opening (mm)	Wt. Retained (g)	Wt. Passing (g)	% Finer
3 in	76.2	0.0	5324.0	100.0%
$1^1/_4$ in	32.0	466.6	4857.4	91.2%
1 in	26.7	316.4	4541.0	85.3%
3/4 in	19.1	744.1	3796.9	71.3%
3/8 in	9.51	1697.3	2099.6	39.4%
1/4 in	6.35	479.5	1620.1	30.4%
# 4	4.75	283.1	1337.0	25.1%
# 10	2.00	484.4	852.6	16.0%
# 20	0.850	251.3	601.3	11.3%
# 70	0.210	526.6	74.7	1.4%
	Pan	74.7	0	0.0%
Total Measured Mass:		5324.0	grams	
% Error =		0.015%		
Acceptable Error =		0.023%		

Appendix C: Sieve analysis data.

Sieve analysis data.

Sieve Analysis				
Sample: R1-2				
Analyst Name:		***Nathaniel Marcoe***		
Test Date:		***June 16, 2000***		
Sample Description:		***Peshastin Creek stream bed.***		
Sample Mass =		**6738.2**	***grams***	
US Sieve Number	Sieve Opening (mm)	Wt. Retained (g)	Wt. Passing (g)	% Finer
3 in	76.2	0.0	6738.1	100.0%
$1^{1}/_{4}$ in	32.0	2645.0	4093.1	60.7%
1 in	26.7	202.0	3891.1	57.7%
3/4 in	19.1	533.0	3358.1	49.8%
3/8 in	9.51	952.1	2406.0	35.7%
1/4 in	6.35	422.9	1983.1	29.4%
# 4	4.75	280.9	1702.2	25.3%
# 10	2.00	697.8	1004.4	14.9%
# 20	0.850	509.9	494.5	7.3%
# 70	0.210	445.5	49.0	0.7%
	Pan	49.0	0	0.0%
Total Measured Mass:		6738.1	grams	
% Error =		0.001%		
Acceptable Error =		0.018%		

Appendix C: Sieve analysis data.

Sieve analysis data.

Sieve Analysis				
Sample: R1-3				
Analyst Name:		***Nathaniel Marcoe***		
Test Date:		***June 16, 2000***		
Sample Description:		***Peshastin Creek stream bed.***		
Sample Mass =		**3968.5**	***grams***	
US Sieve	Sieve Opening	Wt. Retained	Wt. Passing	% Finer
Number	(mm)	(g)	(g)	
3 in	76.2	0.0	3969.6	100.0%
$1^1/_4$ in	32.0	1141.6	2828.0	71.3%
1 in	26.7	458.1	2369.9	59.7%
3/4 in	19.1	239.0	2130.9	53.7%
3/8 in	9.51	641.6	1489.3	37.5%
1/4 in	6.35	254.6	1234.7	31.1%
# 4	4.75	176.1	1058.6	26.7%
# 10	2.00	452.3	606.3	15.3%
# 20	0.850	370.9	235.4	5.9%
# 70	0.210	215.7	19.7	0.5%
	Pan	19.7	0	0.0%
Total Measured Mass:		3969.6	grams	
% Error =		0.028%		
Acceptable Error =		0.030%		

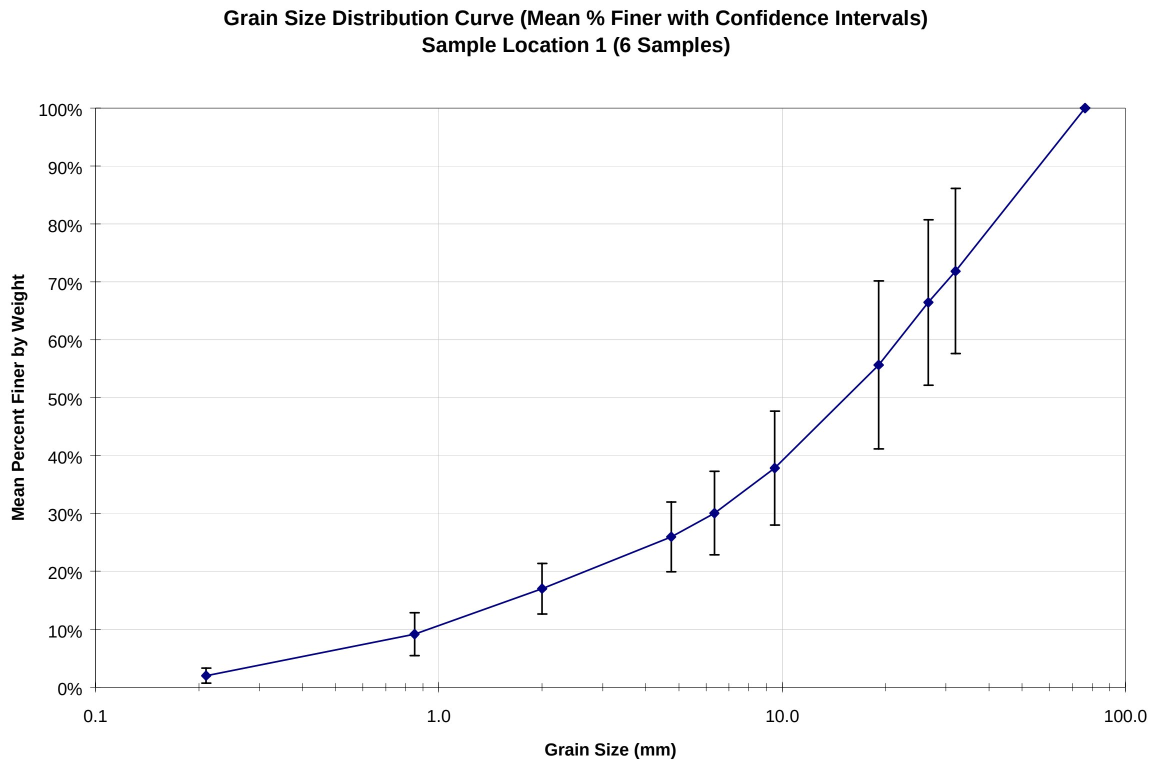
Appendix C: Sieve analysis data.

Sieve analysis data.

Sieve Analysis				
Sample: Traction Sand (Abrasives)				
Analyst Name:		***Nathaniel Marcoe***		
Test Date:		***June 13, 2000***		
Sample Description:		***Abrasive Sand from Hwy. 97***		
Sample Mass =		**1450.1**	***grams***	
US Sieve Number	Sieve Opening (mm)	Wt. Retained (g)	Wt. Passing (g)	% Finer
3 in	76.2	0.0	1449.1	100%
$1^1/_4$ in	32.0	0.0	1449.1	100%
1 in	26.7	0.0	1449.1	100%
3/4 in	19.1	0.0	1449.1	100%
3/8 in	9.51	4.2	1444.9	99.6%
1/4 in	6.35	26.2	1418.7	97.8%
# 4	4.75	51.1	1367.6	94.3%
# 10	2.00	231.0	1136.6	78.4%
# 20	0.850	376.6	760.0	52.4%
# 70	0.210	613.6	146.4	10.1%
	Pan	146.4	0	0.0%
Total Measured Mass:		1449.1	grams	
% Error =		0.070%		
Acceptable Error =		0.083%		

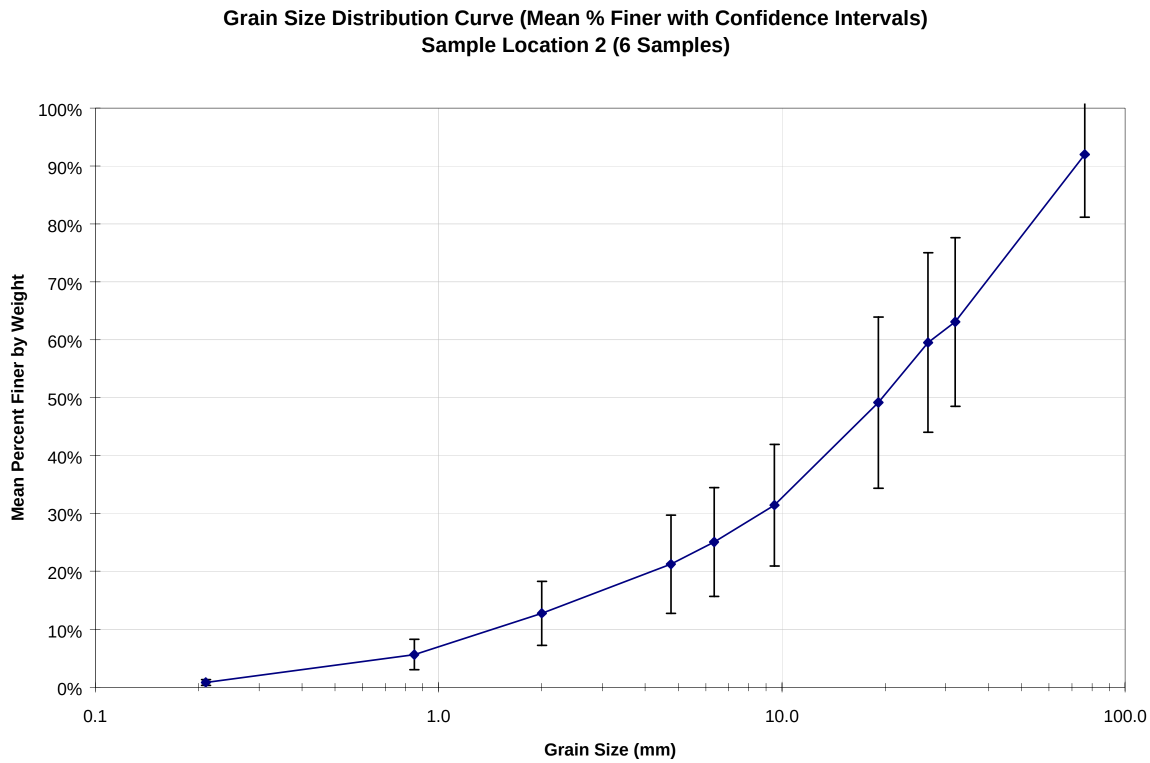
Appendix C: Average grain size distribution curve for Sample Location 1.

Three samples were taken on 3/16/00 and 6/7/00 (for a total of 6 samples) from a known redd. The depth ranged from 1.3 to 1.9 ft and the velocity ranged from 1.50 to 2.42 ft/s.



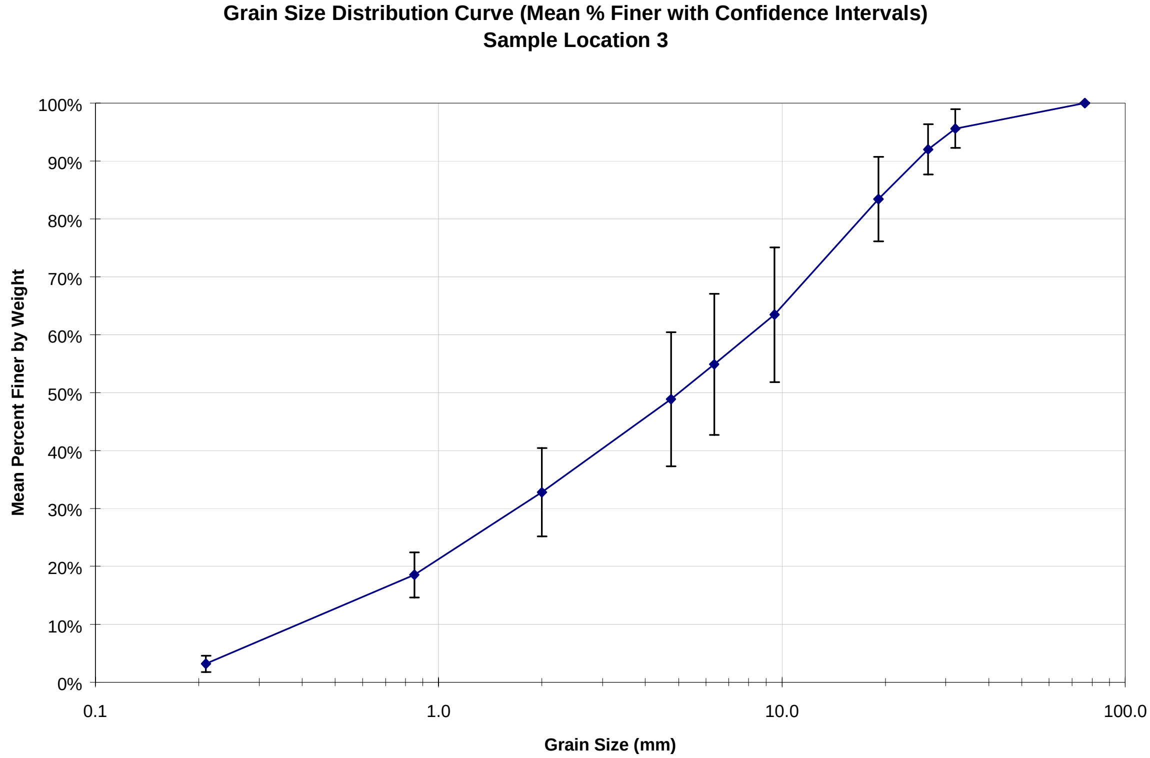
Appendix C: Average grain size distribution curve for Sample Location 2.

Three samples were taken on 3/16/00 and 6/7/00 (for a total of 6 samples) from a known redd. The depth ranged from 1.3 to 2.0 ft and the velocity ranged from 1.98 to 2.80 ft/s. .



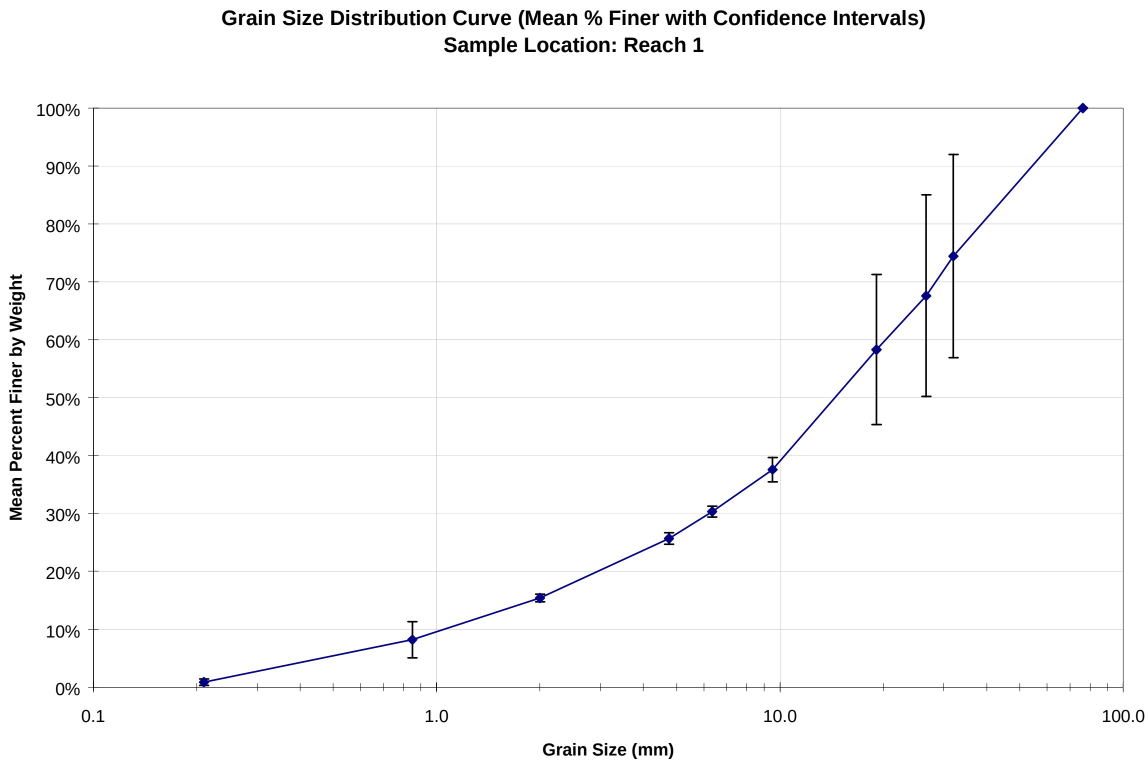
Appendix C: Average grain size distribution curve for Sample Location 3.

Three samples were taken on 3/16/00 from an area just downstream. Therefore, it was an area of known local deposition. The depth was 0.8 ft and the velocity ranged from 1.00 to 2.04 ft/s. .



Appendix C: Average grain size distribution curve for Reach 1.

Three samples were taken on 6/7/00 from a Reach 1 which wsa assumed to be a background. The depth ranged from 0.4 to 0.6 ft and the velocity ranged from 0.29 to 1.94 ft/s. .



Appendix C: Grain size distribution curve for Traction Sand.

Three samples were taken on 11/5/99 from the sand pile located at the WSDOT maintenance shed on Highway 97. A composite sample was taken. .