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Characterization of Storm Events Using an Automated Sampler

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CHARACTERIZATION OF STORM EVENTS USING AN AUTOMATED SAMPLER

Masters Project Report

by

Shem Stygar

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The views, opinions, and findings contained herein are those of the author and do not reflect the official policies of the MHD. This report does not constitute a standard, specification or regulation.

ABSTRACT

The goal of this research was to evaluate the use of an automated sampler in profiling concentrations of deicing agents in storm runoff at a research site in Plymouth, MA. The Massachusetts Highway Department applies a combination of deicing agents in the form of salt, premix and calcium magnesium acetate (CMA) to an 830 m long stretch of State Route 25 during the months of November to April when driving conditions are hazardous. Portions of the applied deicing agents applied are left behind in a depression storage layer which was found to be 2.67 mm. The depression storage layer governs the dissolution kinetics of deicing agents into runoff over the year.

Precipitation, runoff and specific conductivity data for storms over a 4 year period (2001-2004) were used in developing a sampling strategy for an ISCO 6712 automated sampler with 24 available samples. The best sampling rule for a yearly sampling strategy was found to be split into two parts. The first with five samples to capture the first flush at time steps of 15 minutes, while the second part of the rule has 19 samples following completion of the first part of the rule which were taken at 65 minute intervals. The error between the flux for the storm and the flux captured by the sampling rule was 37%. Dividing the sampling strategy into summer and winter seasons provided better results with more samples needed to profile first flush in the winter [11 samples – time spacing (Δt) of 20 min] compared to fewer samples needed for the summer (5 samples – Δt 10 min). The second part of the rule for both summer and winter had time between samples taken of greater than an hour; errors decreased from the yearly sampling. Differences between the flux were 34% for winter sampling and 38% for summer sampling. The results of this rule were used in successive sample collection using the automated sampler.

Samples collected by the automated sampler were evaluated for cations and anions studied (HCO_3^-, Acetate ,Cl^- ,SO_4^{-2} ,Na^+ ,K^+ ,Ca^{+2} ,Mg^{+2}). Amounts of deicing agents were predicted from the observed concentrations of ions showing that maximum concentrations of deicing agents occurred in winter runoff. Sodium and chloride ions dominate the ionic species in the runoff throughout the year. This is shown in the source strength predicted by the loadograph model (average – 1.26×10^{-7} kg/m^2-s) and shown by the graphs of storm events. CMA and premix concentrations persist in significantly less quantities in storm runoff throughout the year.

Models of runoff and Cl^- flux were developed using a one parameter Nash instantaneous unit hydrograph (IUH). Runoff was calibrated for storm events from 2004 using a Fibonacci search to find the runoff decay constant for the study site. Optimum parameters of 1 linear reservoir and a runoff decay constant of 7.79×10^{-4} s^{-1} were found.. The chloride loadograph model was calibrated using a two parameter Fibonacci search for the decay constant and the source term. The runoff decay constant for the loadograph was 9.51×10^{-4} s^{-1} comparable to that found for the hydrograph. The chloride source strength decreased with time varying between 2.17×10^{-9} in March to 7.42×10^{-7} kg/m^2-s in early December with the highest Cl^- source term observed during deicing agent application.

An initial high ion loading rate was observed during the first flush followed by a slower progressive linear trend for the remaining portion of the event that was sampled. These trends decreased with successive events over the year.

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LIST OF SYMBOLS

Symbol	Units	Description
a	m^2	cross-sectional width of flow
$Acetate_{Obs.}$	mg/L	measured concentration of CH_3COO^-
$Acetate_{Pred.}$	mmol/L	predicted concentration of CH_3COO^-
$A_{Eff.}$	m^2	effective area
B	m	dissolution volume width
C	$m^{1/2}/s$	constant for a V-notch weir
cCa+2	mg/L	measured concentration of Ca^{+2}
cCi	mmol	concentration of the i-th ion
cCl-	mg/L	measured concentration of Cl^-
C_K	kg-cm/m^3-µS	chloride constant
c_{Na+}	mg/L	measured concentration of Na^+
C_P	kg/m^3	Cl^- concentration leaving depression storage
Csat	kg/m^3	saturated chloride concentration
D	m^2/s	free liquid diffusivity
E	%	charge balance
g	m/s^2	gravity
H	m	depth of water above V-notch of the weir
h	m	depth of water above V-notch of the weir from "a"
$HCO_3^-{}_{atm}$	mmol/L	bicarbonate from an open system
$HCO_3^-{}_{CMA}$	mmol/L	bicarbonate from CMA biodegradation
H_{Rain}	m	observed rainfall
i_S	s	time at which first runoff value is observed
IS		ionic strength
k_{calc}	µS/cm	theoretical conductivity
k^o	µmho/cm	infinite dilution conductivity
M		number of linear reservoirs
ma	mg/L	major anion concentrations
mc	mg/L	major cation concentrations

LIST OF SYMBOLS CONTINUED

Symbol	Units	Description
$m_{Ca+2\text{-}CMA}$	g Ca^{+2} / mole premix	molar mass of calcium associated with CMA
$m_{Ca+2\text{-}Premix}$	g Ca^{+2} /mole CMA	molar mass of calcium associated with premix
$m_{Cl\text{-}premix}$	g Cl^{-} / mole salt	molar mass of chloride associated with premix
$m_{Cl\text{-}salt}$	g Cl^{-} / mole premix	molar mass of chloride associated with salt
M_{CMA}	mmol/L	molar concentration of CMA
$m_{Na+\text{-}Premix}$	g Na^{+} / mole salt	molar mass of sodium associated with premix
$m_{Na+\text{-}salt}$	g Na^{+} / mole premix	molar mass of sodium associated with salt
M_{Premix}	mmol/L	molar concentration of premix
M_{Salt}	mmol/L	molar concentration of salt
M_{Total}	mmol	total molar concentration of deicing agents
$MW_{Acetate}$	g/mol	molecular weight of Acetate
$MW_{HCO3\text{-}}$	g/mol	molecular weight of bicarbonate
n		porosity
N_E		number of effective data points
P	m/s	precipitation intensity
P_C	kg/m^2	constant mass flow rate
P_g	atm	gauge pressure
Q	m^3/s	flow
Q_{Obs}	m^3/s	observed flow
Q_{Pred}	m^3/s	predicted flow
Q_R	m^3	total runoff volume
R	kg/m^2	output mass per unit surface area
r	m	deicing granule radius
R_M	kg	mass leaving the surface reservoir
S	kg/m^2	solid chloride load
t	s	varying time
t^*	s	time of interest
t_S	s	total storm time
V	m/s	velocity

LIST OF SYMBOLS CONTINUED

Symbol	Units	Description
w	kg	mass in to the surface reservoir
y		monovalent ion activity coefficient
Z	m	elevation
z		ionic valence
z_i		absolute value of the charge of the i-th ion
δ	%	error
Δt	min	time step
ΔT_A	min	time step for part A of the rule
ΔT_B	min	time step for part B of the rule
Γ		gamma function
γ	kg/m^3	specific weight of fluid
φ	°	angle of V-notch weir
λ^o		equivalent conductance
ρ_W	kg/m^3	density of water
Ω	s^{-1}	decay constant for runoff
ω	s^{-1}	source strength
ωS_N	kg/m^2-s	source term
ζ	m	depression storage layer

LIST OF ABBREVIATIONS

AGP	advanced gradient pump
BOD	biochemical oxygen demand
Ca^{+2}	calcium ion
$Ca_{0.3}Mg_{0.7}(CH_3COO^-)_2$	calcium magnesium acetate
$CaCO_3$	calcium carbonate
Cd^{+2}	cadmium ion
CH_3COO^-	acetate
CH_3COO^--K^+	potassium acetate
Cl^-	chloride ion
CMA	calcium magnesium acetate
CO_2	carbon dioxide
Cr^{+3}	chromium ion
CTC	cation trap column
Cu^{+2}	copper ion
DO	dissolved oxygen
EC	Environment Canada
EPA	Environmental Protection Agency
gpm	gallons per minute
H_20	water
HCO_3^-	bicarbonate
I495	Interstate 495
IC	ion chromatography
IS	ionic strength
IUH	instantaneous unit hydrograph
K^+	potassium
LD50	lethal dose which causes 50% death in a group test of animals
MDL	method detection limit
Mg^{+2}	magnesium ion
MSA	methane sulfonic acid

LIST OF ABBREVIATIONS CONTINUED

N	nitrogen
Na^+	sodium ion
NaCl	salt
NADP	National Atmospheric Deposition Program
NaN_3	sodium azide
NCDC	National Climactic Data Center
Ni^{+2}	nickel ion
NPS	non-point source pollution
P	phosphorous
Pb^{+2}	lead ion
QA/QC	quality assurance / quality control
RF	response factor
RO	reverse osmosis
SAS	soil absorption system
SO_4^{-2}	sulfate
SR25	State Route 25
TMDL	total maximum daily load
TOC	total organic carbon
UMass	University of Massachusetts at Amherst
Zn^{+2}	zinc ion

CHAPTER 1

INTRODUCTION

1.1 General Statement

Every winter, to provide for public safety, communities spread hundreds of thousands of tons of salt (in excess of 1.0 x 10^7 tons of sodium chloride ($NaCl$)) and other deicing materials on roads and highways (Fritzsche, 1992). Liquid salt solutions provide immediate deicing upon application to roads and sidewalks, while crystalline forms are slower and longer acting than liquid solutions. Available chemical deicing agents can be expensive and may damage vegetation, landscape structures and surfaces, vehicles, and the environment. Concerns over the various effects of NaCl on the environment led to the development of alternative deicing agents, such as calcium magnesium acetate (CMA; $Ca_{0.3}Mg_{0.7}(CH_3COO^-)_2$). Ideally, any deicing compound should be effective, economical, and cause minimal damage to vehicles, infrastructure and the environment. NaCl is still the most widely used because of its low cost. Studies have shown that CMA is effective at removing snow and ice while having minimal impacts on infrastructure and vehicle corrosion. Additionally, CMA has little impact on the roadside environment (Fritzsche, 1992 ; Caltrans, 1985 ; Winters et al., 1985). The runoff rate generated from rain storms is a function of storm intensity and duration, the water quality is affected by the dissolution of highway deicing materials.

1.2 Research Objectives

The goal of this research is to determine an optimal sampling rule for the use of an automated sampler as well as to discern the results from the collection of runoff samples. Models of the flow and chloride concentration in the runoff were also developed in conjunction with data from the samples collected by the sampler. To create an optimal sampling rule historical storms were analyzed to aid in the development of sampling strategies for future events. Samples collected by the automated sampler were measured for the major anions and cations to profile the change of ion concentration within each event as well as for different events. Models of the hydrographs and loadographs (plot of (load concentration*flow rate) or (mass/time) versus time) were created to identify characteristic parameter values for the runoff decay constant and chloride source strength values.

1.3 Research Approach

The approach of this research involved several tasks:

1. Collecting data
2. Analyzing data with the aid of a model looking for trends and comparisons among the data
3. Analyzing for trends and comparisons in collected water samples of storm runoff
4. Investigating past research on automated samplers and storm runoff
5. Developing an optimal sampling rule for use with the automated sampler
6. Determining the source of ions measured from the samples
7. Determining the characteristic runoff decay constant for the research site using measured precipitation and flow values
8. Determining the source strength for each event based on flux data

The research site and background information for this research, including a literature review of storm runoff and automated samplers are described in Chapter 2. Data collection methods and analysis techniques are described in Chapter 3. Chapter 4 describes in detail the theoretical concepts used in developing sampling rules for the automated sampler, water sample analysis, hydrograph and loadograph development. Chapter 5 presents the results and discussion of the models. The conclusions are presented in Chapter 6 along with recommendations.

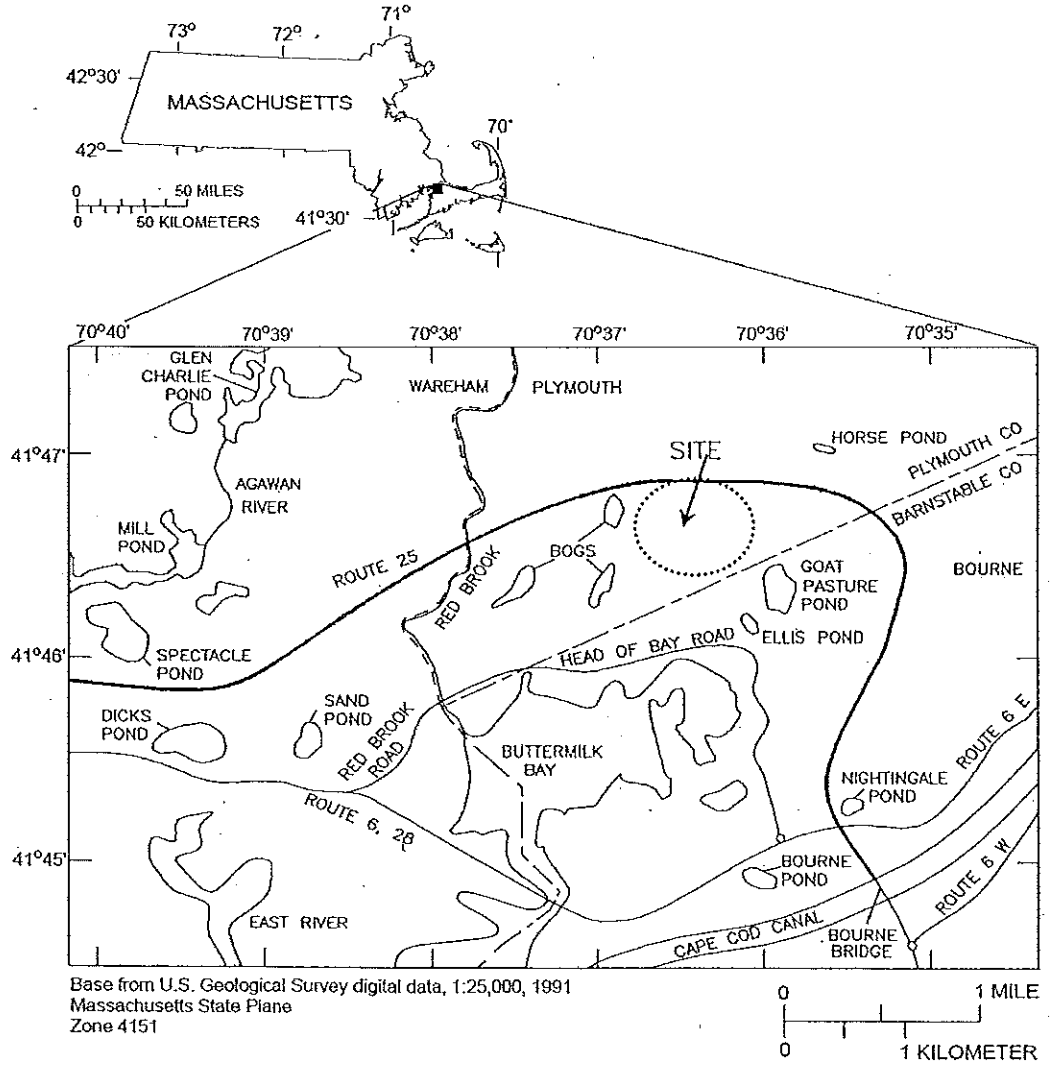
CHAPTER 2

SITE DESCRIPTION AND BACKGROUND

2.1 Site Description

The research site is located along State Route 25 (SR25) in Plymouth, Massachusetts, which is located in the southeastern part of the state approximately 5500 m north of the Cape Cod Canal. The geographical coordinates of the site are 41°46’53” North and 70°36’50” West. The highway opened in August 1987, completing the extension of Interstate 495 (I495) to the Bourne Bridge. SR25 is comprised of six 3.66 m (12 ft) wide travel lanes with two 1.2 m (4 ft) wide inner shoulders, two 3.05 m (10 ft) wide breakdown lanes, and a 30 m (100 ft) wide grass median swale. Environmentally sensitive areas surround the site on three sides: a replacement wetland area to the north, an active cranberry bog to the east, and Weeks Pond to the south. When SR25 was opened, the Massachusetts Department of Environmental Protection enacted restrictions requiring that non-chloride road deicing agents be applied over a 1930 m (1.2 mile) stretch of roadway (Figure 2.1) to protect the actively harvested cranberry bog from the detrimental effects of winter road salt applications. CMA is the road salt alternative deicing agent used along this stretch of roadway except during emergency situations when a chloride-based deicer can be used to maintain safe driving conditions.

The research site extends from the north shoulder of SR25, across the roadway, through the infiltration pond, and to the rest area region south of the highway. The center of the site has a sedimentation pool (recharge pool) used as a collection point for highway runoff. Runoff from the paved portion of the roadway is collected into catch basins spaced 90 m (300 ft) located along the center of the grass swale and along the edges of the paved roadway. The catch basins feed into a storm drainage system that discharges into the recharge pool. Runoff from the rest area parking lot and access roads is collected into a separate drainage system that does not discharge into the basin. Figure 2.2 shows the gravity flow direction of the drainage system discharging into the recharge pool.



Base from U.S. Geological Survey digital data, 1:25,000, 1991
Massachusetts State Plane
Zone 4151

Figure 2.1 – Regional Location of Plymouth Research Site

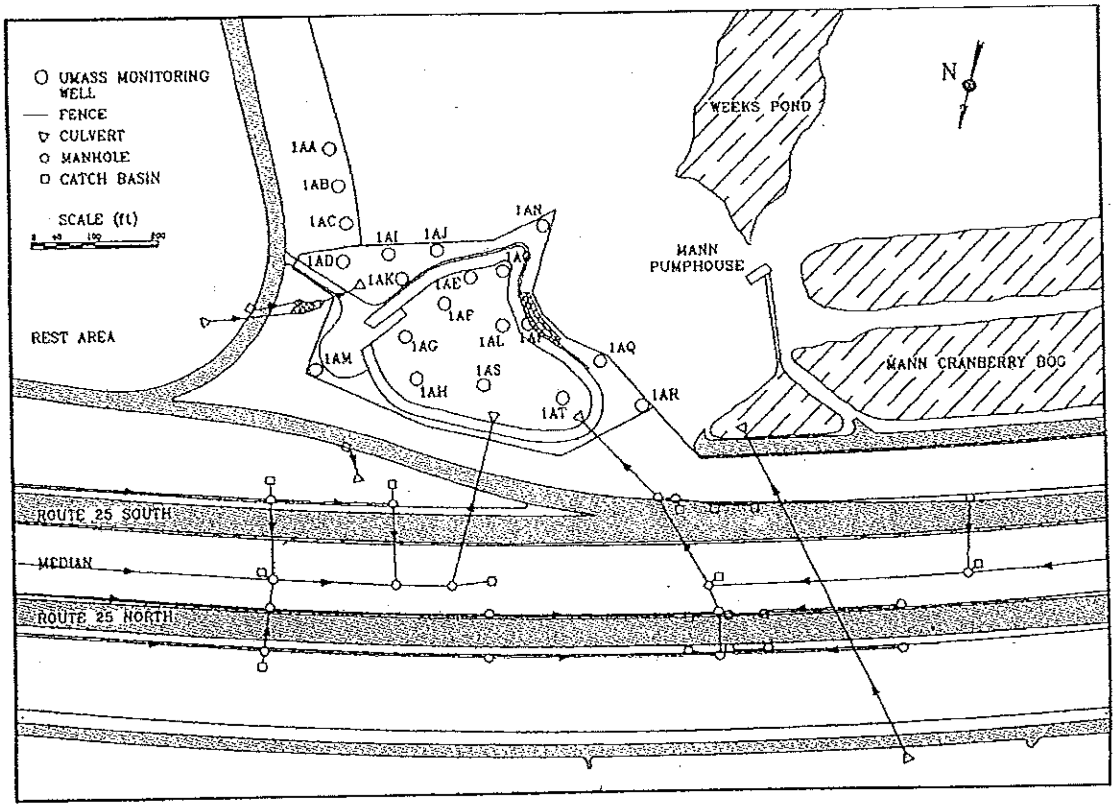


Figure 2.2 – Detail of Research Site and Direction of Runoff

The climate for southeastern Massachusetts is humid and temperate, predominantly influenced by its close proximity to the Atlantic Ocean (Ruffner, 1985). Annual average precipitation for the region is 1.47 m/yr (NCDC, 1991) with an estimated groundwater recharge equal to approximately 45% of the precipitation amount (LeBlanc, 1984). During a typical year, the deicing season lasts from November through March with an average of 0.94 m snow depth, which accounts for 6% of the total annual precipitation (NCDC, 1991).

2.2 Environmental Impacts of Highway Deicing Agents

Improper storage, handling, and application of road deicing agents can result in the introduction of these materials into the environment. Sodium ferro-cyanide can be mixed with deicing agents to prevent clumping during storage and application. Deicing agents applied to roadways can enter the air, soil, groundwater and surface water from direct or snowmelt runoff, release from surface soils, and/or wind-borne spray. Depending on the amount of deicing chemicals carried by melting snow and ice onto vegetation along the roadside and eventually, to local rivers, streams, and other bodies of water, this can have significant environmental impacts. The deicing chemicals can accumulate in soils along the roadside, affecting trees and other vegetation. Elevated salt levels in soils inhibit plants' ability to absorb water and nutrients, thus impeding long-term plant growth. Degradation of roadside vegetation can reduce the ability of these areas to act as buffers intended to slow the runoff of contaminants into the watershed. In some areas, plants that are salt-tolerant (halophylic), such as cattails, have colonized roadside areas.

Testing for multiple sources of chloride found that the absence of certain ions (which were unmentioned) not their presence, showed salt from sources other than road salt. Natural saline from bedrock carries much more fluoride and iodide than road salt. Analysis of 5% NaCl solution showed a high degree of chemical purity. It was clearly shown that road salt's major inorganic components of sodium and chloride harbored the greatest threat to water quality. (Howard et al. 1993).

Deicing agents carried by runoff into aquatic ecosystems can accumulate to sufficient concentrations to affect living organisms and infrastructure.

Macroinvertebrates are less tolerant to salinity; reductions in these populations will have lasting effects throughout the food web. (Kefford et al. 2004) Fish species may vary widely in their tolerance to salt levels; however, if concentrations remain high over a prolonged period some species will be affected. Road salt also corrodes automobiles and infrastructure, particularly bridges. (CalTrans 1985) The major effect on public drinking water supplies is alteration of the taste of water, although the National Research Council's Transportation Research Board (Church and Friesz 1993) warned that high concentrations could contribute to excess dietary intake of sodium, which has been implicated in hypertension. Table 2.1, adapted from Fritzsche (1992), summarizes the impacts of NaCl and CMA on various environmental receptors.

Table 2.1 Environmental Impacts of CMA and Rock Salt (Fritzsche, 1992)

Environmental Impact	CMA	NaCl
Vegetation	Little or no adverse affect. May stimulate roadside plant growth. Acetate ion is the most abundant organic acid metabolite found in nature.	Osmotic stress and soil compaction may harm root system. Spray causes foliage dehydration damage. Many plant species are salt sensitive.
Groundwater	Poor mobility in soil, unlikely to reach groundwater. Increases water hardness.	Mobile Na^+ and Cl^- ions readily reach groundwater. Can increase alkalinity and hardness of groundwater.
Surface Water	Potential for oxygen depletion through BOD at concentrations > 100 mg/L in closed systems. Decomposes in 5 days at 20°C, 10 days at 10°C, and 100 days at 2°C. Will not stimulate algae growth.	Causes density stratification in ponds and lakes, which can prevent re-oxygenation. Increases runoff of heavy metals and nutrients through increased soil erosion.
Aquatic Life	Less toxic to trout than salt. Minimal effects on trout eggs with up to 5 times max expected runoff concentration of 1000 mg/L. No effect on food chain (zooplankton, daphnia, bluegill, and fathead minnows) up to 1000 mg/L	Monovalent ions stress osmotic balance. Toxic levels: 500 mg/L Na^+ for stickleback 400 mg/L Cl^- for trout.
Human / Mammalian	Mild skin and eye irritant. Vinegar odor. Acute oral LD50 in rats > 5000 mg/kg. Essentially non-toxic.	Sodium linked to heart disease, hypertension. Cl^- causes unpleasant taste in drinking water. Mild skin and eye irritant. Acute LD50 in rate 3000 mg/kg. Slightly toxic. Contributes to winter road wildlife kills.
Wastewater Treatment Plants	No increase in chemical oxygen demand or impact on bacterial activity.	No significant impact at expected concentrations.
Air Pollution	Can reduce sand use and resulting particulate emissions.	Can reduce sand use and resulting particulate emissions.
Soil	Acetate is biodegradable in soil. No adverse effect on soil compaction and strength.	May accumulate in soil. Breaks down soil structure, increases soil erosion

2.2.1 Soil and Groundwater Chemistry

Deicing salts applied to roads during the winter are primary sources of solutes to groundwater. Soil structure and chemistry may be impacted by the addition of dissolved road deicing materials. NaCl dissociates in an aquatic system into chloride anions (Cl^-) and sodium cations (Na^+). Chloride ions are less reactive than sodium ions and thus can be transported to surface waters through soil and groundwater without attenuation (Environment Canada, 2000). Conversely, positively charged sodium ions can bond to negatively charged soil particles via physical electrostatic adsorption and cation exchange, retarding their transport in the subsurface, or be taken up in biological processes (Shanley, 1994). Church and Friesz (1993) showed that at a closed drainage site, a closed drainage site with snow berm, and a full-snowberm site, 40%, 50%, and 20%, respectively, of the chloride load was found in the groundwater at the open drainage site, with the remaining amount being transported by surface runoff. Howard et al. (1993) found similar results in their study of an aquifer in Canada. The researchers concluded that 45% of the salt applied is removed through surface runoff while the remaining amount enters into the subsurface.

Repeated use of NaCl can permanently reduce soil permeability, which decreases the ability of water to infiltrate through the soil contributing to increased surface runoff and soil erosion (Meyer, 1999). As sodium ions are exchanged with other monovalent and divalent cations, the electric double layer surrounding the soil particle expands resulting in a dispersed particle environment where particles can freely move and clog the soil pores. In work performed by Amrhein et al. (1993) it was noted that humic acids and iron oxide colloids are mobilized when soils are exposed to sodic water followed by low salinity rainwater. Sodic water is high in sodium (Na^+) concentration relative to concentrations of calcium (Ca^{2+}) and magnesium (Mg^{2+}). The mobilization of soil particles and colloids may increase the potential for the transport of trace metal contaminants sorbed to the particle surface.

There are concerns that CMA may increase the mobility of certain trace metals in roadside soils. Because acetic acid, sodium acetate, and ammonium acetate have been used for metal extraction in soils (Rosa et al. 2002; Miller et. al, 1986), the concern is that CMA can increase the metals concentration in soil matrices, directly resulting in increased metals concentrations in ground waters and surface waters. Both calcium and magnesium are better competitors than sodium for cation exchange sites held by cationic trace metals (Pb^{+2}, Cd^{+2}, Cu^{+2}, Zn^{+2}, Ni^{+2}, Cr^{+3}), leading to possible release of these metals into the pore water solution. Additionally, acetate forms stronger metal-acetate ion pairs than chloride, conceivably increasing soluble trace metal concentrations. Amrhein et al. (1990) and Elliot et. al. (1987) showed that CMA may temporarily increase translocation of metals in strongly buffered acidic roadside soils. Input of acetate ions increases the exchangeable bases with sustained CMA use, making the soil less vulnerable to acidification and inhibition from metal solubilization. The calcium (Ca^{+2}) and magnesium (Mg^{+2}) ions are beneficial to soil structure, maintaining the porosity and aggregate stability, while sodium tends to destroy soil structure. Mobilization of dispersed clays and organic matter occurs when adsorbed Na^+ is high and the ionic strength is low.

Another important environmental property of CMA is that acetate decomposition will increase the soil alkalinity. The acetate fraction of CMA is rapidly oxidized by aerobic microorganisms as shown in Equation 2.1:

$$CH_3COO^- + 2O_2 \rightarrow CO_2 + H_2O + HCO_3^- \tag{2.1}$$

Precipitation of $CaCO_3$ in soils can increase the pH and results in the precipitation of metal carbonates and hydroxides (Amrhein et al. 1989).

2.2.2 Dissolved Oxygen Depletion

The presence or absence of oxygen is one of the most important factors affecting microbial activity (Chilton, 1992). Many organisms require oxygen for aerobic respiration and the breakdown of organic matter; when oxygen concentrations are depleted some bacteria can use alternatives, such as nitrate, sulfate and carbon dioxide through anaerobic respiration. When the unsaturated zone beneath a soil absorption system (SAS) is predominantly anaerobic, both the effluent quality and infiltrative capacity of the system are adversely impacted. A study of wastewater being applied to two columns under aerobic and anaerobic conditions found that in the aerobic column, essentially all of the carbonaceous and nitrogenous substances were removed, while only half of the carbon and nitrogen substances were removed from the anaerobic column (Mahuta and Boyle 1991).

Horner (1988) studied the effects of CMA on dissolved oxygen (DO) depletion in standard biochemical oxygen demand (BOD) tests and in field ponds. Four CMA concentrations ranging from 10 – 5,000 mg/L were tested at different temperatures and incubation times. At concentrations above 10 mg/L, complete oxidation occurred after

2 days at 20°C; with lower temperatures (10°C-20 days; 2°C-40 days) dissolved oxygen depletion was not as rapid. The 10°C bottles needed 12 days to equal the 20°C bottles in DO depletion while in the first nine days, no depletion was noticed at 2°C. Field ponds dosed at 10 mg-CMA/L showed a decrease in DO to levels as low as 5 mg/L. Similar results of temperature influence on DO depletion were reported by Brenner et al. (1992), who also showed a net depletion of 4.5 and 7.0 mg O_2/L when dosed at 10 mg/L for reagent grade and corn-based CMA respectively.

Oxygen demand in groundwater resulting from CMA applications was studied by Ostendorf et al. (1997). Their study showed that O_2 diffused into groundwater as fast as CO_2 was leaving it, concluding that acetate would be significantly degraded under aerobic conditions before reaching the water table, thus reducing the oxygen demand in the groundwater.

2.2.3 Flow Measurements

Weirs are structures that consist of an obstruction, such as either a dam or bulkhead, placed across an open channel with a specially designed opening. The weir results in an increase of water level, which is measured upstream of the structure; flow rate over the weir can be measured based on the head on the weir. Common weir shapes are the V-notch (Figure 2.3), rectangular, and broad-crested. V-notch weirs are constructed from sheet metal and are typically thin and sharp crested because the shape is more amenable to theoretical analysis and reproducibility. Broad-crested weirs are used in various hydraulic structures and are sometimes used to measure water flow.

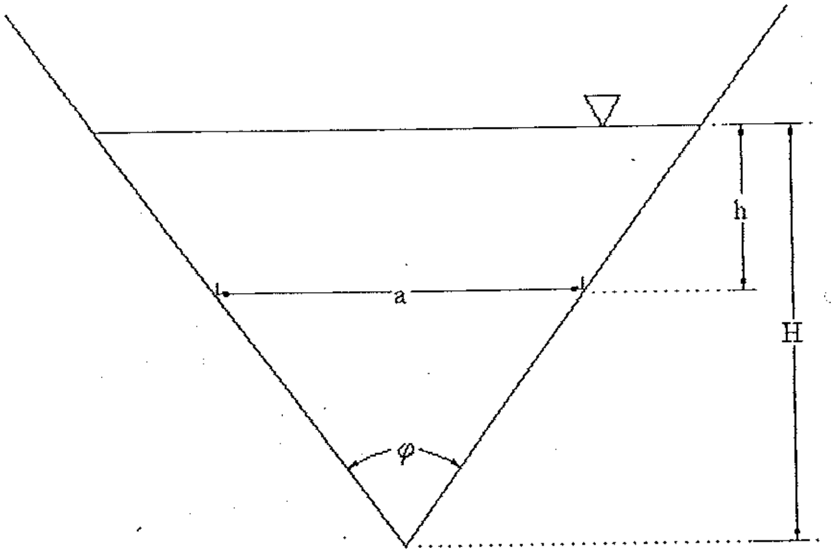


Figure 2.3 – V-Notch Weir

General rules should be followed when constructing a V-notch weir in accordance with established ASTM D (5242) and ISO (1438/1) standards:

- The head (H) should be no less than 0.2 feet and no greater than 2.0 feet for the expected rate of flow.
- For rectangular and Cipolleti weirs, the head should not exceed one-third of the weir length.
- Weir length should be selected so that the head for design discharge will be near the maximum, subject to the limitations mentioned above.
- Measurements are only accurate when the weir is properly set and the head is read at a distance 4*H upstream of the weir, so that the level is not affected by the downward curve of the water

The Bernoulli equation presented in Equation 2.2 states that the static pressure in the flow plus the dynamic pressure and the height above an arbitrary datum must be equal to a second location in the same flow if there is no head loss

$$\frac{P_{g1}}{\gamma}+\frac{V_1^2}{2g}+z_1=\frac{P_{g2}}{\gamma}+\frac{V_2^2}{2g}+z_2 \tag{2.2}$$

where P_g is the measured gauge pressure, V is the velocity, Z is the elevation, g is gravity, and γ is the specific weight of the fluid. For a fluid with a free surface, $P=\gamma h$ where H is the depth of water above the notch in the weir. The velocity behind the weir is insignificant relative to the velocity over the weir; the pressure in a free jet is zero, reducing Bernoulli's Equation to Equation 2.3. Figure 2.4 presents a side view schematic of flow through a V-notch weir.

$$h_1+z_1=\frac{V_2^2}{2g}+z_2 \tag{2.3}$$

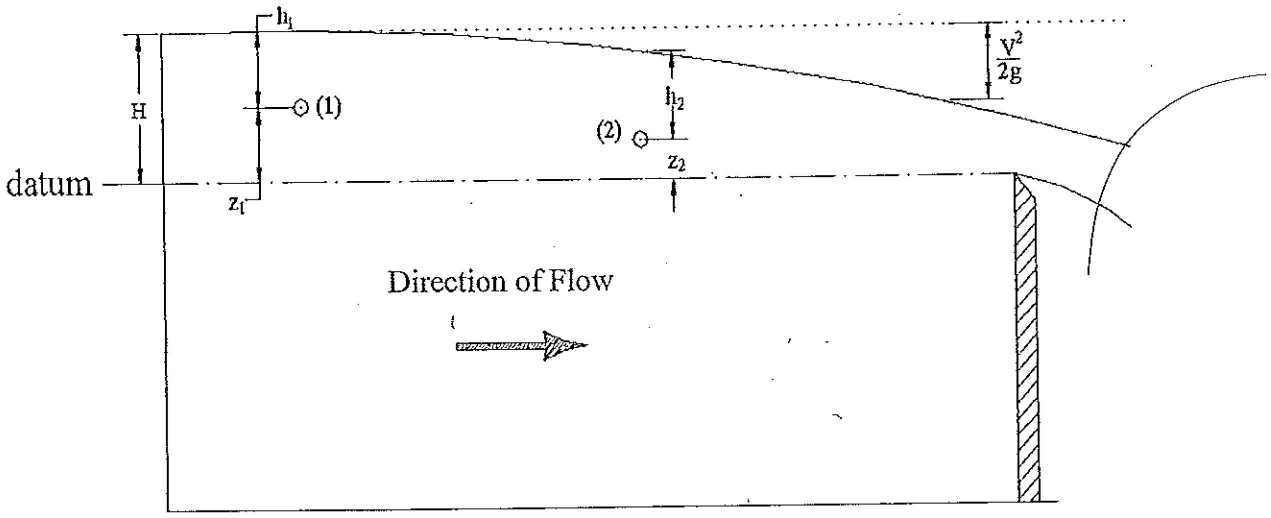


Figure 2.4 – Flow through a V-Notch Weir

Substituting Equation 2.3 in Equation 2.4 yields Equations 2.5 and 2.6.

$$H = h_1 + z_1 = h_2 + z_2 \tag{2.4}$$

$$H = \frac{V_2^2}{2g} + (H - h_2) \tag{2.5}$$

$$V_2 = \sqrt{2gh_2} \tag{2.6}$$

Equation 2.6 is integrated over the area of the weir opening (Equations 2.7 and 2.8) producing Equation 2.9 and resulting in the more commonly known form, Equation 2.10 for a V-notch weir, with constant C defined by Equation 2.11.

$$dA = adh \tag{2.7}$$

$$a = 2(H - h)\tan\frac{\psi}{2} \tag{2.8}$$

$$Q = \int_A VdA = \int_0^H \left[(2gh)^{1/2}\, 2(H - h)\tan\frac{\psi}{2}\right]dh \tag{2.9}$$

$$Q = \frac{8}{15}\sqrt{2g}\tan\frac{\psi}{2}H^{5/2} = CH^{5/2} \tag{2.10}$$

$$C = \frac{8}{15}\sqrt{2g}\tan\frac{\psi}{2} \tag{2.11}$$

The constant, C, for a 90° V-Notch weir with head in feet is 1122 for flow units of gallons per minute (gpm), and is 1.38 $m^{1/2}/s$ with head in meters are flow units of L/s. Where φ is the angled opening of the V-notch weir and Q is the flow in m^3/s.

2.2.4 Prior Research with Automated Samplers

Automated samplers have been used to characterize nutrient loading in runoff from varying sources to aid policy makers in developing guidelines for the assessment of nutrient migration in conjunction with land management practices. Non-point source (NPS) pollution is caused by water movement over and through the land surface. Natural and man-made pollutants are entrained and transported in the runoff to rivers, streams, lakes, wetlands, coastal waters, and ground waters. Federal and state governments have targeted the identification and control of non-point source runoff as major pollution minimization goals (Subra and Walters, 1996). Excessive anthropogenic NPS inputs of the macro-nutrients, nitrogen (N) and phosphorous (P), can create accelerated algal growth degrading aquatic ecosystem health, increasing water treatment costs and diminishing recreational and aesthetic values (Kolbe and Luedke 1993).

Determining minimum flow thresholds (enable level) above which to begin sampling plays an important function in water quality sampling projects. Improperly defining a minimum flow threshold can result in the use of unscientific strategies that may not accurately characterize the actual pollutant flux of a storm. Little published guidance is available on setting minimum flow thresholds; if thresholds are set too low, samples will be taken from every runoff event even though there is no significant pollutant load. If the enable level is set too high, substantial portions of runoff events and possibly entire events can be missed (Harmel et al., 2002).

Guidance on developing appropriate storm sampling strategies for small streams is also limited. Several sampling strategies can be employed when setting up and determinging a rule for an automated sampler: sampling can occur as discrete samples (one sample per bottle), composite samples (several samples per bottle), flow-weighted (based on a pre-set flow volume), or time-weighted (based on set time intervals) (Shih et al., 1994; King and Harmel, 2001; Harmel et al., 2002). Typical storm sampling operation involves setting an enable level to start and stop sampling (either a flow depth or rainfall depth per specified time), and a time or flow interval by which to collect samples after the sampling rule begins. This type of automated storm monitoring is often the cornerstone of small watershed projects, whose objectives are to compare water quality impacts of various land management activities, to evaluate water quality improvement following implementation of best management practices, and to determine annual pollutant fluxes for Total Maximum Daily Load (TMDL) projects (Tate et al., 1999; Robertson and Roerish, 1999). However, because runoff characteristics may be continuously changing over the duration of a storm event, sampling at discrete points is limited in accuracy, some small storms may easily pass by un-sampled, peaks in concentration can occur between sampling times, or large storms may exceed the sampler capacity. For these reasons, it is desirable to continuously accumulate a composite runoff sample for determination of total pollutant loadings (Clark et al. 1981). Much of the previous work done with autosamplers has analyzed the total pollutant load of a storm by collecting a flow-weighted sample of the entire event. This has been done by splitting the flow equally and storing a fraction of the divided flow in a large composite sample container for later analysis.

Prior research on the discrete sampling of storm events was used to aid in the determination of a sampling frequency and setting minimum flow thresholds for the

Plymouth study site. Shih et al. (1994) showed that by varying the frequency of discrete sampling based on historical storm data, a more accurate estimate of the pollutant load could be achieved as compared to fixed time sampling. As an alternative to decreasing the number of discrete samples for nutrient flux measurements because of economical constraints. Other alternatives for sampling strategies exist: time between sample events can be increased, flow volume between samples can be increased, or several samples can be collected in one bottle instead of increasing the minimum flow threshold. The minimum flow threshold should be set such that even small storms are sampled and the enable level should only be raised after careful consideration of the consequences (Harmel et al., 2002).

2.3 Storm Water Chemistry and Analysis

Runoff from transportation and urban land use is a complex physico-chemical heterogeneous mixture of water, heavy metals, particulate matter, inorganic, and organic compounds that depend on variations in flow, concentrations and mass loadings and can vary by orders of magnitude within a single event (Sansalone and Buchberger, 1996; Sansalone and Glenn, 2002). Types of elements typically seen in runoff are Zn, Cu, Cd, Pb, Cr, and Ni, as well as elements associated with winter-maintenance activities, that are often at concentrations significantly higher than ambient conditions.

During the beginning of a storm event, a first flush with a high concentration of elements in the runoff can have a significant impact on the receiving water and has been researched extensively. The concept of first flush was first defined by Metcalf and Eddy (1916) when the greatest concern was a high concentration of suspended and dissolved organic matter originating from equine fecal matter. Since that time the term "first flush" has been used to describe the disproportionately high delivery of either concentration or mass in the initial stages of a runoff hydrograph (Sansalone and Cristina, 2004). Water quality results from a yearlong study of urban storm water runoff indicated high variability of water quality between storm events (Dean et. al., 2002). Pollutant loadings can increase dramatically in snow berms because of its unique characteristics. Snow is a porous matrix with a high surface area along the snow crystals; freezing and thawing can happen within the snowpack concentrating the pollutants and because of its extended residence time, a higher concentration of pollutants may result. For these reasons, snowmelt can have a higher concentration of ions in the first flush than rainfall runoff (Johannessen and Henriksen, 1978; Sansalone and Buchberger, 1996).

CHAPTER 3

METHODS AND MATERIALS

This project used various site characterization techniques to describe the fate and transport of salt contamination. This section describes the field and laboratory methods used between February 2004 and March 2005.

3.1 Field Monitoring Procedures

Periodic surface water samples were collected from the West weir of the Plymouth site located at the western most point of the catchment basin shown in Figure 2.2 near well cluster AT. These samples were analyzed for major cations and anions, pH, and specific conductivity. In addition to the collection of water samples, continuous recorded measurements monitored the specific conductivity, pH, water level and dissolved oxygen (DO) at the research site.

3.1.1 Weir - Flow Monitoring

The flow rate of runoff from the drainage collection system was monitored using 90° V-notch weirs. Two 90° V-notch weirs were installed at each of the drainage outlets to the catchment basin at the site to record runoff data. The West weir (High Flow) receives most of the drainage from SR25. The East weir (Low Flow) sees outflow only during major storm events. The drainage system empties into the catchment basin via 0.9 m (3 ft) diameter pipes. The weirs were constructed of stainless steel sheet metal by the University of Massachusetts metal shop and are approximately 1.2 m (4 ft) wide and 0.7 m (2.25 ft) tall. The weirs were made to fit into the circular outfall pipe. The apex of the V-notch is 15.2 cm (6 in) above the base. The 90° notch opens to 1 m (942 in) width and is 0.5 m (1.75 ft) tall. The maximum flow rate which can be measured by the constructed weirs, is 240 L/min (63.4 gpm).

A model 4230 Bubble Flow Meter (ISCO; Lincoln, NE) records water level measurements at each of the weirs. The flow meters are housed in waterproof cases and are further protected in separate permanent housings adjacent to each weir. The logger is 43 cm tall, 29 cm wide and 27 cm deep. Water level readings are measured by the amount of pressure needed to force a metered amount of air through the end of the tube that is positioned beneath the V-notch. Once calibrated for tube depth, pressure is converted to a water level by the ISCO 4230 flow meter. The water level to flow rate conversion was derived from Bernoulli's equation (Roberson and Crowe, 1995). The final flow conversion can be determined through Equation 2.10. A plastic tube runs from the meter to a 1 cm diameter aluminum tube mounted in place 10 cm below the bottom of the V-notch.

3.1.2 Continuous Measurements

For the continuous monitoring of runoff water quality, an ISCO 4230 meter and an ISCO 6712 portable sampler were used to record the field data every five minutes. The ISCO 4230 meter also records the specific conductivity and pH data using a YSI 600 multi-parameter water quality monitor (YSI; Yellow Springs, OH). Specific conductivity and pH measurements were calibrated upon initial installation of the probes. The YSI 600 was recalibrated as needed. The specific conductivity meter has an accuracy of ± 0.5% for specific conductivity between 0 – 100 mS/cm. The pH probe has an accuracy of ± 0.2 units. The DO probe has an accuracy of +/- 0.2 % of the reading or 0.2 mg/L, whichever is greater. The flow meter logs the specific conductivity, pH, DO and rain gauge data at the same interval as the water level data. The monitored data are downloaded via a cellular phone connection at the site and a modem installed in a computer at the University of Massachusetts-Amherst Environmental Engineering Laboratory.

3.1.3 Rain Gauge Measurements

An ISCO rain gauge model 674L (ISCO; Lincoln, NE) was installed at the site to record precipitation. This rain gauge uses a tipping bucket with a sensitivity of 0.25 mm (0.01") and a capacity of 0.76 m/hr. The gauge has a 20 cm diameter and a 33 cm height. The rain gauge has a precision of 1% of the bucket volume for precipitation rates up to 0.56 m/hr.

The gauge is constructed out of plastic and metal plates that are coated, plated or painted to provide resistance to the weather. A fine metal mesh screen is present on top of the gauge to prevent interference from debris and/or insects blocking the funnel end of the instrument. The gauge was leveled once placed on top of the protective housing adjacent to the low flow weir. As a check on the reliability of the rain gauge data, the data collected at the site were compared to data collected from the UMass-Cranberry Station, (East Wareham, MA) located several miles West of the research site.

3.1.4 Surface Water Sample Collection

Surface water samples were manually collected into dedicated 400 mL polypropylene cups (Cole Parmer, Vernon Hills, IL), directly from the West weir during storms events. Water samples to be analyzed for major anions were placed in clean, numbered 20 mL vials, pre-tared on a Fisher Scientific Model Accu 2202 to the nearest 0.01 g. Approximately 2 mL of 0.5% sodium azide (NaN_3) solution (Labchem, Inc; Pittsburg, PA) was added to the surface water sample to prevent aerobic biodegradation of acetate during sample transport and storage (Aelion and Bradley, 1991). The vials were capped with a screw-on top lined with a teflon/silicon septum with headspace.

Surface water samples that were to be analyzed for bicarbonate were placed into clean, numbered 6 mL glass autosample vials. These vials were sealed with a screw cap and Teflon septa (Fisher Scientific; Pittsburgh, PA). The vials were sealed with no headspace to preserve sample quality.

Surface water samples from the West weir to be analyzed for major cations were filtered using a 0.45 micron in-line syringe filter (Millipore Corporation, Bedford, MA) into numbered, 1 mL polypropylene autosample vials (National Scientific; Lawrenceville, GA). The vials were pretreated with 5 µL of 12.5% nitric acid for pH adjustment to less than 2 units to prevent the adsorption of dissolved cations to possible iron oxide precipitates. All the vials were placed in coolers with ice for transport to the UMASS laboratory.

The remaining water sample was measured for pH using an Accumet AP-61 portable pH meter (Fisher Scientific; Pittsburgh, PA). The water sample was also measured for specific conductivity and temperature using a YSI-30 conductivity meter (YSI Inc; Yellow Springs, OH). The meter auto-corrects the specific conductivity reading to specific conductance at 25°C. The pH and conductivity meters were calibrated with known standards before each sampling trip.

3.2 Dissolved Ion Laboratory Analysis

Sample vials containing surface water collected from the West weir were stored in a refrigerator set at 4 °C at the UMass Lab before being analyzed.

3.2.1 Laboratory Surface Water Sample Preparation

The cation and bicarbonate samples did not require further preparation prior to analysis. The 20 mL anion samples needed further preparation prior to being analyzed. The vials were reweighed on a top mounting balance (Fisher Scientific model Accu-2202) with an accuracy of 0.01 g. Samples that had measured conductivities above 3,000 μS/cm were diluted at a ratio 1:10 in a separately washed and cleaned 20 mL vial. The surface water sample was completely mixed by shaking and then, using an Eppendorf autopipeter (accuracy 0.001 mL), 1 mL of surface water was extracted and injected into the sub-sample vial. Using a glass pipette (accuracy 0.1 mL), 9 mL of water treated by reverse osmosis (RO) was then placed into the 20 mL sub-sample vial. A sample was withdrawn using a 3 cc syringe, a 0.45-micron in-line filter was attached to the syringe, and a sample was filtered into the appropriate 2 mL auto-sample vial.

3.2.2 Anion Analysis by Ion Chromatography

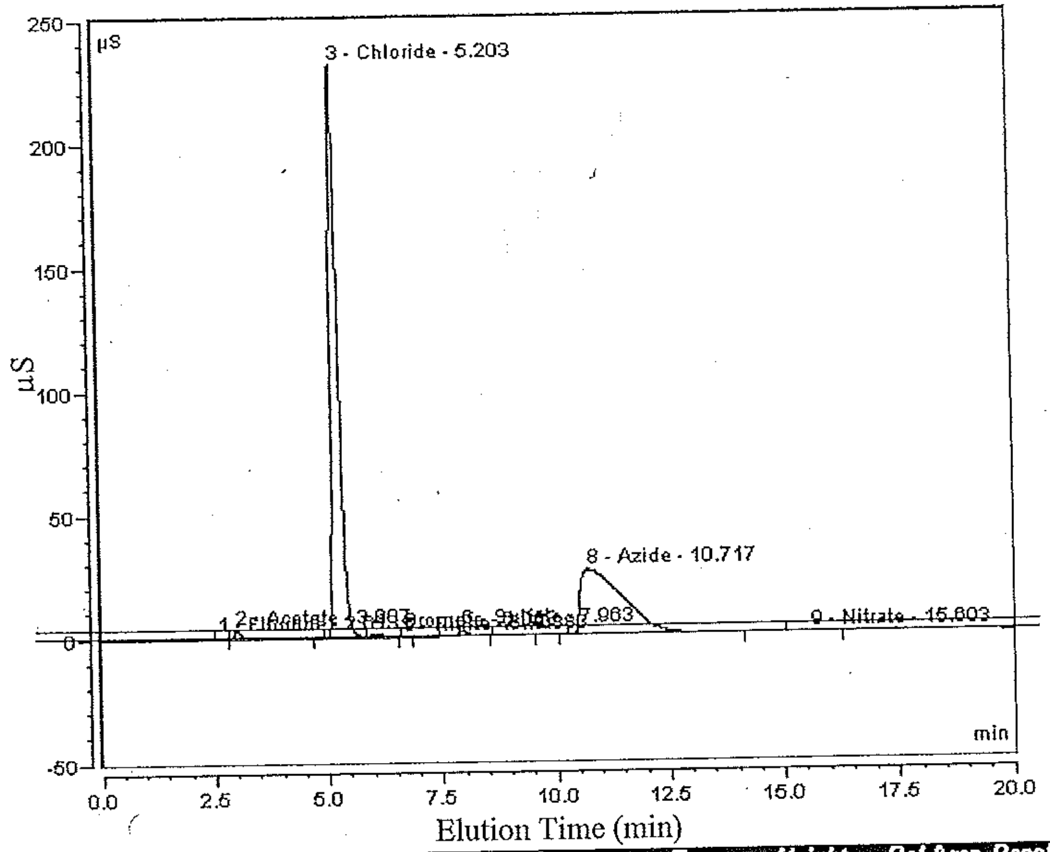
Filtered anion samples were analyzed for acetate (CH_3COO^-), chloride (Cl^-), and sulfate (SO_4^{-2}) concentrations using a Dionex ICS-2500 Ion Chromatograph (IC) (Dionex Corporation; Sunnyvale, CA). The IC system includes a GP-50 gradient pump, a CD25A electrical conductivity detector, CR-ATC continuously regenerated anion trap column, IonPac AG15 guard column, EG50 eluent generator, and IonPac AS15 analytical column. Also included in the system are the Atlas and SRS ULTRA self-regenerating suppressors set in recycle mode and an AS40 auto-sampler. Dionex Chromeleon Software recorded the data.

The AS40 autosampler was programmed with sample identification information before the samples were analyzed. During each sample analysis, 10 µL of sample was injected using the Pushloop (High) injection method to inject the sample through the 25 µL sample loop and into the CR-ATC trap column. Samples were carried through the columns, suppressor, and conductivity detector at an eluent flow rate of 2.0 mL/min. The syringe was auto-cleaned after every injection by rinsing with RO water and discharging the rinse fluid to a waste line.

No external eluents were required for operation. The EG50 eluent generator automatically produced the required eluents from 36 mM potassium hydroxide and RO water. RO water was stored in vessels and pressurized with ultra high-purity helium (Merriam Graves; Springfield, MA). An anion analysis method program developed by Dionex detected and evaluated sample concentrations for each of the anions of interest (Dionex Corporation, 1993; 1995, 2000). Table 3.1 presents typical elution times for anions from the IC. An output report was generated for each run with the corresponding chromatogram. A sample of a typical anion chromatogram is presented in Figure 3.1, and a small peaks magnification is presented in Figure 3.2. Concentrations of the samples were adjusted for effects of dilution by sodium azide (NaN_3) and water.

Table 3.1 IC Anion Elution Times

Anion	Elution Times (min)
CH_3COO^-	3.0
Cl^-	5.2
SO_4^{-2}	8.0



No.	Peakname	Ret.Time min	Area µS*min	Amount	Type	Height µS	Rel.Area %	Resolution
1	Flouride	2.613	0.0469	n.a.	BM *	0.442	0.06	2.07
2	Acetate	3.007	0.6052	7.2011	MB*	3.273	0.80	8.29
3	Chloride	5.203	44.9553	166.4857	BMB*	231.458	59.69	5.24
4	Bromate	6.033	0.2443	n.a.	Rd*^	0.881	0.32	n.a.
5	Nitrite	6.703	0.0011	n.a.	Rd*^	0.008	0.00	n.a.
6	Sulfate	7.963	0.5552	2.7576	Rd*	2.004	0.74	n.a.
7	n.a.	8.883	0.0315	n.a.	Rd*	0.071	0.04	n.a.
8	Azide	10.717	28.8698	n.a.	BMB^	26.224	38.33	4.01
9	Nitrate	15.603	0.0042	0.0278	BMB*^	0.012	0.01	n.a.
Total:			75.3135	176.4723		264.374	100.00	

Figure 3.1 –Anion Sample Chromatogram and Peak Analysis

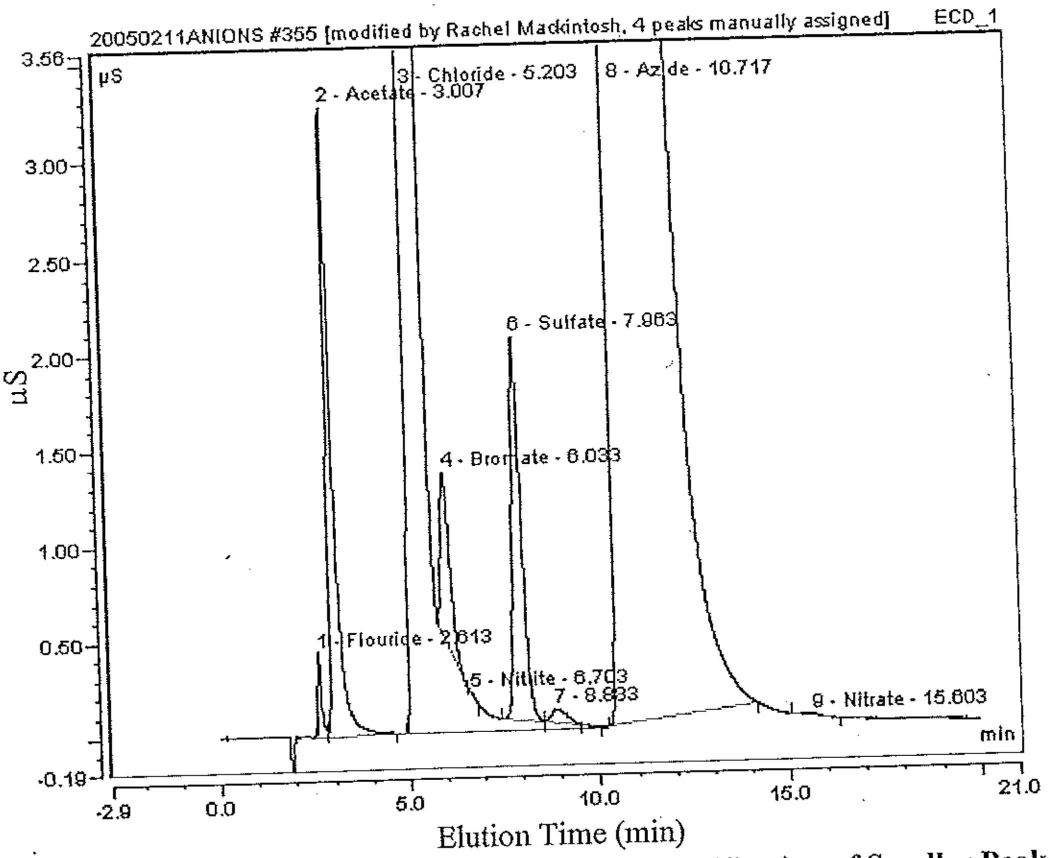


Figure 3.2 – Anion Sample Chromatogram - Magnification of Smaller Peaks

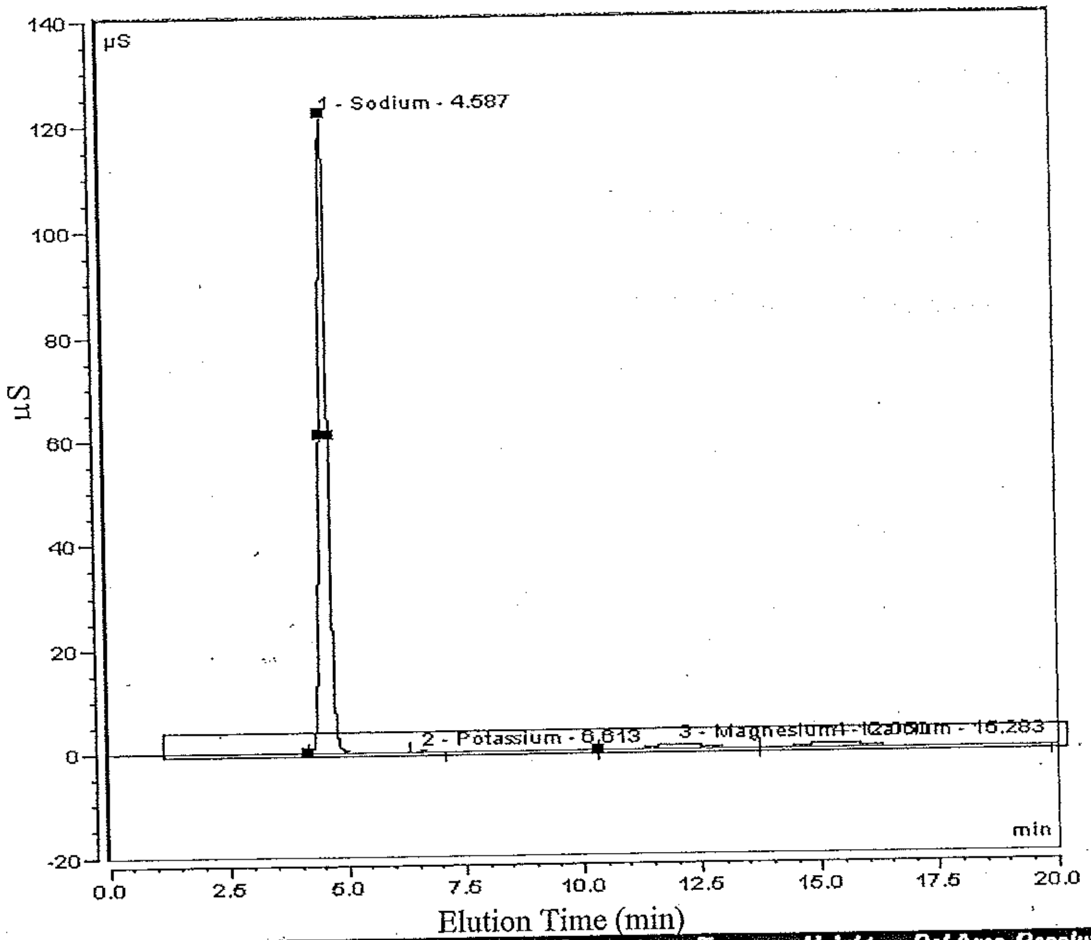
3.2.3 Cation Detection by Ion Chromatography

Filtered surface water samples were analyzed for sodium (Na^+), potassium (K^+), magnesium (Mg^{+2}), and calcium (Ca^{+2}) using a Dionex DX-300 Ion Chromatograph (Dionex Corporation; Sunnyvale, CA). The IC system included an advanced gradient pump (AGP), a pulsed electrochemical detector set in conductivity mode, a CTC-1 cation trap column, a CG12 guard column, a CS12 analytical column, a CSRS-1 anion suppressor set in recycle mode, and an AS3500 autosampler. Dionex peaknet software was used to record the data.

Degassed, deionized, ultra-filtered (DIUF) water (Fisher Scientific; Pittsburgh, PA) and 18 mN methane sulfonic acid (MSA) eluents were required for operation. The eluents were stored in glass vessels and pressurized with ultra high-purity helium (Merriam Graves; Springfield, MA). A cation analysis method program, developed by Dionex, detected the four cations. The program used a 16.5-minute run time with the 18 mN MSA eluent as 100% of the flow. Table 3.2 shows the expected elution times for cations. An output report was generated for each run with the corresponding chromatogram. A sample of a typical cation chromatogram and peak analysis are presented in Figure 3.3, and a small peaks magnification is presented in Figure 3.4. Concentrations of the samples were adjusted for effects of dilution.

Table 3.2 Cation Elution Times

Cation	Elution Times (min)
Na^+	4.6
K^+	6.6
Mg^{+2}	12.0
Ca^{+2}	15.3



No.	Peakname	Ret.Time min	Area µS*min	Amount mg/L	Type	Height µS	Rel.Area %	Resolution
1	*Sodium*	*4.587*	*25.0315*	*122.7487*	*BM **	*122.004*	*91.24*	*6.53*
2	Potassium	6.613	0.0596	0.4361	Rd*	0.253	0.22	n.a.
3	Magnesium	12.050	1.0736	2.7789	M *	0.870	3.91	1.52
4	Calcium	15.283	1.2699	5.0725	MB*	0.879	4.63	n.a.
Total:			27.4345	131.0363		124.005	100.00	

Figure 3.3 – Typical Cation Sample Chromatogram and Peak Analysis

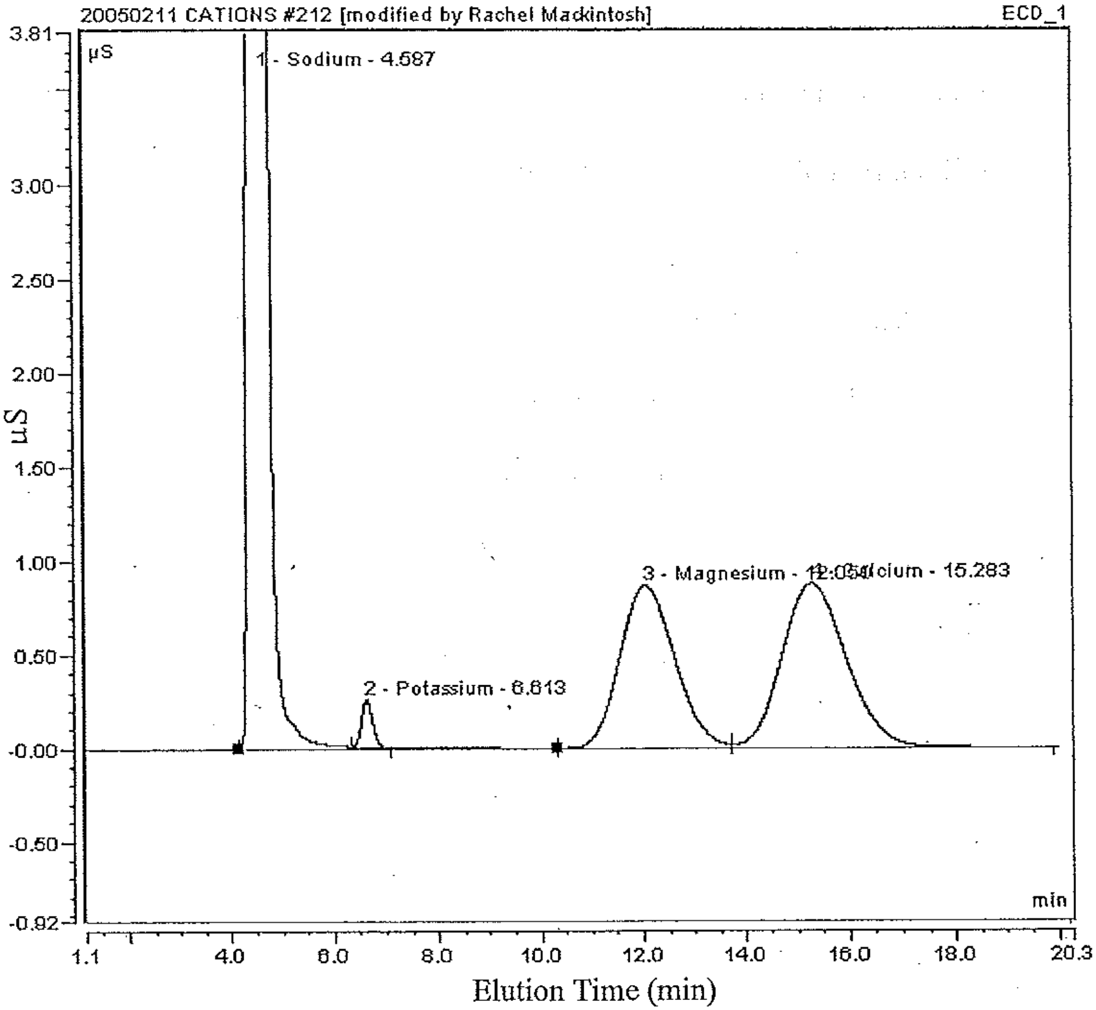
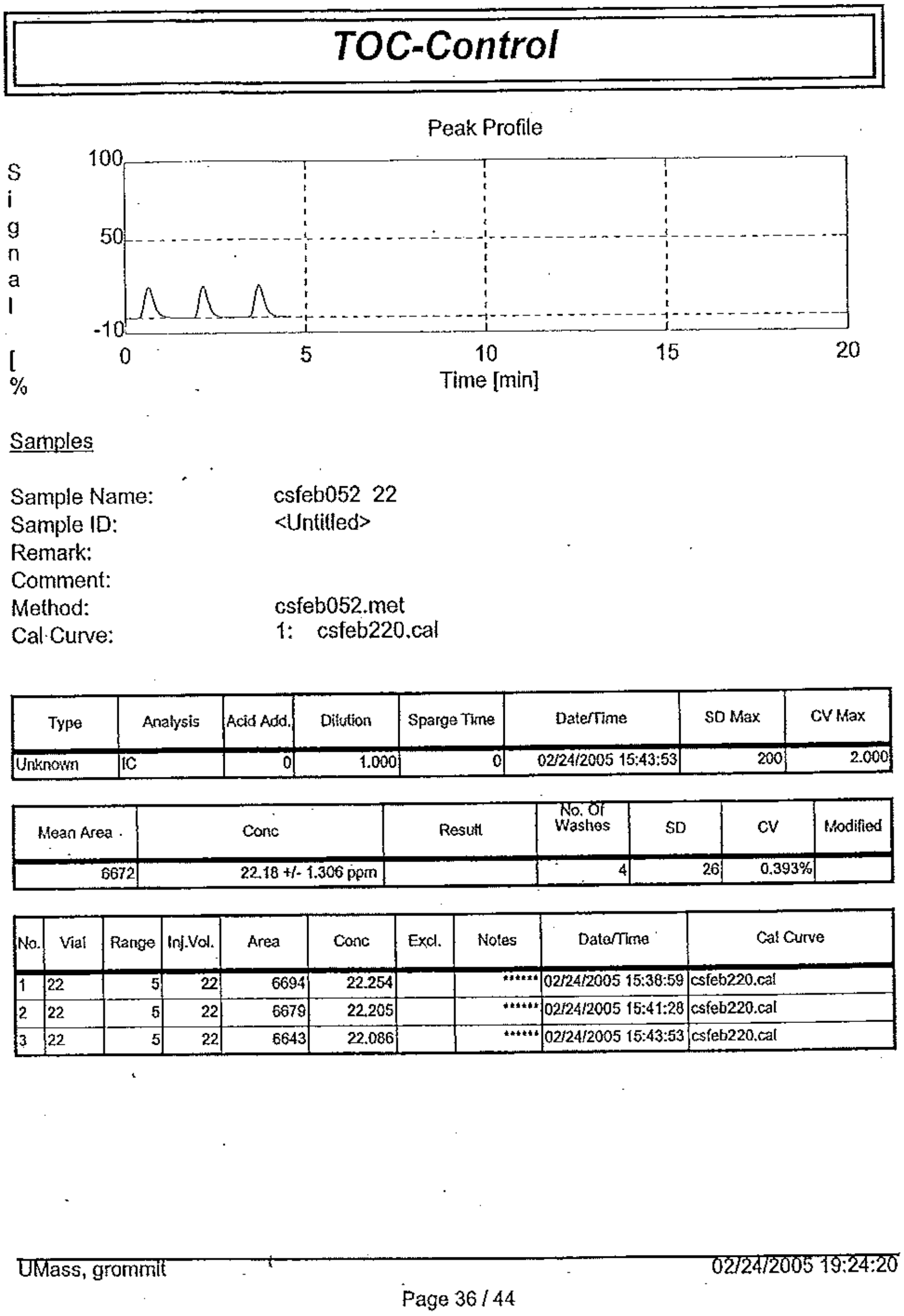


Figure 3.4 – Cation Sample Chromatogram - Magnification of Smaller Peaks

3.2.4 Bicarbonate Analysis

Bicarbonate concentrations were measured using the Shimadzu TOC-5050A total organic carbon analyzer (Shimadzu Corporation; Kyoto, Japan) equipped with an ASI-5000A auto-sampler. Phosphoric acid reagent (25%, Shimadzu Corporation; Kyoto, Japan) reacted with the inorganic carbon components of the water sample converting those constituents into carbon dioxide (CO_2) gas. The generated CO_2 was injected into the sample cell of the infrared gas analyzer by ultra-zero grade air carrier gas. The peak area determined by the data processor corresponded to the inorganic carbon concentration. Each sample was injected a minimum of three times (six times maximum) until the standard deviation between injections was less than 200 area units to ensure the maximum accuracy of the analysis.

The TOC-5050A concentrations were reported as mg/L of inorganic carbon. A sample of this output is shown in Figure 3.5. The inorganic carbon concentration was converted to total bicarbonate concentration by multiplying by the molecular weight ratio of bicarbonate to carbon (61.02/12.01). The total bicarbonate concentration was adjusted to an actual field concentration using the measured field pH to account for the speciation of carbonic acid in a closed system.



TOC-Control

Samples

Sample Name: csfeb052 22
Sample ID: <Untitled>
Remark:
Comment:
Method: csfeb052.met
Cal Curve: 1: csfeb220.cal

Type	Analysis	Acid Add.	Dilution	Sparge Time	Date/Time	SD Max	CV Max
Unknown	IC	0	1.000	0	02/24/2005 15:43:53	200	2.000

Mean Area	Conc	Result	No. Of Washes	SD	CV	Modified
6672	22.18 +/- 1.306 ppm		4	26	0.393%	

No.	Vial	Range	Inj.Vol.	Area	Conc	Excl.	Notes	Date/Time	Cal Curve
1	22	5	22	6694	22.254		******	02/24/2005 15:38:59	csfeb220.cal
2	22	5	22	6679	22.205		******	02/24/2005 15:41:28	csfeb220.cal
3	22	5	22	6643	22.086		******	02/24/2005 15:43:53	csfeb220.cal

UMass, grommit 02/24/2005 19:24:20
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Figure 3.5 – Typical Carbon Analysis Diagram

3.2.5 Quality Assurance and Quality Control

A quality assurance and control (QA/QC) program was used to ensure the accuracy and precision of all field and analytical work.

(i) Field Blanks

Field blanks consisted of samples taken from water treated through reverse osmosis and brought into the field in a separate container. Blank samples were preserved and analyzed using the same procedures as the collected samples. The blank samples were run to verify that cross contamination did not occur.

(ii) Field Spikes

Field spikes were randomly collected samples from the West weir. A predetermined volume of known ionic concentration solution was added to the surface water sample. The recovered ion concentration is compared to the known concentration of the spiked solution. This procedure was used to determine if the extracted ion concentrations reflected the pore fluid concentration with the spike solution. Typical spike recoveries were between 90 and 110%, indicating that the sampling methods are accurately reporting the surface water ion concentrations.

(iii) Duplicate Samples

Duplicate samples were collected at the same time and from the same location. One in every ten samples was sampled in duplicate. Analytical results from each duplicate pair were then compared to ensure the reproducibility and precision (Equation 3.1) of sample collection and preparation. The percent difference between duplicate samples typically ranged from ± 25% with an average difference of ± 1%.

$$\text{Precision}(\%) = \left(1 - \frac{\text{Replicate value} - \text{Replicate mean}}{\text{Replicate mean}}\right) \times 100 \quad 3.1$$

(iv) Analytical QA/QC

Quality assurance and control methods were also used to check the accuracy of the analytical methods. The same techniques used to check the field samples were used to check the machine response. The techniques used were blank water injections, standard solution injections, replicate injections, net ion charge balances, electrical conductivity balances and method detection limits. These checks are described in further detail below:

1) Stock Solutions and Dilutions

Upon returning from the field, samples were prepared for anion, cation, and inorganic carbon analysis. Typically four days were needed to analyze the samples using the IC. A set of 3 to 4 standards were prepared from stock solutions for sample analysis. The range of standard dilutions spanned the range of concentrations observed in the field. An example of a typical anion stock solution and its dilutions is presented in Table 3.3. For expected higher concentrations, a high concentration stock solution of Cl^- (Absolute Standards, Inc.) with a concentration of 1000 mg/L was used.

Table 3.3 Anion Stock Solution and Dilutions

	Stock (mg/L)	1:2 (mg/L)	1:5 (mg/L)	1:10 (mg/L)	1:100 (mg/L)
Cl^-	200	100	40	20	2
SO_4^{-2}	100	50	20	10	1
NO_3^-	5	2.5	1	0.5	0.05
PO_4^-	5	2.5	1	0.5	0.05

Serial dilutions of a known cation solution (Absolute Standards, Inc.; Hamden, CT) were prepared and run. The ranges of standard dilutions were prepared based on the expected range of concentrations from the field samples. The stock solution and range of dilutions are presented in Table 3.4.

Table 3.4 Cation Stock Solution and Dilutions

	Stock (mg/L)	1:2 (mg/L)	1:10 (mg/L)	1:100 (mg/L)
Na^+	100	50	10	1
K^+	10	5	1	0.1
Mg^{+2}	20	10	2	0.2
Ca^{+2}	25	12.5	2.5	0.25

For high concentrations of sodium and calcium, a separate stock solution (Baker Chemical; Mumbai, India) with a concentration of 1,000 mg/L was used. For acetate a separate stock solution was prepared from solid potassium acetate (CH_3COO^--K^+) preserved with sodium azide to prevent acetate degradation. The stock solution and its dilutions are presented in Table 3.5. Other stock solutions required for analysis are made as needed.

Table 3.5 Acetate Stock Solution and Dilutions

Stock	4:5 (mg/L)	2:5 (mg/L)	2:25 (mg/L)	1:20 (mg/L)
12.5	10	5	1	0.5

2) Water Blank, Standard Dilutions, Replication Injections

Deionized water blanks and standard ion solutions were injected every ten samples to prevent interference in the standard response by residual ions and to also detect any operational errors with the analytical instruments. Every 10th sample was run twice as replicate injections. The concentrations of the replicate injections were compared to the prior run to check the instrument performance.

Standard ion solutions were used as checks on the operation of the instrument and to generate the standard curves for each IC run. Peak area response was calibrated to ion concentration by running a series of standards with known ion concentrations. Peak area for each standard concentration was plotted against its respective ion concentration and a linear regression was fit to correlate the machine's response to that of the known ion concentrations (Concentration/Area units). This correlation is also known as the standard curve, where the slope is the response factor of the IC and is unique for each ion of interest. An example of typical standard calibration data is illustrated in Table 3.6, Figure 3.6, and Figure 3.7.

Table 3.6 Example of Calibration Data for Chloride

	Ret. Time	Resp. Fact.	Amount (mg/L) STD 100-50-2.5-2.5	Amount(mg/L) STD Blank	Amount (mg/L) STD 400-200-10-10
Chloride	5.740 min	1.000	100.000	0.000	400.000
Sulfate	8.800 min	1.000	50.000	0.000	200.000
Nitrate	20.900 min	1.000	2.500	0.000	10.000
Phosphate	24.000 min	1.000	2.500	0.000	10.000

	Amount (mg/L) STD 200-100-5-5	Amount (mg/L) STD 16-8-0.4-0.4	Amount (mg/L) STD 4-2-0.1-0.1	Amount (mg/L) STD Chloride 1000
Chloride	200.000	16.000	4.000	1000.000
Sulfate	100.000	8.000	2.000	0.000
Nitrate	5.000	0.400	0.100	0.000
Phosphate	5.000	0.400	0.100	0.000

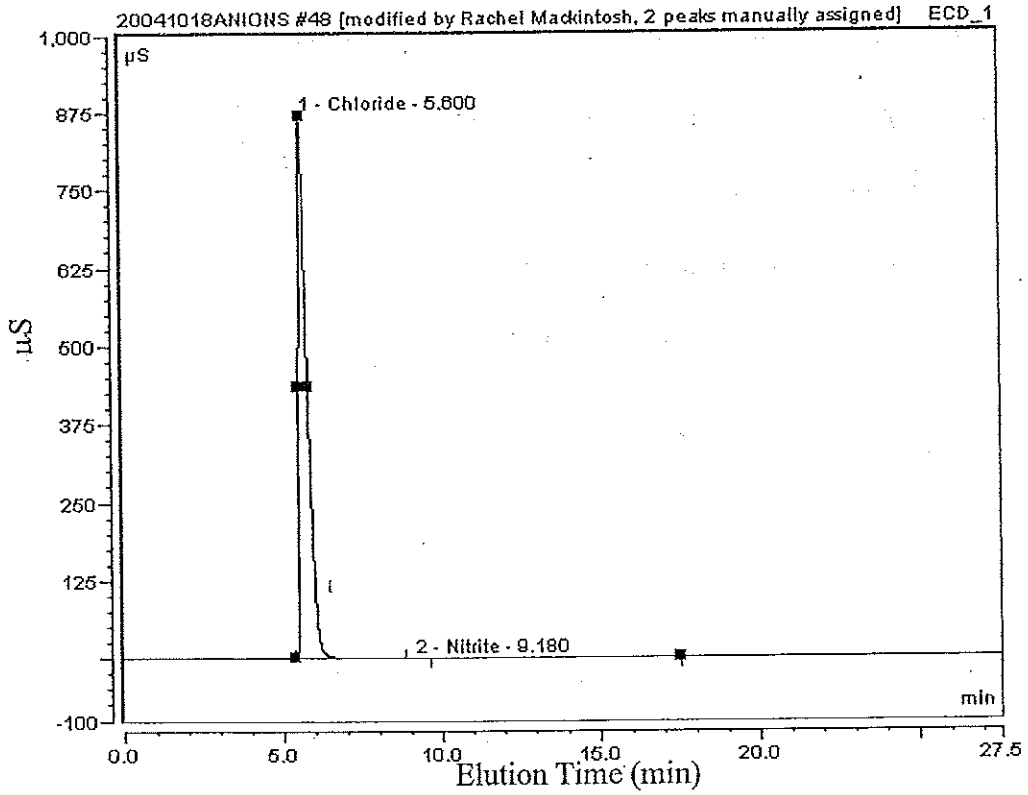

Figure 3.6 – Sample Chloride Standard Chromatogram

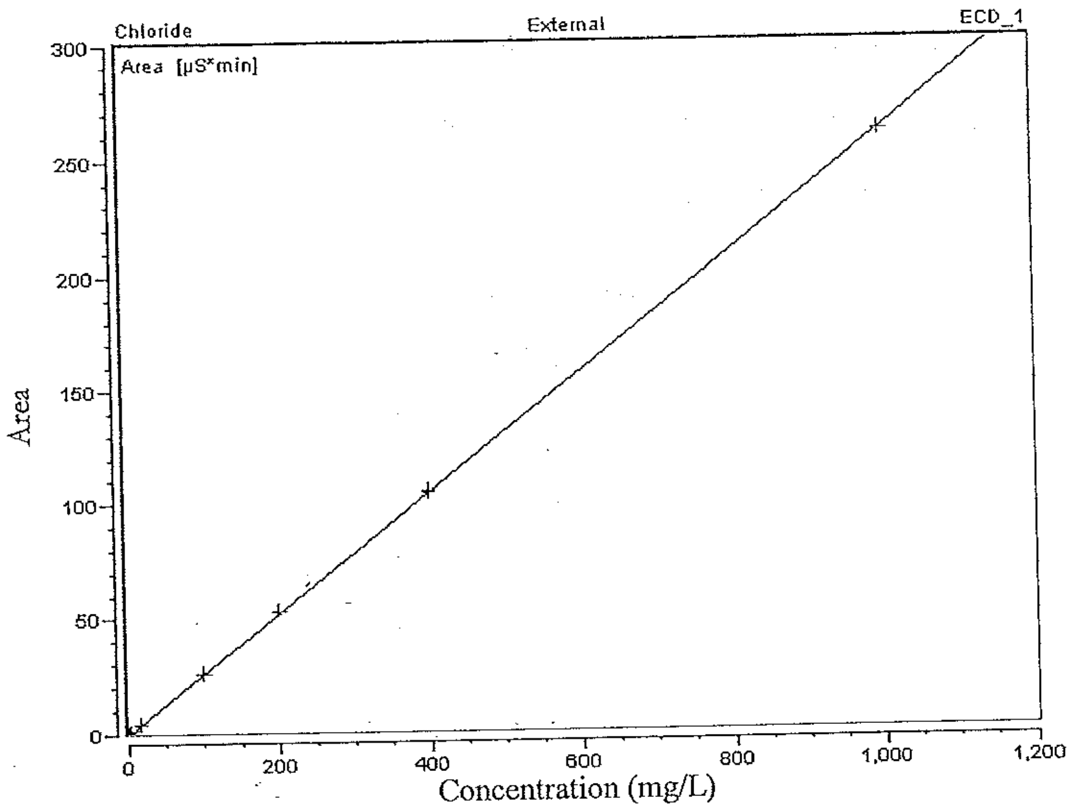

Figure 3.7 – IC Calibration Curve for Chloride

The range of standard calibrations used to calibrate the IC response is based on the range of expected concentrations from the research site. This produced the most accurate response factor (RF) used in calculating the concentrations of the samples. A new calibration curve was created for each new set of samples collected.

3) Method Detection Limits

The method detection limit (MDL) was used to assess the lowest reliable concentrations that could be reported by the analytical instruments and is also used to determine the spike solution. The EPA defines MDL as “the minimum concentration that can be determined with 99% confidence that the true concentration is greater than zero” (40 CFR 136). The lowest limit that can actually be detected is 2.5 times greater than the MDL. Generally, the spike solutions should be 5 to 50 times the MDL. The

MDL is computed as three sample standard deviations about the sample mean, with a sample defined as a sequence of seven replicate injections of a known standard solution (*Standard Methods*, 1995). The MDL for the ions of interest are presented in Table 3.7.

Table 3.7 Method Detection Limits using IC Analysis

Major Ion	MDL (mg/L)
Acetate	0.009
HCO_3^-	0.900
Ca^{+2}	0.019
Cl^-	0.017
Mg^{+2}	0.013
K^+	0.005
Na^+	0.067
SO_4^{-2}	0.019

4) Specific Conductivity Analysis

The theoretical conductivity for each sample was calculated using the procedure described in *Standard Methods*, 1995. In calculating the theoretical conductivity of the sample based on the amount of observed ions in the water the following steps were used:

1. Calculate the Infinite Dilution Conductivity, k° (μmho/cm)

$$k^o = \sum |z_i| (\lambda^o{}_{+i})(cC_i) + \sum |z_i| (\lambda^o{}_{-i})(cC_i) \qquad 3.2$$

Where:

z_i = absolute value of the charge of the i-th ion

cC_i = concentration of the i-th ion (millimoles)

$\lambda^o{}_{+i}$, $\lambda^o{}_{-i}$ = equivalent conductance of the i-th ion

2. Calculate the Ionic Strength (IS) (moles)

$$IS = \sum z_i^2 (cC_i)/2000 \quad 3.3$$

3. Calculate the monovalent ion activity coefficient, y, using the Davies Equation

$$y = 10^{-0.5} \cdot \left[\frac{IS^{1/2}}{\left(1 + IS^{1/2}\right) - 0.3 \cdot IS} \right] \quad 3.4$$

4. Calculate the theoretical conductivity, k_{calc}, of the sample.

$$k_{calc} = k^{o} \cdot y^{2} \quad 3.5$$

The calculated specific conductivity of the sample was then compared with the field-measured conductivity; these values should be within 15% of each other if all of the major ions in the sample were identified and accurately measured. Figure 3.8, presents the calculated conductivity based on measured ion concentrations versus the measured conductivity. The measured conductivity matches well with the calculated conductivity values at a 1:1 relationship with the intercept going through zero.

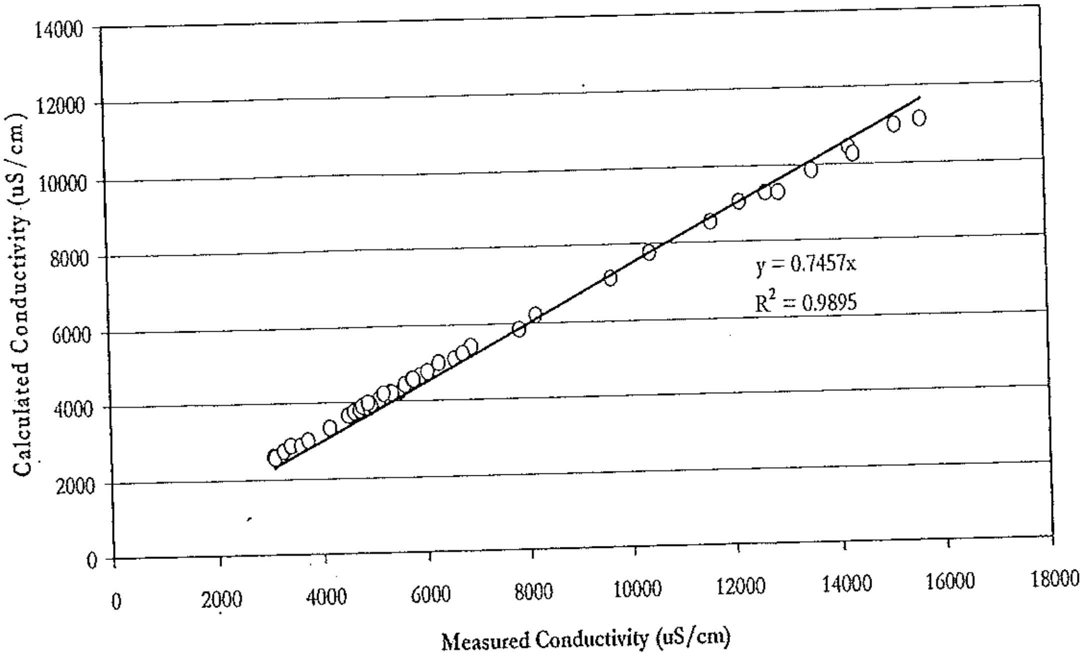

Figure 3.8 - Specific Conductivity Balance

CHAPTER 4

THEORETICAL DEVELOPMENT

4.1 Automated Sampling Strategy

The 6712 automated sampler used at the West weir has the ability to be configured in a variety of methods to sample runoff events. Sampling events can be triggered/started based on changes in water level over a defined time step or by changes in the analytical measurements recorded by the sampler (i.e. specific conductivity, pH, rainfall). The sampler has 24 plastic sampling bottles that can be used to collect either sequential or composite samples based on a user-defined sampling time period (uniform or non-uniform) or a predetermined flow. The sampling strategy can be divided into one or two parts(Part A, Part B) , which can be independently triggered.

For this research, the automated sampling event began when a rate of change in the measured weir water level rose a tenth of a foot in an hour (0.1 ft./1hr = 0.031 m/hr). The two parts of the sampling rule had independent preset time steps. End time for the event was when the last sample was taken. The enable level needs to be set so that a minimum threshold does not capture short un-meaningful events, but should also be set so that short intense events as well as long persistent events can be sampled.

Historical data collected from the site was analyzed in order to determine an optimal sampling rule for the automated sampler,. The parameters of interest are water level, rainfall, specific conductivity, dissolved oxygen and pH. Specific conductivity is the ability of a material to conduct electric current. Ionic charge in solution facilitates the conductance of electric current; the conductivity can be used to determine dissolved ion concentration. This is indicative that conductivity can be used as a surrogate measurement for the total dissolved mass related to a runoff event. The flux (Specific Conductivity /time) entering the catchment is defined as:

$$Flux = \frac{\sum_{i}^{x} Spec.Cond_i \times Q_i}{\sum_{i}^{x} Q_i \times \Delta t} \qquad \mathbf{4.1}$$

with Q_I being the measured flow at a time (i) and Δt being the time step. The maximum flow (Q_{Max}) and maximum conductivity ($Cond_{Max}$) were the observed maximum values for each event.

There are four parameters associated with the sampler that can change the effectiveness of the sampling rule: the number of samples (bottles) for part A (the first part of the sampling rule), number of samples (bottles) for part B (the second part of the sampling rule), time between samples for part A, time between samples for part B. Varying these four parameters manually and using Visual Basic, the flux, $Cond_{Max}$, and Q_{Max} resulting from the for the sampling strategy were compared with continuously recorded data for the entire storm event and an error found for each parameter. The error was minimized across each event, across events within the same month, and then over the year, and compared in a summary spreadsheet to determine the optimal sampling rule. The Visual Basic program is presented in Appendix A along with example spreadsheets of the input and output in Appendix B.

4.2 Stoichiometry of Water Samples

The anion and cation concentrations in runoff can be compared using a calculated charge balance. An ion charge balance is defined as the percentage charge imbalance of the samples (*Standard Methods*, 1995). In water, the sum of the positive charges must equal the sum of the negative charges.

$$\sum z \cdot mc = \sum z \cdot ma \qquad 4.2$$

$$\left[Na^{+}\right] + 2\left[Mg^{+2}\right] + 2\left[Ca^{+2}\right] + \left[K^{+}\right] = \left[Cl^{-}\right] + \left[HCO_3^{-}\right] + 2\left[CO_3^{-2}\right] + 2\left[SO_4^{-2}\right] \qquad 4.3$$

$$E = \left(\sum z \cdot mc - \sum z \cdot ma\right) / \left(\sum z \cdot mc + \sum z \cdot ma\right) * 100 \qquad 4.4$$

The electro-neutrality equation can be expressed as Equation 4.2, where mc and ma are the molarities of the cationic and anionic species respectively and z is the ionic valence. Common ions comprise a majority of the ionic content of a water sample and are analyzed individually when assessing errors in charge balance using methods developed in Chapter 3. For example, if the major cation and anion concentration values in molar units are substituted into Equation 4.2 and subsequently into Equation 4.3, both sides of the equation should be roughly equivalent. Charge balances are reported as percentages, which are generated by substituting Equation 4.3 into Equation 4.4.

Ion charge balances of greater than 10% typically indicate that either an analytical error has occurred or that an ionic species found in high concentrations has been excluded from analysis (Freeze and Cherry, 1979).

4.2.1 Cation Chemistry and Chloride Check

To aid the discussion of cation chemistry theory for the collected samples, one sample is used from the storm event collected on February 7, 2004 at 3:05 p.m. with a charge balance of 1.6%. General equations are presented first followed by a table summarizing the sample. The charge balance suggests that all the major cations and anions in the water sample have been identified. To estimate the source of the runoff dissolved ions, the surface water ion concentrations can be compared with the known chemical composition of various highway-deicing agents used along the particular stretch of roadway pertaining to this project. The total molar concentration (M_{TOTAL}), Equation 4.5, of the collected sample is assumed to be comprised of NaCl, premix ($Na_{0.79}Ca_{0.10}Cl$), and CMA ($Ca_{0.3}Mg_{0.7}(C_2H_3O_2)_2$).

$$M_{Total} = M_{Salt} + M_{Premix} + M_{CMA} \tag{4.5}$$

The premix chemical formula is based on a weight fraction of 80 % NaCl and 20% $CaCl_2$. In analyzing the charge balance of the collected sample, it is assumed that the sole source of magnesium is from CMA; the mass based concentration of magnesium can be used to recover using the mass concentration of CMA. It is assumed that there is no cation exchange in the collected sample and that cations associated with the deicing agents are conservative.

The molar mass of CMA can be found by dividing the observed concentration of Mg^{+2} by the molecular weight of Magnesium associated with CMA, Equation 4.6.

$$M_{CMA} = \frac{c_{Mg}}{m_{Mg-CMA}} \tag{4.6}$$

Knowing the total amount of CMA, it is then possible to find the amount of Ca^{+2} associated with CMA based on its stoichiometry. The observed concentration of calcium (c_{Ca+2}) is the sum of the calcium associated with CMA ($m_{Ca+2\text{-}CMA}$) and the calcium associated with premix ($m_{Ca+2\text{-}premix}$).

The molar amount of premix (M_{Premix}) is determined by the molar mass of calcium associated with the CMA; the remaining calcium is associated with premix, thus determining the total amount of premix.

$$c_{Ca^{+2}} = M_{CMA} \cdot m_{Ca^{+2}-CMA} + M_{Premix} \cdot m_{Ca^{+2}-premix} \tag{4.7}$$

The dissolved NaCl and premix together, Equation 4.8, are assumed to yield the observed mass based sodium concentration, c_{Na+}.

$$c_{Na^+} = (M_{salt} \cdot m_{Na^+-salt}) + (M_{premix} \cdot m_{Na^+-premix}) \tag{4.8}$$

The calculated results for NaCl, premix, and CMA can be compared to the observed chloride concentration, which is attributed to the dissolution of salt and premix in the sample. The calculated chloride value should be roughly equivalent to the observed chloride value, Equation 4.9

$$c_{Cl^-} = M_{Salt} \cdot m_{Cl-Salt} + M_{premix} \cdot m_{Cl^--premix} \tag{4.9}$$

Table 4.1 Cation Chemistry and Chloride Check Values

c_{Mg+2}	165	mg/L
c_{Ca+2}	201	mg/L
c_{Na+}	2501	mg/L
$m_{Mg\text{-}CMA}$	17.02	g Mg^{+2}/mole CMA
$m_{Ca+2\text{-}CMA}$	12.02	g Ca^{+2}/mole CMA
$m_{Ca+2\text{-}Premix}$	4.81	g Ca^{+2}/mole Premix
$m_{Na+\text{-}Salt}$	22.99	g Na^{+}/mole Salt
$m_{Na+\text{-}Premix}$	20.23	g Na^{+}/mole Premix
$m_{Cl\text{-}Salt}$	35.45	g Cl^{-} /mole Salt
$m_{Cl\text{-}Premix}$	39.70	g Cl^{-} /mole Premix

M_{CMA}	9.7	mmol/L
M_{Premix}	17.6	mmol/L
M_{Salt}	93.3	mmol/L
c_{Cl-}	3856	mg/L
c_{Cl-} Obs.	3428	mg/L
Error	11.1%	

The amount of chloride found is within 11% of the observed chloride value of 3428 mg/L.

The observed acetate concentrations cannot be used to validate the deicing agent partitioning. Biodegradation of acetate to bicarbonate in the drainage system with degassing of carbon dioxide does not allow bicarbonate to be used as an accuracy check for prediction of deicing agent amounts.

4.2.2 Anion Chemistry

Following the analysis of sample cation concentrations of the sample discussed above, the anions are identified and related to the application of deicing agents. In reality, the anions being studied herein are not conservative; for purposes of discussion, the anions are assumed conservative to compare the predicted concentrations against the observed concentrations from analysis. It is assumed that acetate can only come from CMA because there is no other known source; assuming this, the following relationship is obtained:

$$Acetate_{pred} = CMA_{pred} * 2 \qquad \textbf{4.10}$$

The observed molar concentration for acetate is the measured mass concentration divided by the molecular weight of acetate as shown in Equation 4.11.

$$Acetate_{obs} = \frac{Acetate_{Obs}}{MW_{Acetate}} \qquad \textbf{4.11}$$

Table 4.2 Acetate Values

$MW_{Acetate}$	118	g/mol
$Acetate_{Pred.}$	19.4	mmol/L
$Acetate_{Obs.}$	29.4	mmol/L

Acetate can be biodegraded by aerobic microorganisms generating bicarbonate as shown in Equation 2.1. Bicarbonate in the water sample is attributed to one of two possible sources: the atmosphere or biodegradation of CMA. Bicarbonate in an open water system is influenced by the pH. The pH of runoff ranges between the values of 7 and 8 with few exceptions over the year. Bicarbonate is the dominant form of soluble carbon species for an open carbon system. The partial pressure of CO_2 that is standard for aquatic chemistry of an open carbon system is $10^{-3.5}$ as utilized in Figure 4.1.

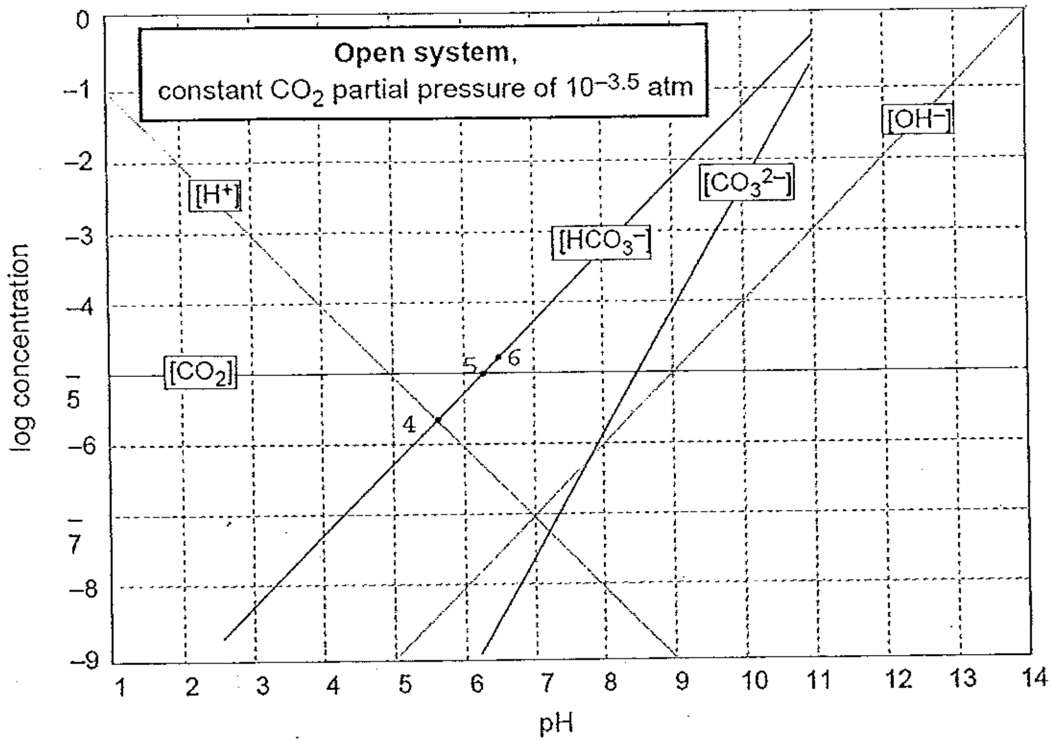

Figure 4.1 – Open Carbon System (Lowler, 1999)

It is expected that some acetate biodegrades to bicarbonate between the time of application on the paved road surface to the time the sample is collected coming over the weir. The amount of bicarbonate measured in the sample are greater than the amount of bicarbonate expected from the available carbon in the atmosphere. The amount of bicarbonate expected from the atmosphere is subtracted from the amount of measured bicarbonate through analysis and the remaining amount is attributed to the biodegradation of CMA. This is shown in Equation 4.12.

$$Acetate_{pred.} - \left(\frac{Acetate_{Obs.}}{MW_{Acetate}}\right) = HCO_3^{-}{}_{CMA} + HCO_3^{-}{}_{atm} \qquad \textbf{4.12}$$

At a pH of 8, it is expected that 61.02 mg/L of HCO_3^- is available from the atmosphere; at a pH of 7, 0.61 mg/L can be expected. Comparing the predicted value of bicarbonate to the measured value indicates another possible source of bicarbonate instead of the two sources expected to dominate, CMA and the atmosphere.

$$HCO_3^-{}_{atm} = \frac{MW_{HCO_3^-}}{10^{8-pH}} \tag{4.13}$$

$$HCO_3^-{}_{CMA} = Acetate_{pred} - Acetate_{Obs} \tag{4.14}$$

Table 4.3 Bicarbonate Values

pH	7.9	
MW_{HCO3-}	61.0	mg/L
$HCO_3^-{}_{Obs.}$	112	mg/L
HCO_3^-atm	48.5	mg/L
$HCO_3^-{}_{CMA}$	-10	mmol/L

Figure 4.2 shows results of an analysis performed in the laboratory where bicarbonate was generated as acetate biodegraded.

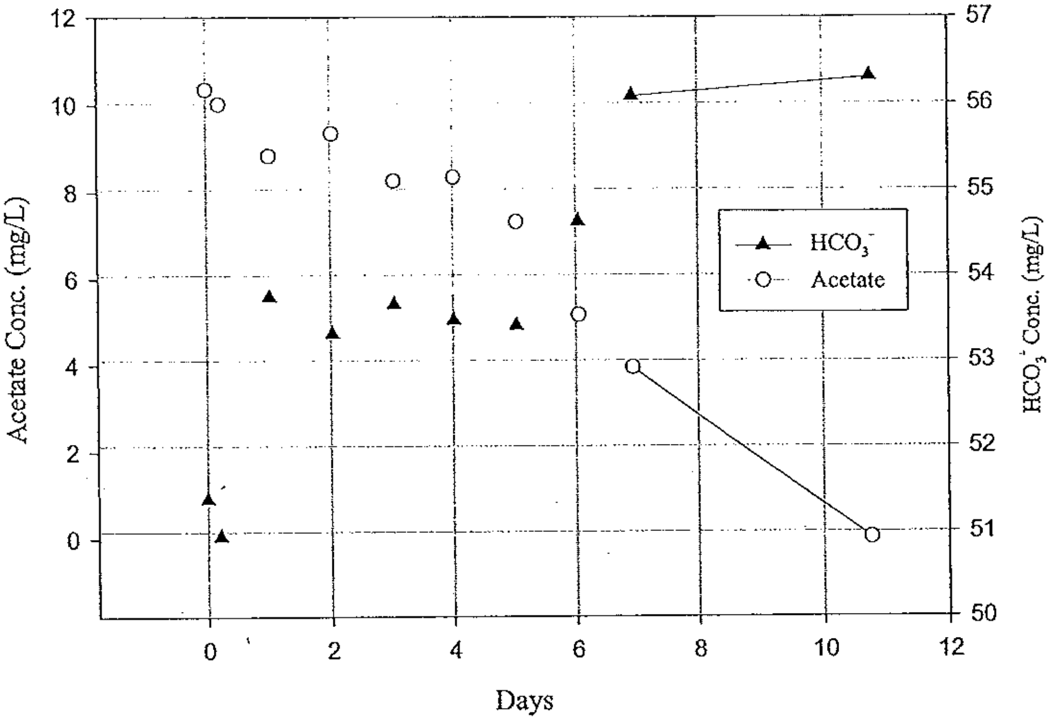

Figure 4.2 – Degradation of CMA / Generation of HCO$_3^-$

4.3 Hydraulic Model Development

The hydraulic and chloride flux model for the SR 25 runoff basin was developed based on the work of prior graduate students and researchers studying the Instantaneous Unit Hydrograph. The reasoning and methods used to develop models for the hyetographs, hydrographs and loadographs for this site are outlined below.

4.3.1 Effective Watershed Area

It is intuitive that all of the precipitation that falls on a watershed will not become observed as runoff. Runoff losses are attributed to components of the hydrologic cycle: infiltration/percolation, evaporation and evapo-transpiration should be addressed when creating a model of rainfall events. These losses vary as a percentage of the total rainfall depending on the storm size. At one extreme, a small storm may lose its entire mass to puddling and infiltration. As storms progressively increase, smaller and smaller percentages of the total water mass are lost to places other than runoff. It is important that these losses are accounted for when analyzing any storm; in this way an appropriate "effective rainfall" from a given storm can be used as input for the development of the runoff model.

A common method of examining the relationship between rainfall and runoff entails plotting runoff as a measurement of water height above a weir vs. rainfall in water height (Mead, 1919). Rather than plotting runoff vs. rainfall, an idealized effective runoff area vs. rainfall was graphed. The resulting curve is similar to that proposed by Mead (1919) because the effective area is the idealized runoff area that would be produced from all of the observed runoff (100%).

A separate calculation of the effective runoff area was performed for each storm analyzed during this research. The effective runoff area, A_{Eff}, is calculated as the area that would make the observed rainfall, H_{Rain}, equal the total volume of runoff, Q_R, Equation 4.15.

$$H_{Rain} \cdot A_{Eff.} = Q_R \qquad \textbf{4.15}$$

For example, if the data show that 1 m of rain produced 0.5 m of runoff; the data will be presented as 1 m of rain resulting in a 50% effective runoff area of the actual watershed.

A plot of storms from 2004 (Figure 4.3) and the effective watershed area calculated for each individual event shows the trend predicted by Linsley, *et al.* (1958).

Events with total runoff volumes less than 10,000 gallons (37.85 m^3) were not used for this research because the values indicate an A_{Eff} <10%; there is not enough flow to characterize the event and make similar comparisons to other events. As expected, smaller storms have the lowest runoff and consequently the lowest effective watershed area. As the storm size increases, the area approaches an effective area equal to that of the watershed. The total watershed area for the Plymouth site is 23,275 m^2.

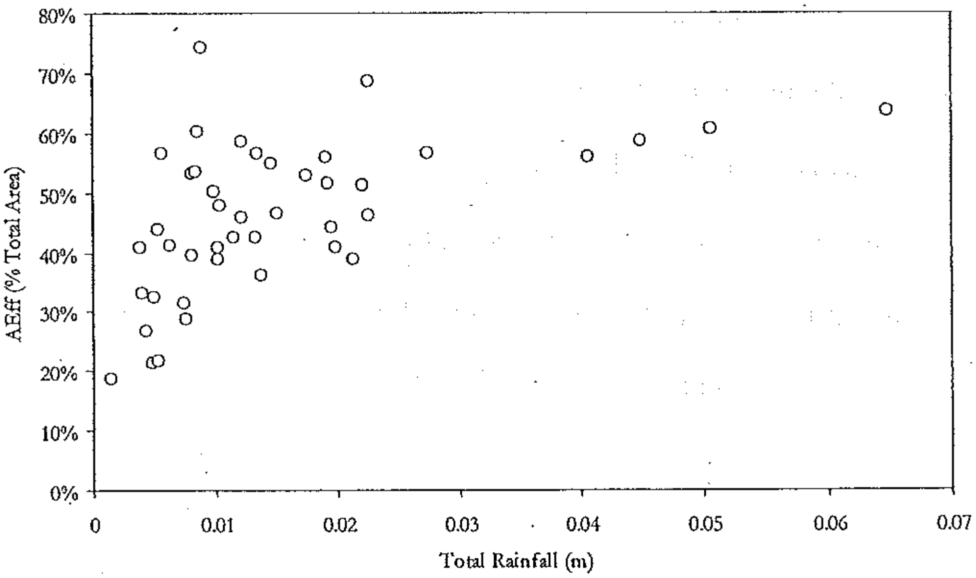

Figure 4.3 – Plymouth Effective Watershed Area (Storms from 2004)

4.3.2 Stormwater Hydraulics

The hydraulic response of the given site was modeled as a cascade of linear reservoirs as defined by Nash (1957) who derived a model for the instantaneous unit hydrograph (IUH) by building upon the work of prior investigators. A watershed's response to rainfall depends on a wide variety of factors: watershed topography and geology, land-use (i.e. agriculture, urban development), river conditions (dams) and initial conditions (degree of saturation of soil and aquifers).

(i) Unit Hydrograph

The basis for the unit hydrograph, a graphical representation of runoff versus time, was first described by Sherman (1932), expressing that the characteristics of a watershed remain unchanged over time. This allows rainfall with complementary durations and intensities over a watershed to yield similar runoff hydrographs. The unit hydrograph is the hydrograph resulting from one unit (typically expressed as 1 in or 1 cm) of runoff generated from an even distribution of rain falling at a uniform rate for a specific duration on the entire watershed. The unit hydrograph is a hypothetical unit response of the watershed to a unit input of rainfall allowing for the easy calculation of the runoff response to any arbitrary input by performing a convolution integral between the rain input and the unit hydrograph output.

This linear system response theory holds that a basin's response to a rainfall input is linear and time invariant. All unit hydrographs are based on two fundamental principles (Dooge, 1959):

1. Invariance – the hydrograph of surface runoff from a catchment due to a given pattern of rainfall excess (rainfall minus infiltration and similar losses) is invariable.
2. Superposition- the resulting hydrograph from a given pattern of excess rainfall can be built up by superimposing the unit

hydrographs due to the separate amounts of rainfall excess occurring in each unit period.

These assumptions are important, allowing the addition of separate runoff increments and other practical assumptions to be made for convenience. Peeling (1999) goes into further explanation of assumptions and work done by prior investigators.

(ii) Nash (1957) Instantaneous Unit Hydrograph (IUH)

There are many types of design hydrographs that have been developed to suit numerous purposes. The conceptual two-parameter model put forth by Nash (1957) suggested that a watershed's response could be predicted through a series of "M" linear reservoirs. By varying the number of storage reservoirs and the storage coefficient (characteristic decay constant) a runoff response can be predicted from a given input. Because the research site is well instrumented, precipitation measurements can be used as input to the model and used to create a predicted flow which can be compared with the measured flow. The number of linear reservoirs and the storage coefficients can be optimized for any site.

The unit hydrograph of individual events of finite length can be superimposed allowing for the development of the S-hydrograph. The construction of the S-hydrograph involves the summation of a series of unit hydrographs of duration D and lag of the same time D. When reduced, the result is an infinitely small time step (IUH).

(iii) Depression Storage Layer

Water that accumulates in surface depressions and eventually either infiltrates or evaporates is defined as the depression storage layer. Depression storage on impervious ground remains there until it evaporates. Depression storage can be a sizable fraction of total precipitation with values ranging between 0 to 8 mm (Washington.edu); in Sweden values found for impervious surfaces range from 0.7 to 1.5 mm (Niemczynowicz 1999). For this research the depression storage depth ζ, was quantified as the amount of precipitation P, observed before the onset of runoff. This is expressed in Equation 4.16 where i_S is the time at which the first $Q_R > 0$ value is observed

$$\zeta = \sum_{0}^{i_S} P \cdot dt^* \qquad (Q < 0) \qquad 4.16$$

(iv) IUH Model

Nash (1957) developed a widely used IUH model by considering the watershed as a cascade of M linear reservoirs. The model Nash (1957) created optimizes the IUH by varying two parameters, the number of reservoirs and the storage coefficient of the reservoirs. By analyzing the conservation of mass equation for the reservoir (4.17) a model can be developed.

$$-w \cdot A_{Eff} + R_1 A_{Eff} + A_{Eff} \frac{dH}{dt} = 0 \qquad 4.17$$

With mass in w, mass out R_1 and stored mass A_{Eff}(dH/dt). The linear reservoir assumption for the Nash model is that the output is proportional to the depth (H) of the reservoir with Ω being the runoff decay constant characteristic of the watershed.

$$R_1 = \rho_W \cdot \Omega \cdot H_1 \qquad \mathbf{4.18}$$

Taking the time derivative of 4.17 and substituting into the conservation of runoff mass yields with runoff rate, w and R is the output mass per unit surface area:

$$w = \frac{1}{\Omega}\frac{dR}{dt} + R_1 \qquad \mathbf{4.19}$$

The boundary conditions prescribed for these events are as follows, with t_S being the time until the last input of rain fell and t being time from the beginning of the event where P_C is a constant mass flow rate.

$$w = P_C \qquad (0 < t < t_S) \qquad \mathbf{4.20}$$

$$w = 0 \qquad (t < t_S) \qquad \mathbf{4.21}$$

The result of equation 4.19 for the first and second boundary conditions gives:

$$R_1 = w \cdot (1 - e^{-\Omega \cdot t_S})e^{[\Omega \cdot (t_S - t)]} \qquad \mathbf{4.22}$$

Simplifying the above expression for $\Omega t_S \ll 1$ we get where $P = wt_S$:

$$R_1 = \Omega P e^{[-\Omega t]} \qquad \mathbf{4.23}$$

Carrying forward this analysis of the first reservoir with input to the second reservoir being the output from the first:

$$R_2 = e^{-\Omega t}\Omega \int e^{\Omega t}\{P \cdot \Omega e^{-\Omega t}\}dt \qquad 4.24$$

$$R_2 = \Omega^2 \cdot P \cdot t \cdot e^{[-\Omega t]} \qquad 4.25$$

This continues for each successive reservoir. For the Mth reservoir the output can be computed as:

$$R_M = \frac{\Omega^M \cdot P \cdot t^{M-1}}{\Gamma(M)} e^{-\Omega t} \qquad 4.26$$

$$\Gamma(M) = (M-1)! \qquad \text{(M integer)} \qquad 4.27$$

$$\Gamma(M) = \int_0^\infty x^{M-1} e^{-x} dx \qquad \text{(M non-integer)} \qquad 4.28$$

Considering a runoff increment dV_R originating from a storm increment $PA_{Eff}dt$ entering the cascade of reservoirs at a defined storm time t, the watershed response is given by Nash as Equation 4.29 and was subsequently used in creating a runoff model as follows:

$$Q_R = A_{Eff} \int_0^t P(t^*) R_M (t - t^*) dt^* \qquad 4.29$$

4.3.3 Storm Water Chemistry Modeling

The watershed characteristics, which govern hydrographs, can also be used to model the flux of ions in the runoff. Before runoff is generated, precipitation enters the depression storage layer and interacts with residual deicing agents left in the layer. The mass balance for the depression storage layer with deicing agent is defined by Equation 4.30 and shown mathematically in Equation 4.31:

$$\Delta\text{StoredMass} + \text{MassOut} = \text{Dissolution(DeicingAgent)} \tag{4.30}$$

$$nB^2\zeta\frac{dC_P}{dt} + B^2PC_P = 4\pi r^2\frac{Dn^{4/3}C_{Sat}}{B} \tag{4.31}$$

where n is the porosity, B is the dissolution volume width, C_P is the concentration of ions leaving the depression storage layer and w is the precipitation intensity. On the right hand side, r is the granule radius, D is the free liquid diffusivity and C_{Sat} is the saturated granule concentration (Ostendorf et al. 2001).

Equation 4.31 is simplified by introducing two terms, ω and S, which are assumed to be constant for each storm event are shown in Equations 4.32 and 4.33 resulting in Equation 4.34 which suggests that the source of the ions observed in the runoff comes from the depression storage layer.

$$\omega = \frac{6Dn^{4/3}C_{Sat}}{\rho_i\zeta R} \tag{4.32}$$

$$S = \left[\frac{4\pi\rho_i}{3}\left(\frac{\zeta}{2}\right)\left(\frac{1}{R^2}\right)\right]r^2 \tag{4.33}$$

$$\frac{dC_i}{dt} + \frac{wC_i}{n\zeta} = \frac{\omega S}{n\zeta} \tag{4.34}$$

Solving Equation 4.34 we end up with Equation 4.35, which can be used as an input term in the model developed for the Nash (1957) hydrograph.

$$C_{P_t} = \frac{\dfrac{\omega S_N}{n\zeta} + \dfrac{C_{P_{t-1}}}{\Delta t}}{\dfrac{P_t}{n\zeta} + \dfrac{1}{\Delta t}} \qquad 4.35$$

Equation 4.35 was used in conjunction with Equation 4.36 to model the flux of ions entering the catchment basin from runoff.

$$Q_R = A_{Eff} \int_0^t P(t^*) R_M (t - t^*) \cdot C_{P_t} dt^* \qquad 4.36$$

CHAPTER 5

RESULTS

Four characteristics associated with using an automated water sampler for the characterization of road runoff events were studied and evaluated for this research. A sampling rule was created based on historical data and used in the collection of runoff samples from storm events. Storm runoff samples were analyzed for major ions over the course of separate events and compared with continuous remote measurements of specific conductivity. The samples were beneficial in developing a model of a hydrograph and loadograph by providing ion concentrations for the storm event. Modeling of hyetographs, hydrographs and loadographs are based on data collected from the remote loggers and samples collected by the automated sampler. The last characteristic studied was changes in runoff chemistry on a seasonal scale. Events were normalized by the concentrations of ions, sample collection frequency and flow generated from the runoff. The results and discussion of these analyses are presented in this chapter.

5.1 Sampler Strategy

The sampling strategy for the automated sampler was determined using continuously measured flow and conductivity data collected over four years (2001-2004) using one storm per month. The specific conductivity from continuously recorded measurements were used in creating an optimal sampling strategy. The sampling rule was optimized by manually comparing the errors associated with flux using specific conductivity as a surrogate measurement for the flux. Using a visual basic program (Appendix A) the time of maximum observed flow, the maximum specific conductivity, and flux for each event was calculated by changing the parameters associated with the automated sampler rule for each event (Table 5.1). Delta time is the time between successive measurements for the remote field equipment: for 2001 measurements were taken every ten minutes, for the years 2002-2004 data were taken at 5 minute intervals. Delta A is the sampling frequency in minutes associated with the first part of the sampling rule and Delta B is the sampling frequency in minutes for the second part of the rule., Number of A and Number of B are the number of samples associated with each part of the rule respectively with a total of 24 samples that can be divided between the two parts of the sampling rule. These four parameters were optimized by comparing a mean error between calculated values for the storm event and the results from the same parameters based on continuous measurements for the sampling rule. A sampling strategy with the time step and samples associated with each part of the rule is shown in Figure 5.1.

Table 5.1 Typical Input of Historical Analysis (Summary)

INPUT	
Delta Time (min)	5 - 10
Delta A (min)	15
Delta B (min)	60
No. of A (Number of samples)	5
No. of B (Number of samples)	19

Storms from the four years were studied and defined as follows: the start of the sample collection for an event was indicated by a change in both level and flow, increasing until a peak height and then decaying. The total volume of runoff for the events used in this research was greater than 37.85 m^3 (P = 5.08 mm) so that a representative runoff response could be used for storm analysis. Storms with rainfall less than this lost a large percentage of their water mass to interception and evaporation significantly affecting the ability of the storm event to be modeled. Table 5.1 presents the input for a sample run while Table 5.2 presents the output from each month and year studied.

For the month of September 2003 there were no recorded storms. Precipitation, flow, and level data as a function of time for each storm event are presented in Appendix B for a typical event. From the results of a yearly analysis it can be seen that during the winter months from late November to March there is a large error associated with the flux. To develop a more accurate rule the year was divided into two seasons (winter / summer) to compare a seasonal analysis to a uni-modal strategy for the year. Including larger errors associated with the winter months along with the lesser errors observed in the summer months, the best sampling strategy for the year is an average of the two seasons.

Table 5.2 Typical Flux Output of Historical Analysis

	January				*February*				*March*			
	2001	2002	2003	2004	2001	2002	2003	2004	2001	2002	2003	2004
Rule Average {(µS/cm)/m³}	3029	44737	10951	247923	66431	14357	95891	44137	1188	2215	22683	273209
Storm Average {(µS/cm)/m³}	3450	29514	8223	179499	39690	17333	90389	15154	2839	1986	11566	249335
Storm Duration Err.	0.2%	3.3%	1.7%	55.0%	2.9%	2.7%	88.9%	32.7%	1.1%	480.4%	10.8%	149.2%
Max. Spec. Cond. Error	12.9%	0.0%	0.0%	0.0%	0.0%	0.1%	2.8%	0.4%	0.0%	0.0%	-35.1%	0.7%
Max Q (m³/s)	2.99E-02	1.40E-02	2.48E-02	9.94E-03	1.75E-02	1.48E-02	6.38E-03	3.16E-02	4.08E-02	4.06E-02	5.38E-04	3.29E-03
Flux Average Error	12.2%	51.6%	33.2%	38.1%	67.4%	17.2%	6.1%	191.3%	58.2%	11.6%	96.1%	9.6%
Flux Month Average	33.8%				70.5%				43.9%			
Abs Difference {(µS/cm)/m³}	421	15223	2729	68424	26740	2976	5503	28983	1652	230	11117	23875

	April				*May*				*June*			
	2001	2002	2003	2004	2001	2002	2003	2004	2001	2002	2003	2004
Rule Average {(µS/cm)/m³}	60088	1926	74546	5677	597	757	10000	19150	198	354	1060	1064
Storm Average {(µS/cm)/m³}	49669	1542	67025	2954	736	674	5659	13229	287	220	1038	770
Storm Duration Err.	5.4%	12.2%	3.2%	64.8%	1.5%	6.5%	6.3%	297.5%	55.2%	5.6%	53.8%	405.9%
Max. Spec. Cond. Err.	0.0%	0.0%	0.6%	0.0%	0.0%	0.0%	0.0%	-4.6%	0.0%	0.0%	0.0%	3.1%
Max Q (m³/s)	9.14E-03	3.91E-02	4.01E-03	2.15E-02	4.59E-02	6.53E-02	6.81E-03	5.09E-03	1.51E-01	4.13E-02	2.53E-03	3.55E-02
Flux Average Err.	21.0%	24.9%	11.2%	92.2%	18.9%	12.3%	76.7%	44.8%	31.0%	61.1%	2.1%	38.3%
Flux Month Average	37.3%				38.2%				33.1%			
Abs Difference{(µS/cm)/m³}	10419	384	7521	2723	139	83	4341	5921	89	134	21	295

Table 5.2 Continued…

	July				*August*				*September*			
	2001	2002	2003	2004	2001	2002	2003	2004	2001	2002	2003	2004
Rule Average {(μS/cm)/m^3}	321	94	11690	5426	187	15907	381	1216	908	108		142
Storm Average {(μS/cm)/m^3}	203	122	53812	5978	156	9912	231	951	870	66		87
Storm Duration Error	250.0%	5.9%	7.6%	46.2%	4.7%	6.7%	2.3%	70.0%	4.8%	1.3%		22.9%
Max. Spec. Cond. Err.	0.0%	0.0%	0.3%	0.0%	0.0%	0.0%	0.0%	5.6%	14.3%	0.0%		0.0%
Max Q (m^3/s)	5.67E-02	1.08E-01	4.67E-03	6.90E-03	6.96E-02	2.06E-03	8.11E-02	1.24E-02	2.48E-02	1.76E-01		6.43E-02
Flux Average Err.	58.6%	22.9%	78.3%	9.2%	19.7%	60.5%	65.0%	27.9%	4.4%	62.6%		63.9%
Flux Month Average	42.2%				43.3%				43.6%			
Abs Difference {(μS/cm)/m^3}	119	28	42122	553	31	5995	150	266	38	41		55

	October				*November*				*December*			
	2001	2002	2003	2004	2001	2002	2003	2004	2001	2002	2003	2004
Rule Average {(μS/cm)/m^3}	942	684	5314	3980	3647	557	568	568	10403	12584	9782	9782
Storm Average {(μS/cm)/m^3}	822	757	3189	2137	2749	404	555	555	5903	6315	6122	6122
Storm Duration Err.	1.9%	0.9%	2.0%	34.9%	2.0%	3.4%	2.6%	2.6%	1.2%	0.0%	116.0%	116.0%
Max. Spec. Cond. Err.	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	6.3%	0.0%	1.1%	1.1%
Max Q (m^3/s)	2.19E-02	1.63E-02	1.35E-02	6.30E-03	6.64E-03	1.44E-02	2.41E-02	2.41E-02	1.68E-02	3.00E-02	2.79E-02	2.79E-02
Flux Average Err.	14.6%	9.6%	66.6%	86.2%	32.6%	37.9%	2.4%	2.4%	76.3%	99.3%	59.8%	59.8%
Flux Month Average	44.3%				18.9%				73.8%			
Abs Difference{(μS/cm)/m^3}	120	72	2124	1843	898	153	14	14	4501	6270	3660	3660

Analyzing storm events for two seasons minimized the flux error and provided better results. The rule was performed in the same way as done previously for the yearly optimal sampling strategy.(Appendix A) The results of seasonal rule programming are presented in Table 5.3 for December through April events and Table 5.4 for May through November events with the optimal sampling rule highlighted in each table.

Table 5.3 Seasonal Scale Modeling (December through April)

Time A (min)	Time B (min)	No. of A	No. of B	Error	Abs. Diff. {(μS/cm)/m^3}
30	65	8	16	43.8%	42.2
30	70	9	15	43.3%	42.9
20	75	9	15	41.7%	32.6
20	55	9	15	37.9%	28.7
10	65	7	17	54.0%	35.7
20	70	10	14	45.2%	26.8
40	65	8	16	57.5%	69.7

Table 5.4 Seasonal Scale Modeling (May through November)

Time A (min)	Time B (min)	No. of A	No. of B	Error	Abs. Diff. {(μS/cm)/m^3}
15	60	5	19	38.4%	8.93
10	60	5	19	36.4%	7.67
10	60	6	18	35.1%	7.83
10	60	7	17	34.6%	8.27
15	60	7	17	33.9%	8.99
15	65	7	17	35.7%	8.69
15	65	7	17	38.2%	9.10

The absolute differences and errors for the specific conductivity obtained with the sampling rule are four times higher in the winter months than they are during the summer months. The time of maximum specific conductivity and time of maximum flow occurred within the first hour with few exceptions and were most always sampled by following the rule.

Sampling rule results from storm events for the previous four years (2001-2004) show that better capture of storm events are inferred from extended sampling collection frequency in winter, and reduced sampling collection frequency in summer. Both summer and winter sampling strategies require frequent sample collection at the beginning of runoff. During the winter, precipitation is often frozen in the form of either snow or ice and requires a longer time to generate runoff after the onset of precipitation. In the winter, double the number of samples is necessary as compared to the number of samples needed during the summer months. This is due to an order of magnitude difference between specific conductivities observed during the beginning of winter storms (25000 μS/cm) compared to the specific conductivity observed later in the events, dictating that more samples need to be taken at the onset of runoff to reduce the flux error.

Precipitation quickly generates runoff flushing the pavement of residual salts during the summer. The specific conductivities vary slightly during the summer, remaining within the same order of magnitude with maximum conductivities of 3000 μS/cm decreasing with each successive event. The first flush dictates that a shorter sampling interval is needed at the onset of runoff to provide better characterization of each event.

For a yearly sampling strategy an average of optimal results from the two seasons (winter and summer) is shown in Table 5.5 with more samples used in the latter part of the event. More samples need to be taken during the second part of the rule because the range of conductivity values become less with each successive event as residual deicing agents are washed out. These results are summarized and shown in Table 5.5 with the optimal sampling rule for seasonal sampling and yearly sampling shown. For the yearly sampling strategy, the minimum average errors are shown as a percent. For the seasonal summaries, the sampling strategy with the least absolute difference between the predicted flux by the sampling rule and the flux for the storm as well as the rule with the least average error are shown respectively.

Table 5.5 Sampling Strategy Summary

No. A # of Samples	No. B # of Samples	ΔT_A min	ΔT_B min	Avg. Errors %	$\lvert$Storm Average - Rule Average$\rvert$ $(\mu S/cm)/m^3$
Year Sampling					
5	19	15	65	37.1%	
Seasonal Sampling - December through April					
11	13	20	75	44.8%	25.00
9	15	20	55	37.9%	28.74
Seasonal Sampling - May through November					
5	19	10	60	36.4%	7.67
7	17	15	60	33.9%	8.99

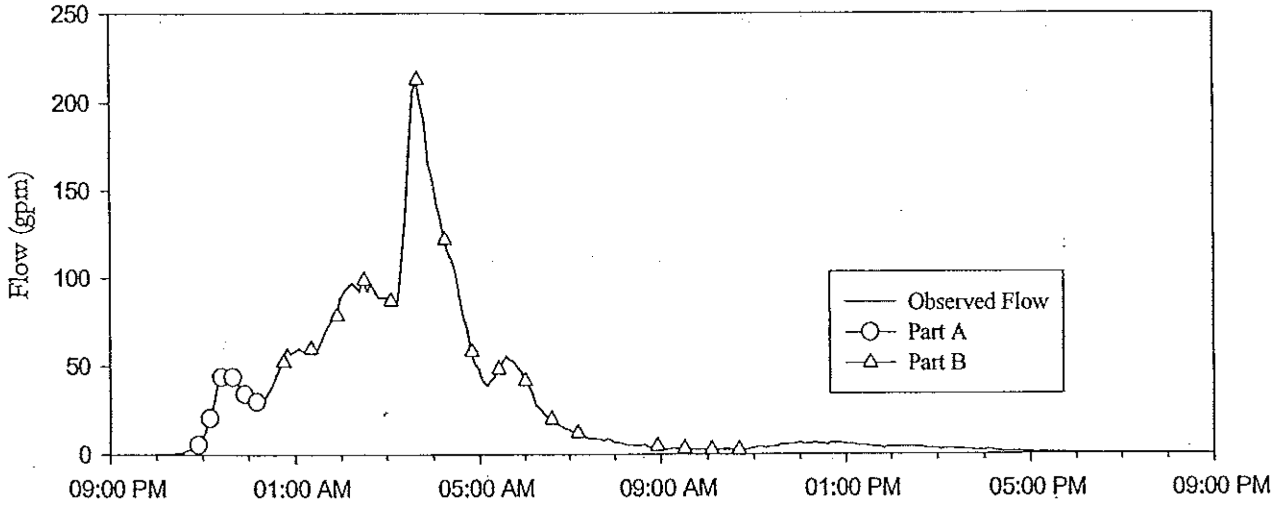

Figure 5.1 – Storm Capture (2/14/2005) A-15 min, B-35 min

Figure 5.1 presents the capture of a storm event on February 14th of 2005 with a less frequent sampling time for the end of the event (water sample taken every 35 min) and a more frequent sampling time (water sample taken every 15 min) for the beginning of the storm.

5.2 Runoff Chemistry

Samples physically collected by the automated sampler were sampled according to the sampling rules developed for the automated sampler. Water samples were analyzed for typical anions and cations, which are also analyzed in monthly samples from monitoring wells at the site. Water samples were taken at discrete times during each event. For the particular event on February 2nd of 2004 used as an example the observed (Concentrations from water samples taken) and predicted (concentrations from records of deicing agent application supplied by MHD) amounts of CMA, premix, and salt are shown in Table 5.6.

Table 5.6 Predicted Deicing Agents

	Observed (mmol/L):	Predicted (mmol/L)	Applied (kg):	Capture
CMA	1.11	2.72	2722	26.3%
Premix	1.68	3.86	--	--
Salt	12.93	49.45	9357	30.3%

The predicted deicing agent values for each sample taken from the storm can be summed and compared to the amount of deicing agents which Mass Highway logs as applied to the pavement during each event. Records of daily spreading rates along SR 25 over the winter season were supplied by Mass Highway showing tons of each deicing agent applied to the stretch of roadway during the event. Salt and premix are applied over the entire stretch of roadway while CMA is applied solely to the stretch of roadway with runoff entering the research site.

The difference between the observed, predicted and applied values can possibly be explained by the deicing agents that remain as residue between storm events. The runoff composition for each storm will change depending on the mass of deicing agents residing in the depression storage layer. For the event on February 7, 2004 it is seen that no premix was applied yet is still present as a part of the runoff. The automated sampler did not capture the entire event; 30% of the salt mass and 26% of the CMA applied was profiled by runoff sampling. Mass for the sampled portion of the event was found by summing up the flow times the concentration in the runoff event samples. Deicing agent mass can be lost to retention in the depression storage layer, runoff onto the median swale or interception.

The mass of deicer applied per event can be compared to the total deicing agents applied for the season to evaluate if the runoff is similar to what is being applied. Table 5.7 presents the amount of deicers observed during the February 7, 2004 event and shows that salt is the primary deicing agent observed (91%), premix follows at a much lower level (7%) and CMA is the least used (2%).

Table 5.7 Deicing Agents Observed on 2/7/04 versus Entire Season

	2/7/2004		Season	
	Total (lbs)	% of Total	Total (tons)	% of Total
CMA	1576.51	18.3%	85	2.0%
Premix	799.98	9.3%	280	6.7%
Salt	6251.81	72.5%	3820	91.3%

For the 2005 season it is known that Mass Highway did not apply premix to the roadway. When premix was removed from the stochiometric calculations, the chloride error improved by one percent. In the absence of premix all the calcium is provided from CMA. The CMA amount can be calculated using calcium as well as magnesium results; these two values should lead to similar results. However, the calculations show different results: more CMA is predicted based on calcium, measured acetate and magnesium concentrations predict similar amounts of CMA. Calcium is associated with both premix and CMA, part of the measured calcium concentrations come from the dissociation of premix in the water.

The dominant ionic species in the water samples throughout the year are sodium and chloride which can vary by as much as two orders of magnitude from its time of application in the winter months (48.5 g-Cl/L) to the minimum value observed before the beginning of the salt season in November (0.57 g-Cl/L). Other ions which make a significant contribution to the charge balance (SO_4^{2-}, Ca^{2+}, Mg^{2+}, etc.) are also present throughout the year and vary by a factor of 3 within the same order of magnitude, at less than 100 mg/L. The exception to this is acetate which is present in high concentrations during the winter (6.7 g-Acetate/L) and is less than 1 mg/L shortly following the salt season.

The measured concentrations of anions and cations were used to calculate a sample specific conductivity using standard procedures (Standard Method,s 1995). The calculated conductivities were then compared to the field measured values. The measured conductivity of the sample from February 7, 2004 from the field sonde was 13168 μS/cm while the calculated conductivity was 8979 μS/cm. As the specific conductivity increases the reliability of field instruments decreases, as the sonde uses only one point for calibration.

Figure 5.2 presents measured specific conductivity (mS/cm) and measured major ion concentrations (mg/L) on the right hand side versus time for the 2/7/04 event. The figure shows excellent agreement between the rise in ion concentration with an increase in specific conductivity. Figure 5.3 and Figure 5.4 present predicted acetate and bicarbonate concentrations respective to measured concentrations of two ions for 2/7/04.

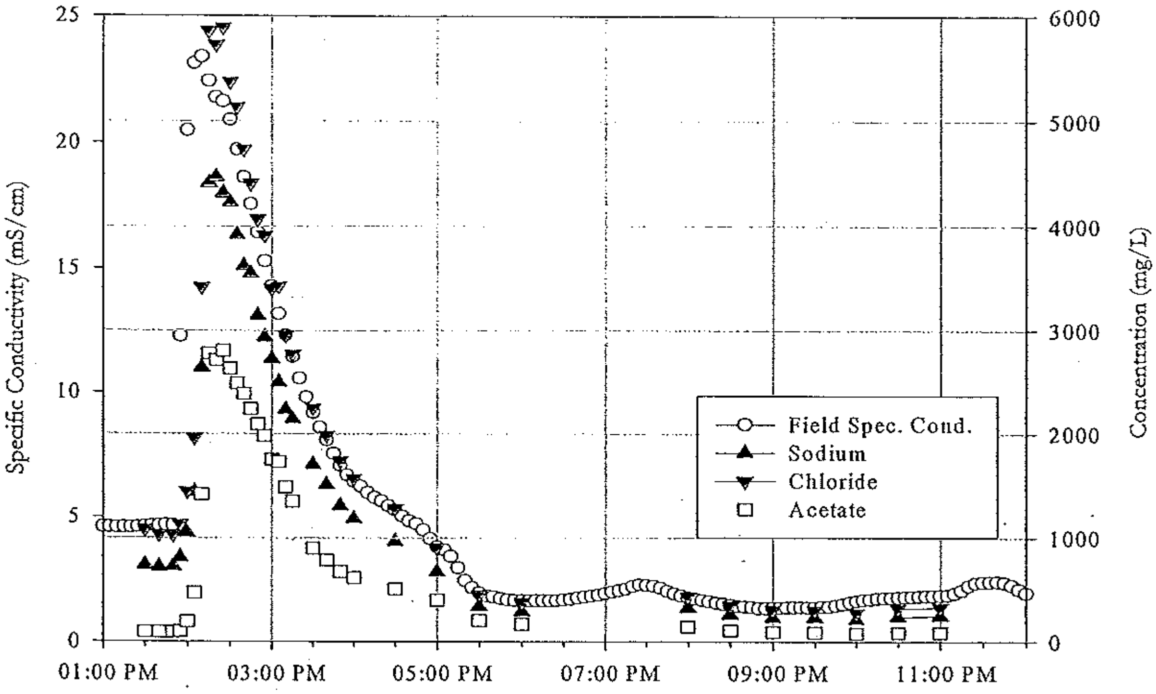

Figure 5.2 – Specific Conductivity versus Time (2/7/2004)

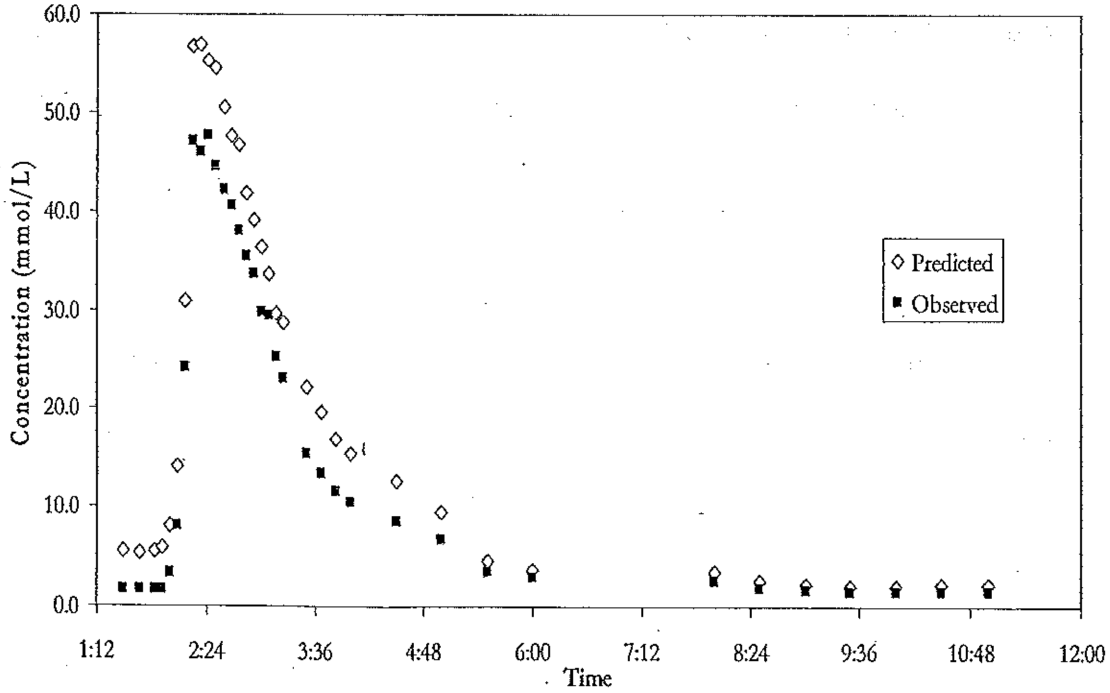

Figure 5.3 –Acetate Profile: Predicted versus Measured (2/7/2004)

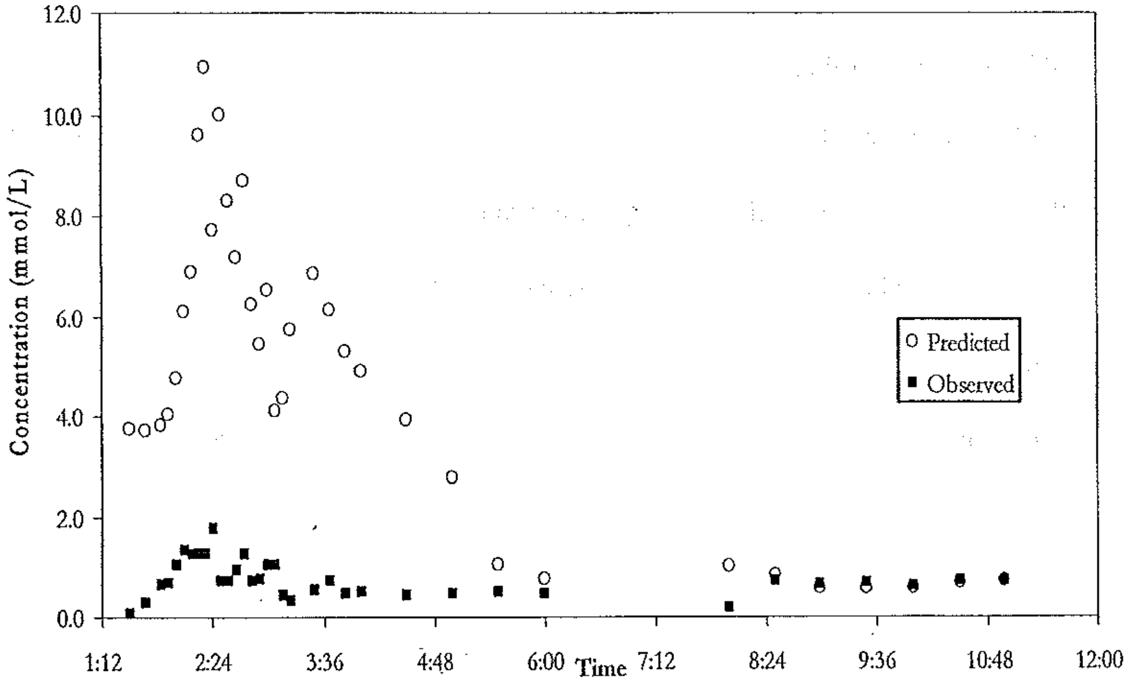

Figure 5.4 – Bicarbonate from Acetate: Predicted versus Measured (2/7/2004)

Figure 5.3 shows that the predicted concentrations of acetate match well with the observed concentrations, showing that the acetate associated with CMA is quick to dissolve in the runoff. This shows that the degradation of acetate is minimal due to the short time between application of deicing agent and sampling with minimal time for microbial populations to degrade the acetate. The difference between the observed and predicted acetate concentrations should match the bicarbonate results. As seen in Figure 5.4, the measured bicarbonate concentrations do not match well with the observed concentrations, the observed values consistently less than 2 mmol/L while the predicted concentrations reach a maximum of 10.9 mmol/L. Towards the end of the runoff sampling the predicted bicarbonate concentrations from CMA match the values observed. Data for a typical event is shown in Appendix E.

Bicarbonate generated from the biodegradation of acetate may be slow to dissolve into the water or may degas before being collected in the sample. Bicarbonates can release carbon dioxide when exposed to an acid such as acetic acid. However, this is unlikely because specific conditions (temperature and pressure) are needed to influence the water chemistry. The amount of bicarbonate can be attributed to the influence of pH. The pH of rainfall collected during the week of 2/3/04 and 2/10/04 by the National Atmospheric Deposition Program (NADP) located in Lexington, MA was 4.75 with a specific conductivity of 12.5 μS/cm. This value was adopted as a typical pH for the precipitation over the site because of the close proximity if the NADP site. The precipitation pH is below the runoff pH of 7.9 (during the year pH in the runoff ranges between 6.5 and 8).

5.3 Hydrograph Modeling

Hydrographs for thirty-two rain events from 2004 were modeled based on data collected from the Plymouth site with M equal to one. With this large database a sound model can be developed for all types of storms. Because the data is collected from across an entire year with storm events independently calibrated, comparisons of the runoff decay constant can be made between the results.

Modeled storm events were differentiated by allowing sufficient time between events for the development of a distinct hydrograph for each storm. A sufficient magnitude of precipitation was required when determing which storm events to model representative storm events that had negligible losses of precipitation to interception and evaporation. Storms with total runoff volumes less than 10,000 gallons (37.85 m^3) were eliminated from modeling. Events during the winter that showed a delay in runoff due to snowmelt or melting frozen precipitation impacted the modeled hydrograph negatively and were not able to be accurately modeled. Examples of two modeled events from 2004 are shown in Figure 5.6 and Figure 5.7 with a typical storm input/output for the model presented in Appendix C.

When the model was first calibrated, values for the number of linear reservoirs and the decay constant were optimized using a two parameter golden section Fibonacci search. The optimum number of linear reservoirs found for four different events in 2004 varied between 1 and 1.5. Because the values for M did not vary and were near the value of one, subsequent modeling of storm events was performed using one linear reservoir and optimizing the Ω values for each event. The simplicity of the model allowed the number of linear reservoirs chosen to be one.

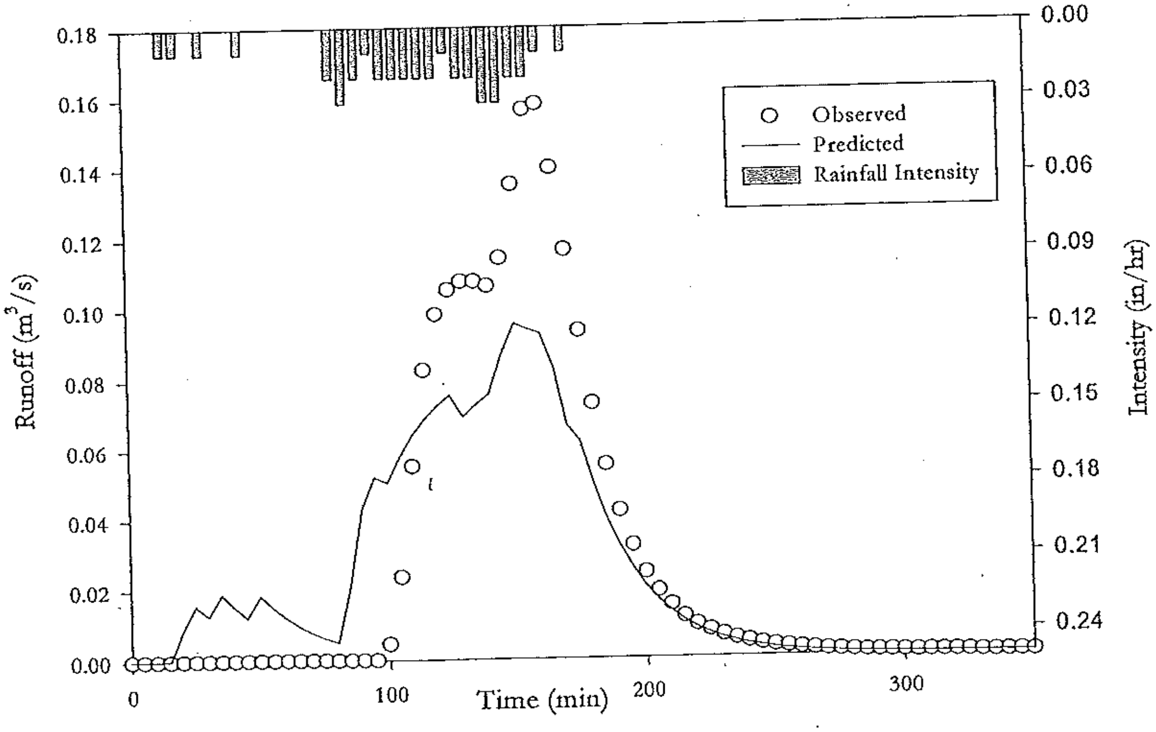

Figure 5.5 – Observed (7/28/2004) vs. Modeled Hydrograph Without Depression Storage layer

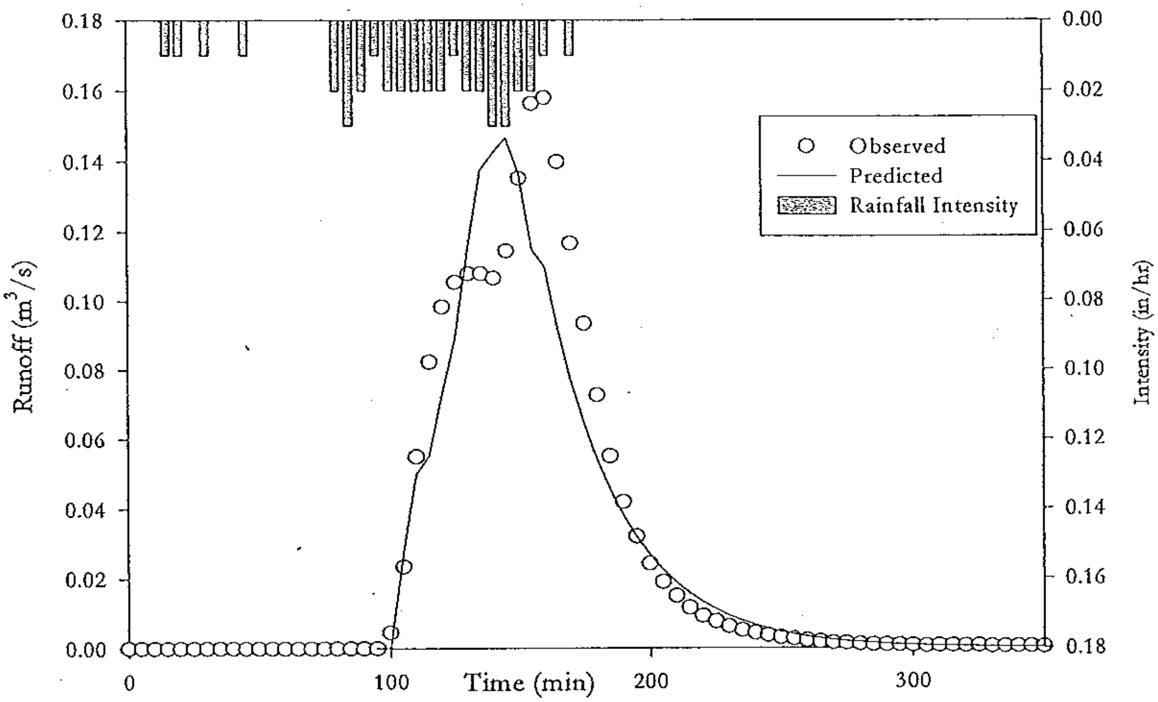

Figure 5.6 –Observed (7/28/2004) versus Modeled Hydrograph With Depression Storage Layer

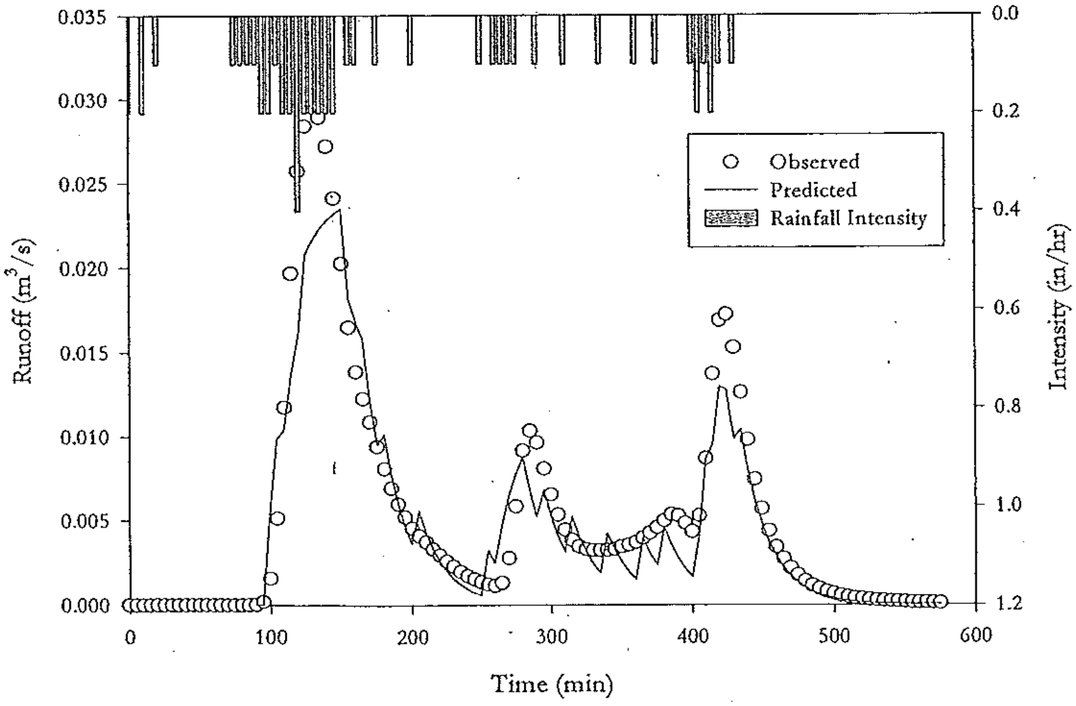

Figure 5.7 –Observed (11/28/2004) versus Modeled Hydrograph with Depression Storage Layer

Precipitation that fell prior to the first observed runoff was stored in depression storage. If modeled runoff was not allowed to accumulate in a depression storage layer then the model hydrograph would resemble Figure 5.5 where precipitation immediately generates runoff. With the introduction of the depression storage term, as shown in Figure 5.6, the predicted runoff rates approach the observed runoff rates. The depression storage layer was calculated as the sum of the precipitation observed prior to the first observed runoff. Results for parameter values for the 32 storms modeled for 2004 are summarized in Table 5.8 and presented in Table 5.9.

Table 5.8 Summary of Hydrograph Results (2004 Storms)

Depression Storage: ζ (mm)			Decay Constant : Ω (s^{-1})		
Low	High	Avg	Low	High	Avg
1.02	6.86	2.67	3.20E-04	1.61E-03	7.79E-04

A_{Eff} (% of Total Area)			Error: δ (%)		
Low	High	Avg	Low	High	Avg
39%	105%	64%	28.3%	901%	151%

M = Number of linear reservoirs

M	1

The model without the depression storage term over predicts runoff in early stages of the storm events, Figure 5.5. With the introduction of the depression storage term, the model more accurately predicts runoff response to a storm but still under predicts the flow at peak runoff times, Figure 5.6. The model does not accurately simulate storms with sharp peaks; flow peaks were predicted at the correct times but under-predicted the observed flows by almost 50%. Storms with rounded peaks were better matched by the model. In a study of the suitability of the gamma function for the Nash IUH, Haktanir and Sezen (1990) found that gamma function hydrograph models do not simulate hydrographs with sharp, wedge-like peaks very well. This offers an explanation of why the model does not accurately match the observed values.

Table 5.9 Hydrograph Results (2004 Storms)

Date of Storm:	Ω (s^{-1})	Dep Storage: ζ(mm)	A_{Eff} (m^2)	T_S (min.)	δ (%)
1/18/2004	9.05E-04	2.0	15120	2455	211%
3/31/2004	6.45E-04	2.0	14923	2620	74.2%
4/4/2004	3.94E-04	1.8	11260	275	29.9%
4/13/2004	6.20E-04	2.8	14503	3660	901%
4/14/2004	4.75E-04	1.3	16352	960	49.7%
4/24/2004	6.79E-04	1.8	16101	420	50.2%
4/26/2004	5.90E-04	2.5	12927	370	28.3%
4/27/2004	3.77E-04	1.0	13160	650	137%
4/28/2004	5.52E-04	1.8	12146	280	36.7%
5/27/2004	1.61E-03	3.6	23483	1005	92.7%
5/28/2004	8.78E-04	2.3	14116	405	50.9%
6/1/2004	6.25E-04	2.5	14241	745	67.8%
6/14/2004	1.09E-03	4.6	20977	520	46.0%
7/2/2004	1.44E-03	6.9	24345	575	88.6%
7/5/2004	6.30E-04	2.0	11283	470	250%
7/13/2004	3.77E-04	1.8	11720	2130	121%
7/28/2004	9.06E-04	3.0	16885	485	37.7%
7/29/2004	8.30E-04	2.3	16869	230	62.4%
8/5/2004	6.06E-04	3.3	11038	590	131%
8/13/2004	1.05E-03	4.3	19642	330	54.0%
8/13/2004	1.27E-03	3.3	19925	185	217%
8/21/2004	9.81E-04	1.3	12381	335	42.9%
8/31/2004	6.24E-04	4.6	12861	745	779%
9/16/2004	9.35E-04	3.6	13402	345	441%
9/18/2004	7.39E-04	3.3	14885	2145	120%
9/28/2004	7.38E-04	2.5	14875	1595	130%
10/16/2004	1.05E-03	4.8	15973	785	74.9%
10/19/2004	3.20E-04	1.3	9102	610	40.1%
11/28/2004	8.58E-04	2.3	16499	485	43.3%
12/1/2004	7.42E-04	2.3	13570	395	42.2%
12/7/2004	7.56E-04	1.0	11593	1575	297%
12/10/2004	6.21E-04	1.8	11419	1720	81.0%

A golden section Fibonacci search with 50 iterations was used to find the runoff decay constant (Ω) values for each storm while minimizing the error(δ) between the observed and predicted flow rates. The upper and lower limits used in the Fibonacci search for Ω did not force a result as the program arrived at the optimum value without reaching the limits. The error was defined as the absolute error between the measured and predicted flows (Equation 5.1), as averaged over the effective number of data points calibrated. The number of effective data points (N_E) was calculated as the number of points after the depression storage layer was satisfied until the end of the event.

$$\delta = \frac{1}{N_E}\left(\frac{|Q_{PRED} - Q_{OBS}|}{Q_{OBS}}\right) * 100\% \qquad \textbf{5.1}$$

The largest value for the depression storage layer (6.86 mm) was observed in July 2004; this could be due to greater losses from evaporation before the start of runoff. The smallest value for the depression storage layer occurred during the winter months (December through April 2004) with the depression storage layer being filled with frozen precipitation. The minimum value for the depression storage layer was found to be 1.02 mm and an Ω of $3.20\text{x}10^{-4}$ s^{-1}. The true characteristic value found for the depression storage layer depth for storm events from 2004 was 2.7 mm with an Ω of $6.90\text{x}10^{-4}$ s^{-1}; inverting the storage coefficient gives the characteristic response time for the site of 1278 seconds (24.2 minutes) for pavement runoff, which is a function of watershed characteristics such as slope and roughness of the drainage system. These results of Ω and ζ are similar to those found by Ostendorf et al. (under review) Washington.edu (2005) and .Niemczynowicz (1999).

Storms with successive peaks in runoff were also not accurately simulated by the model. The model was able to generate successive peaks within the same event at the appropriate time. However, if a significant period of time had elapsed, i.e. greater than an hour between the decrease in flow and the next peak. The predicted flow suggests that losses of precipitation can occur within the event. The precipitation gauge at the study site measures an accumulation of rainfall so even if precipitation is slowly falling it is accumulating until there is enough to measure. Precipitation can be lost to interception during an event and may not be measured as runoff while it is still being measured as precipitation. The tail end of the predicted hydrograph quickly drops to zero faster than the actual hydrograph. This may be due to the fact that interflow and baseflow are not taken into account by this model.

5.4 Loadograph Modeling

Using values for the hydrograph decay constant based on storms from 2004 analyzed using the hydrograph model, a loadograph {plot of (load concentration*flow rate) or (mass/time) versus time} for chloride was developed for 25 events. The same rules governing the hydrographs also governed the loadographs as well. The model was first developed based on inputs from the optimized hydrograph model. Reviewing the results of the optimum chloride flux values for the events showed a large disparity between the measured and predicted flux values. To improve the results of the chloride flux model a two parameter golden Fibonacci search was used to find values for the source term (ωS_N) and decay constant (Ω) for each event. Flux values for chloride were found by multiplying the specific conductivity by a calibration coefficient C_K (kg-cm/m^3-μS) which varied by month based on the ratio of measured chloride concentrations to the specific conductivity. The C_K factors are shown in Table 5.10 and show a decreasing trend with time. The runoff decay constant for the loadograph (9.51 x 10^{-4} s^{-1}) was near the optimum value found for the hydrograph model (7.79 x 10^{-4} s^{-1}) allowing the use of a two parameter search.

The decreasing C_K values with time show that chloride ions associated with salt and premix from deicing agent applications dissolve faster into the runoff than CMA does. Chloride is linearly related to the specific conductivity values because of the equivalent conductance associated with the ion. When more salt ions are present in the water, in January (0.279 kg-cm/m^3-μS) the chloride has a higher C_K value, as time progresses and salt dissolves into the runoff it becomes less present, in early December (0.169 kg-cm/m^3-μS) shown by the decreasing trend of the C_K values. Figure 5.8 shows observed chloride flux and the predicted chloride flux from a storm in July of 2004.

Table 5.10 C_K Values (2004 Storms)

Month	C_K (kg-cm/m^3-μS)
January	0.279
February	0.229
March	0.290
April	0.254
May	0.273
June	0.255
July	0.241
August	0.206
September	0.193
October	0.218
November	0.230
Early December	0.169

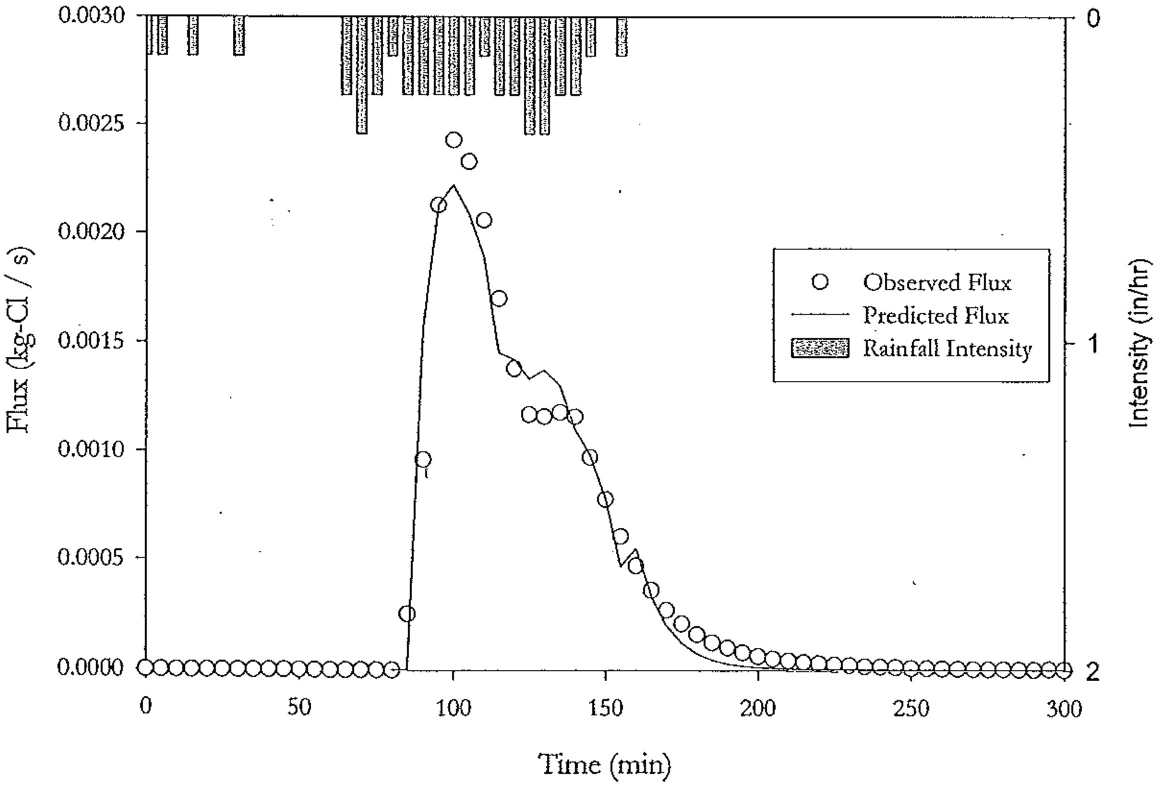

Figure 5.8 –Loadograph Observed vs. Modeled (7/28/2004)

The predicted flux matches well with the observed flux for the event on July 28/2004 with capture of successive peaks. A summary of results of the flux model are presented in Table 5.12, while a summary of the flux model is shown in Table 5.11 and a comparison of the Ω values for the hydrograph and loadograph. The average Ω values for the two models are only 22% different with the error defined as: {(Loadograph-Hydrograph)/Hydrograph * 100%}. Equation 5.2 shows how the error was calculated to find an optimum source term for each event.

$$\delta = \frac{1}{N_E}\left(\frac{|Flux_{PRED} - Flux_{OBS}|}{Flux_{OBS}}\right) * 100\% \qquad 5.2$$

Table 5.11 Loadograph Results Summary (2004 Storms)

	Average	High	Low
Decay Constant : Ω (s^{-1}) -Loadograph	9.51E-04	3.59E-03	1.46E-04
Decay Constant : Ω (s^{-1}) - Hydrograph	7.79E-04	1.61E-03	3.20E-04
Error: δ (%)	82.7%	6074%	38.0%
Source Strength: ωS_N (kg/m^2-s)	1.26E-07	7.42E-07	2.17E-09

Table 5.12 Loadograph Results (2004 Storms)

Date:	Source Term ωS_N (kg/m^2-s)	Runoff Decay Constant Ω (s^{-1})	Error δ (%)
4/4/2004	1.08E-07	5.41E-04	94.4%
4/13/2004	8.12E-08	5.97E-04	67.4%
4/13/2004	2.93E-07	3.59E-03	98.8%
4/13/2004	5.70E-08	4.65E-04	55.5%
4/24/2004	1.31E-07	1.14E-03	90.4%
4/26/2004	1.13E-07	6.84E-04	38.0%
4/27/2004	1.84E-07	5.86E-04	86.6%
4/28/2004	1.34E-07	6.35E-04	45.5%
6/14/2004	1.00E-08	1.04E-03	42.5%
7/2/2004	7.39E-09	2.81E-03	94.0%
7/5/2004	1.42E-07	6.01E-04	71.7%
7/5/2004	1.72E-07	1.01E-03	48.2%
7/28/2004	3.80E-08	1.70E-03	64.5%
7/29/2004	7.27E-08	9.79E-04	78.4%
8/5/2004	3.00E-08	9.93E-04	85.6%
8/5/2004	1.00E-08	2.91E-04	142%
8/13/2004	1.77E-08	1.40E-03	84.1%
8/21/2004	1.28E-08	7.60E-04	66.2%
8/31/2004	3.98E-08	1.24E-03	65.3%
8/31/2004	1.70E-08	7.14E-04	93.1%
9/16/2004	2.51E-08	1.38E-03	77.1%
10/19/2004	1.20E-08	2.53E-04	135%
11/28/2004	9.72E-09	6.74E-04	60.4%
12/1/2004	1.55E-08	9.34E-04	76.9%
12/10/2004	2.17E-09	3.55E-04	68.9%
1/14/2005	1.27E-07	2.07E-03	6074%
2/3/2005	3.35E-07	1.46E-04	70.2%
2/10/2005	1.24E-07	4.41E-04	284%
2/14/2005	3.89E-07	5.58E-04	78.7%
3/8/2005	7.42E-07	4.64E-04	116%
3/28/2005	4.17E-07	6.71E-04	43.1%
4/2/2005	1.76E-07	7.62E-04	50.1%
4/8/2005	1.77E-07	1.26E-03	64.5%
4/24/2005	7.16E-08	5.70E-04	93.7%

As expected, the source strength of the chloride decreases over time from the time of application. The results of Table 5.12 are better seen graphically and are presented in Figure 5.9. Storm events on the same day are averaged and used as one value in Figure

5.9. Figure 5.10 presents the applied deicing agents for the 2003-2004 salt season and the 2004-2005 salt season. Source strengths increase with the application of deicing agent.

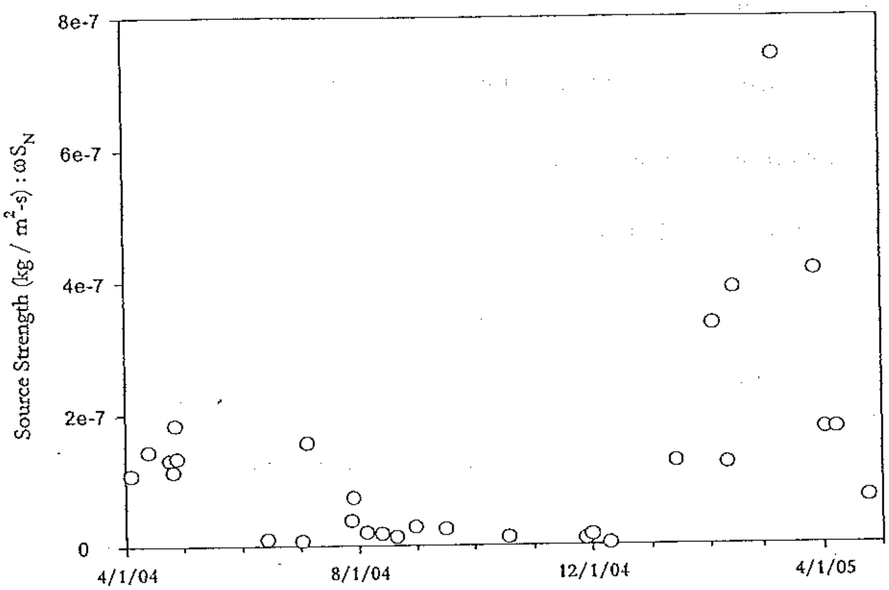

Figure 5.9 –Residual Source Strength 2004

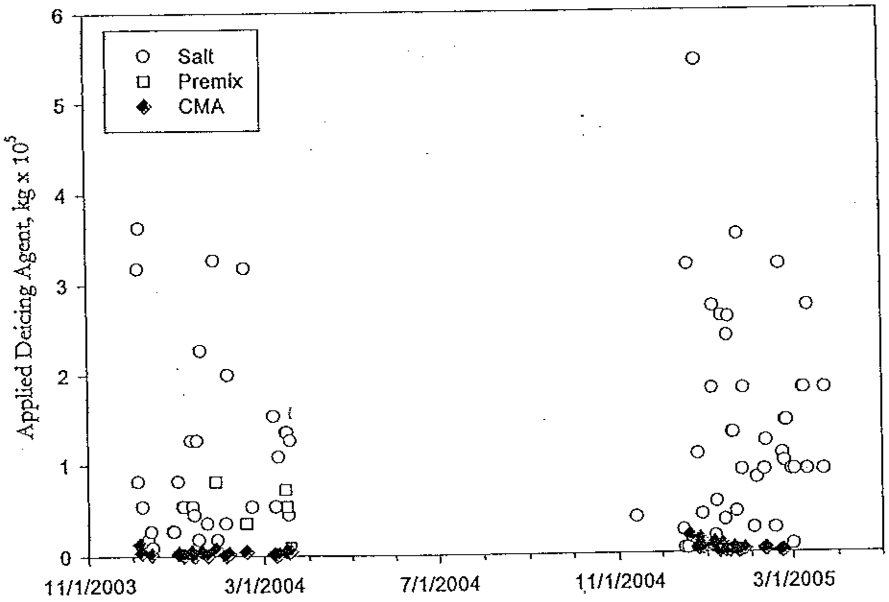

Figure 5.10 –Applied Deicing Agent 2003 to 2005

5.5 Sampler Results

Runoff samples collected by the automated sampler are graphically presented in this section. During each event, flow, conductivity and precipitation intensity are presented followed by the concentration of ions analyzed. Graphs are normalized for both time and concentration so that comparisons can be made between different events that have varying lengths of total storm time. Time is normalized by dividing the observation time by the duration of the event. Concentration is normalized by dividing by the maximum observed concentration. Specific conductivities for the total event are shown as symbols along with the rainfall intensity. The portion of the storm event sampled by the automated sampler is shown shaded on the graphs (a). The specific conductivity is also presented as a shaded regions in the graphs (b) adjacent to the graph showing the flow.

Presented are storms from four months across 2004 and 2005 showing the change of ion concentration in storm runoff as a function of time. Salt, premix and CMA residuals are flushed from the depression storage layer which acts as a sink holding deicing agent residual until it is flushed out. The amount of residual flushed out of storage is a function of the precipitation amount and its intensity.

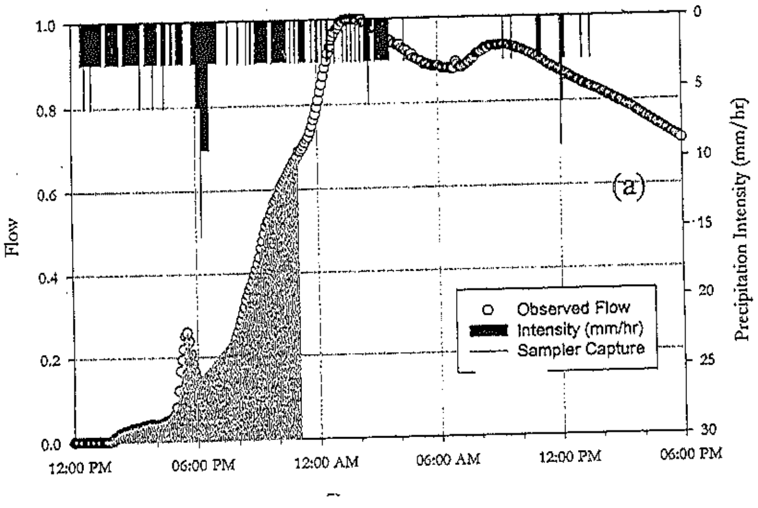

Figure 5.11 –Flow and Sampler Capture (2/7/2004)

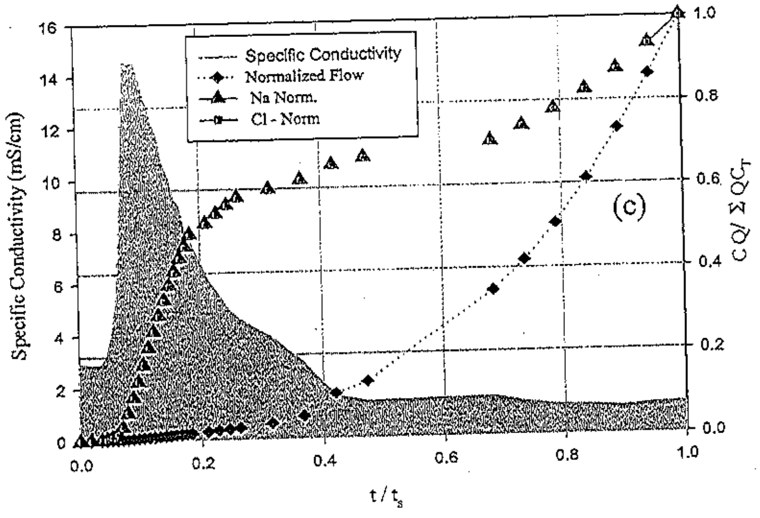

Figure 5.12 –Major Ions: Profile (2/7/2004)

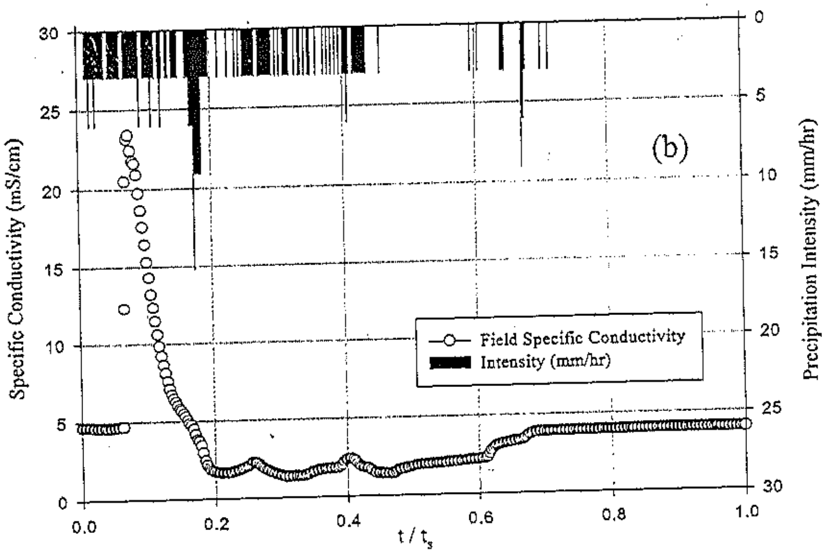

Figure 5.13 –Specific Conductivity Profile (2/7/2004)

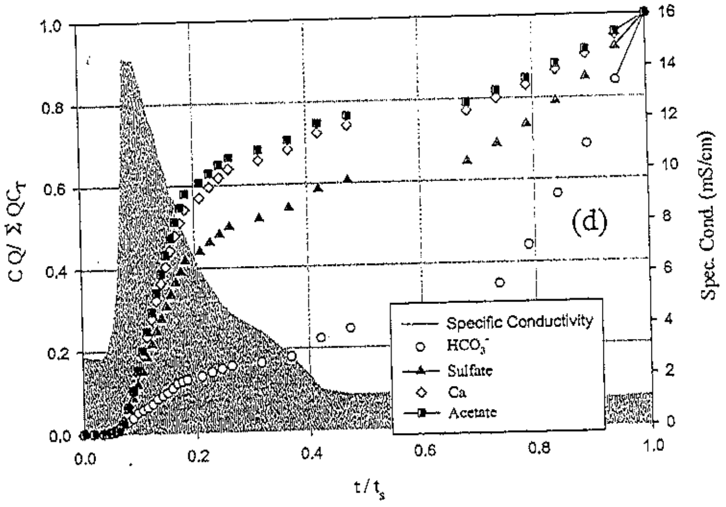

Figure 5.14 –Minor Ions: Profile (2/7/2004)

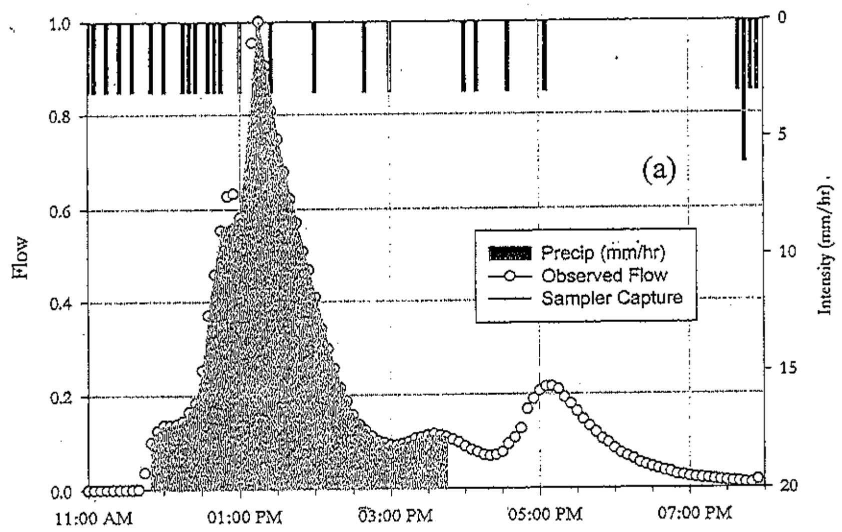

Figure 5.15 – Flow and Sampler Capture (7/19/2004)

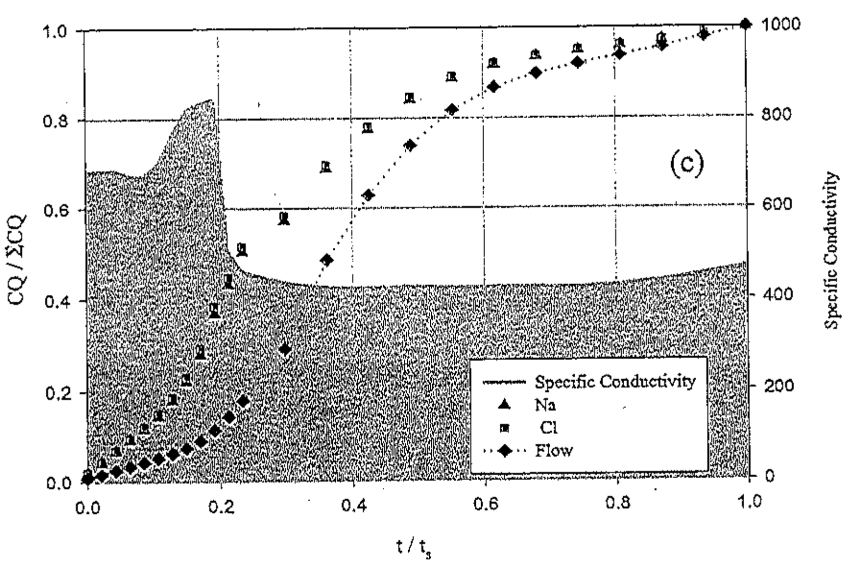

Figure 5.16 –Major Ions: Profile (7/19/2004)

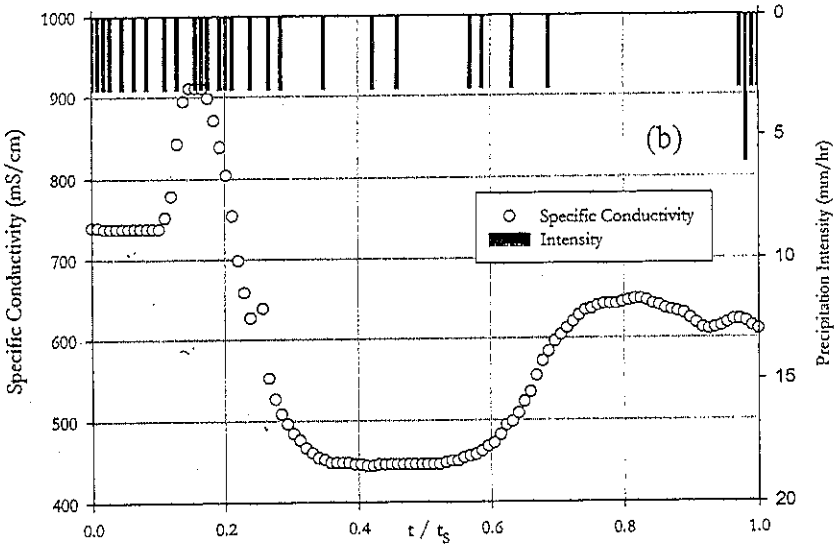

Figure 5.17 –Specific Conductivity Profile (7/19/2004)

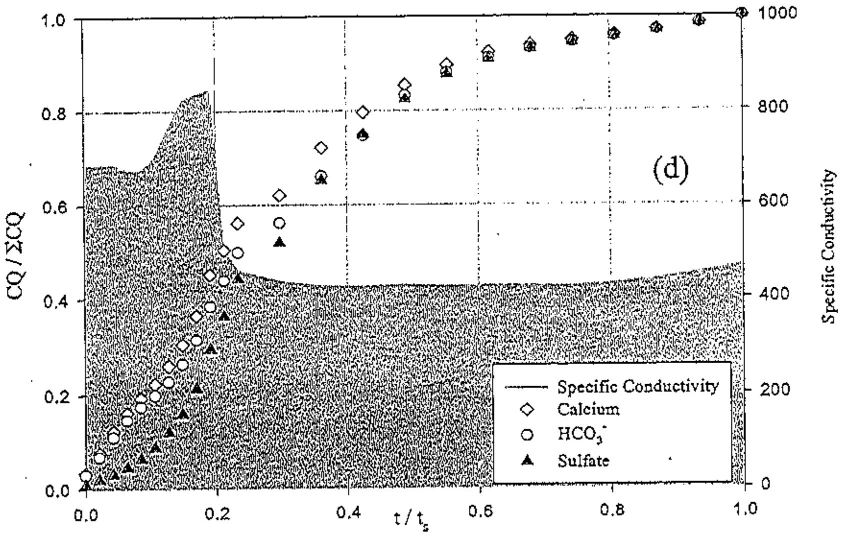

Figure 5.18 –Minor Ions: Profile (7/19/2004)

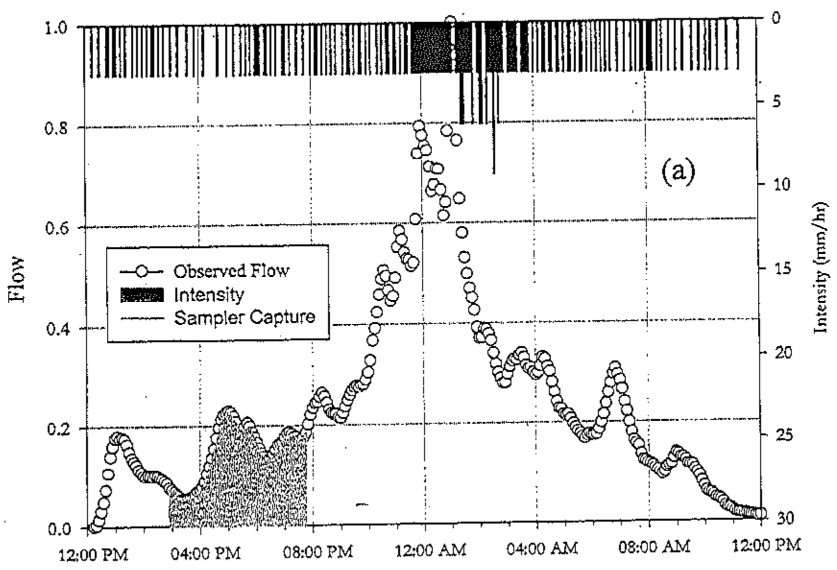

Figure 5.19 – Flow and Sampler Capture (11/12/2004)

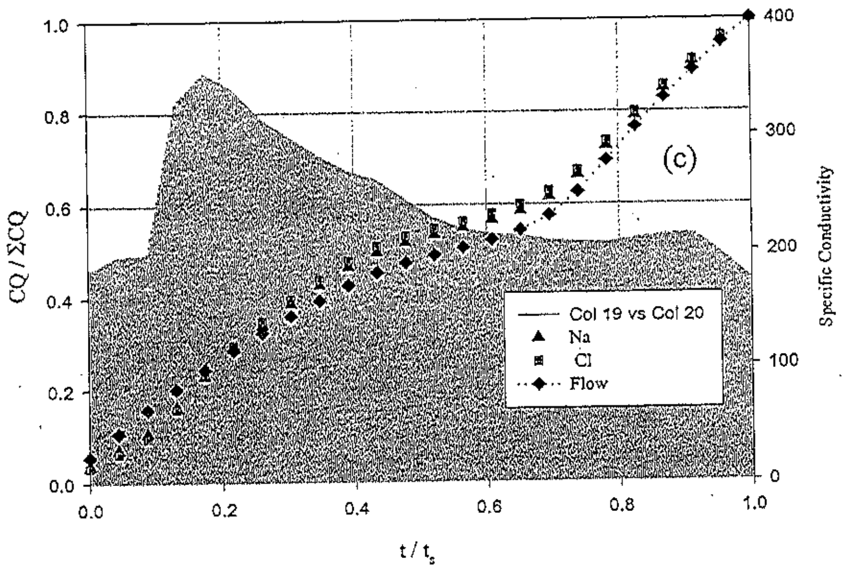

Figure 5.20 –Major Ions: Profile (11/12/2004)

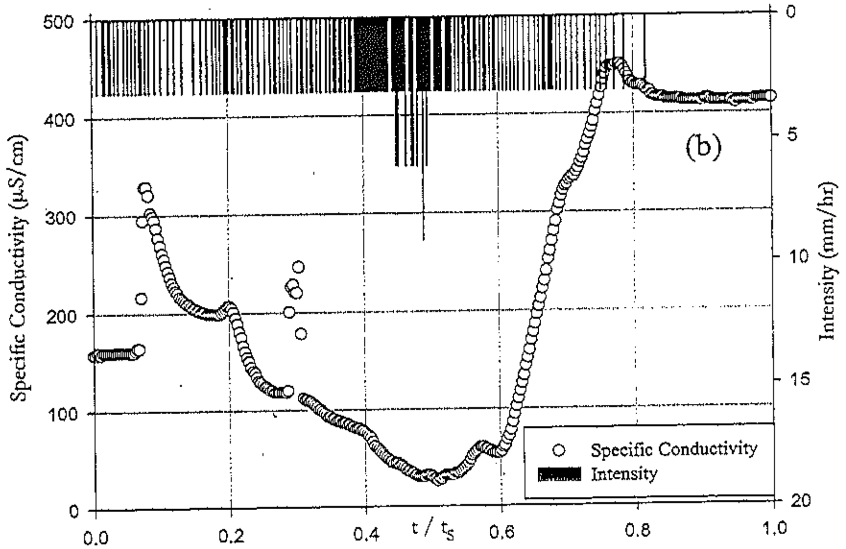

Figure 5.21 –Specific Conductivity Profile (11/12/2004)

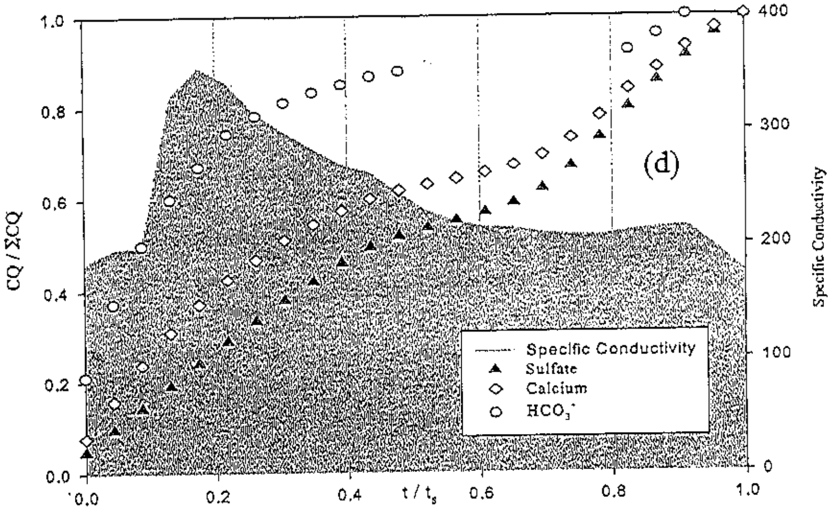

Figure 5.22 –Minor Ions : Profile(11/12/2004)

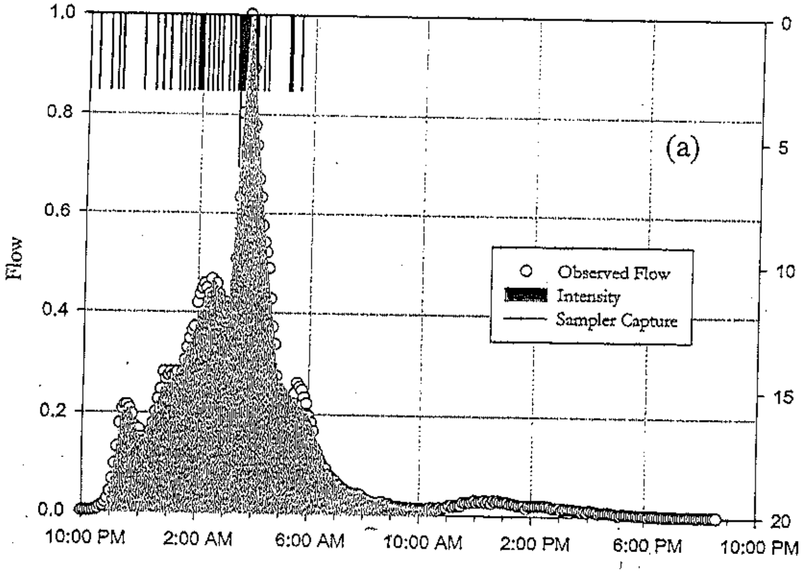

Figure 5.23 – Flow and Sampler Capture (2/14/2005)

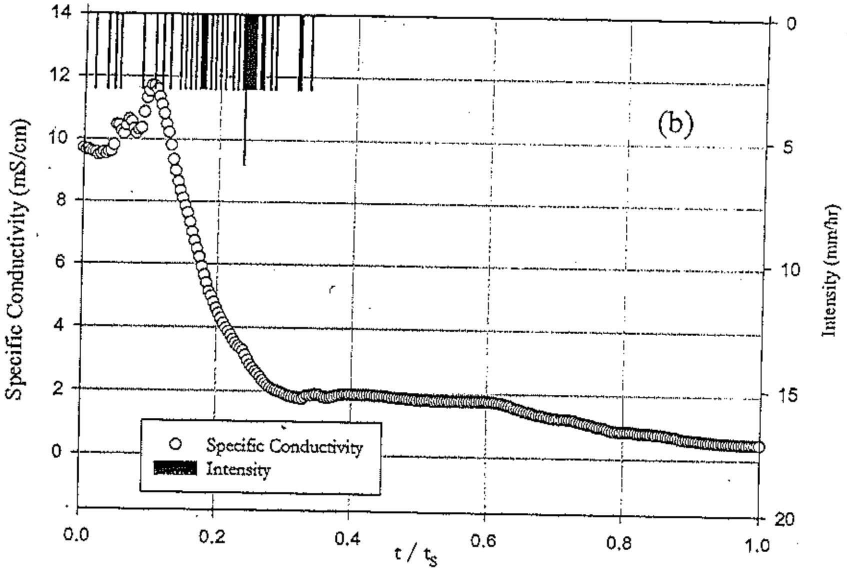

Figure 5.25 –Specific Conductivity Profile (2/14/2005)

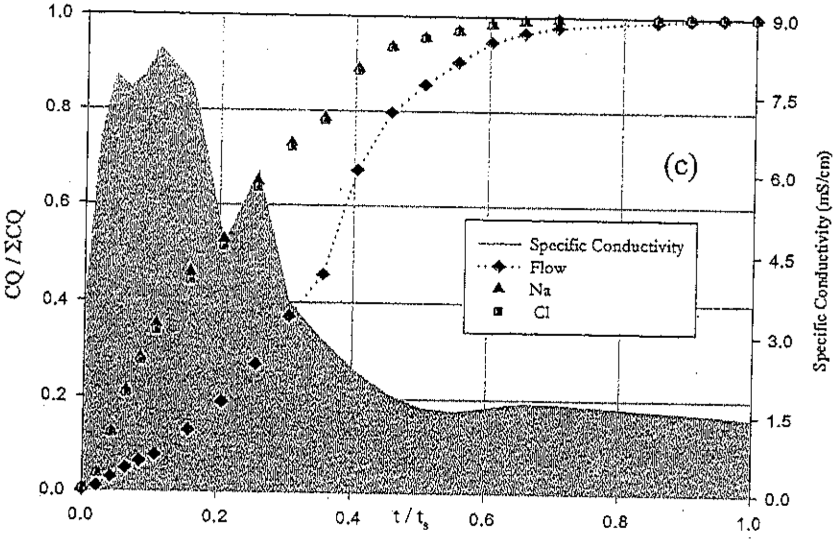

Figure 5.24 –Major Ions: Profile (2/14/2005)

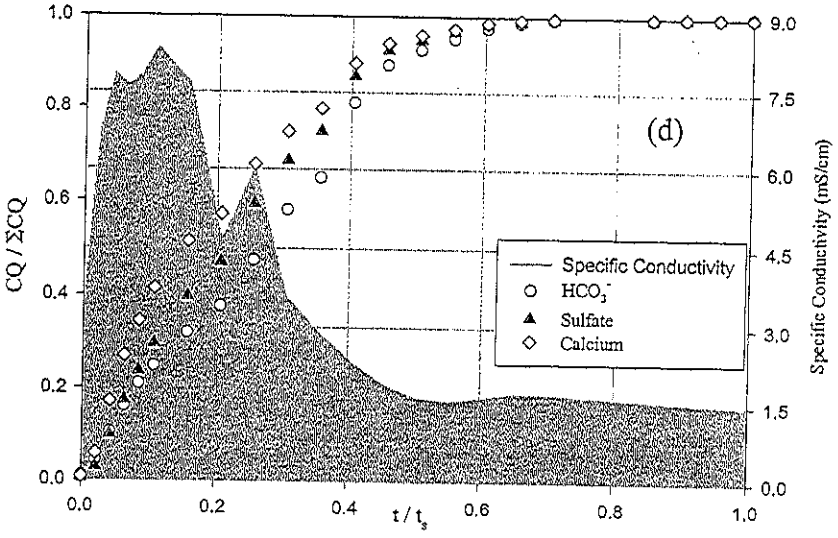

Figure 5.26 –Minor Ions: Profile (2/14/2005)

Figure 5.11 through Figure 5.26 show that during the winter months, peak specific conductivity occurs within the first 10% of the storm duration and at 20% of the storm duration for the rest of the events (Figure b for each event). The peak conductivity corresponds to the maximum flux of ions entering the catchment basin. In the winter months more deicing agents enter the study site with the first flush when compared to the rate of loading during the summer months. As time passes the loading of deicing agents decrease until it reaches a linear response in November and again becoming curvilinear with deicing agent application. Sodium and chloride values are the dominant species in the collected samples. The lesser constituents (bicarbonate, sulfate and calcium) follow the same trend of sodium and chloride with lower total concentrations. For the events presented, most of the event was sampled by the automated sampler as shown in Figure a of each event.

The time of maximum flow often does not correspond to the time of maximum conductivity. As shown in Figures (a) and (b) of each event, flow is in response to an input of precipitation, while specific conductivity decreases as the residual deicing chemicals in the depression storage layer get washed out. For the storm on November 12, 2004 (Figure 5.21) the specific conductivity rises as the storm progresses. This corresponds to an increase in precipitation intensity flushing out more residual from the depression storage layer. With constant precipitation intensity, the peak specific conductivities are observed in the beginning of the storm event and reach a steady state as the flow tapers off. Table 5.13 presents a summary of the events presented in Figure 5.11 through Figure 5.26, showing the duration of the event, maximum flow, total precipitation, maximum precipitation intensity and the maximum observed specific conductivity. Table 5.14 presents the maximum observed concentrations of deicing agents in mmol/L based on the samples collected by the automated sampler for CMA, NaCl and premix during each event.

Table 5.13 Summary of Analyzed Events

Date:	t_S (hrs)	Q Max. (gpm)	Total Precip. (in , mm)	Max. Intensity {(in/hr),(mm/hr)}	Spec. Cond. Max (µS/cm)
2/7/2004	30	6767	1.39 / 35.3	0.6 / 15.24	23380
7/19/2004	9.1	70	0.30 / 7.62	0.24 / 6.09	910
11/12/2004	30	400	1.60 / 40.6	0.4 / 9.14	450
2/14/2005	23	212	0.36 / 9.14	0.24 / 6.09	11710

Table 5.14 Maximum Observed Concentrations from Analyzed Events

Date:	CMA (mmol)	Salt (mmol)	Premix (mmol)
2/7/2004	20.3	176	21.8
7/19/2004	0.34	5.89	3.05
11/12/2004	0.14	1.29	2.18
2/14/2005	14.2	105	2.22

Figure 5.27 shows the changes of the maximum observed concentrations of salt, CMA and premix in mmol/L as a function of time across the seasons. Data are presented for the storms which were auto-sampled and range from February 7th of 2004 to the 14th of February 2005. The highest concentrations of deicing agents are in the winter, slowly decreasing over the course of a year. CMA concentrations rapidly decrease while salt and premix values steadily decrease with time as remaining concentrations are flushed out of the depression storage layer.

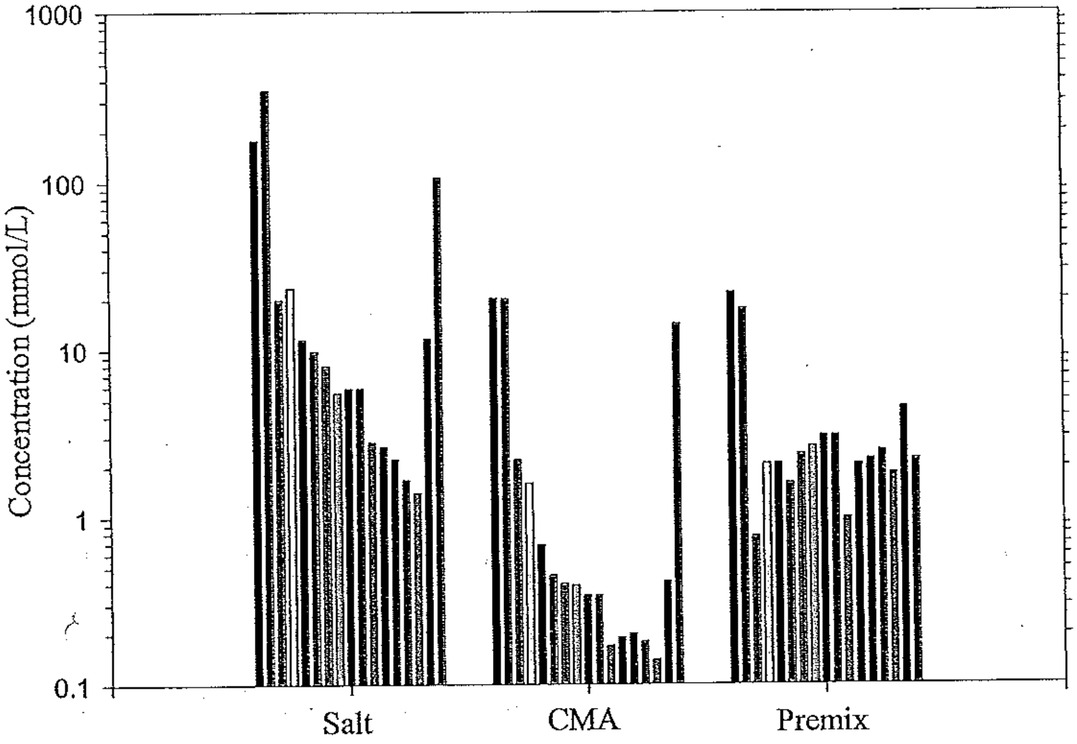

Figure 5.27 –Progression of Maximum Observed Deicing Agent Concentrations

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

The results of this research support some conclusions and suggest recommendations for future research.

6.1 Automated Sampling Strategy

The sampling rule for an automated 6712 sampler was determined for remote sampling of storm events. A total of 24 discrete samples can be used based on the limitations of the automated sampler. The optimum number of samples necessary to capture the first flush for a yearly sampling strategy is five samples with a time step between each sampling point of 15 minutes. The remaining 19 samples are taken every 65 minutes after completion of the Part A of the rule with a flux error of 37% between the flux for each storm event versus the flux for the event using the sampling strategy. During the winter samples need to be taken more frequently in order to capture the higher first flush with a first period of 11 samples spaced 20 minutes apart and a second period of the rule had 13 samples spaced 75 minutes apart with a flux error of 34% between the flux for each storm event versus the flux for the event using the sampling strategy. For summer sampling five bottles could be used to sample the first flush with ten minutes between samples. The remaining 19 bottles collected samples at one hour intervals and the error associated with the sampling rule was 38% between the flux for each event versus the flux for the sampling strategy.

During the winter a higher concentration of ions enters the catchment with the first flush as the applied deicing agents and residuals are carried off the paved surface. The sampling rule is designed to minimize the flux error (flux for the storm event versus flux found by sampling strategy), and the flux is consistently the highest in the initial stages of runoff events. Longer sampling intervals are needed for the second part of the rule as dissolution of the deicing agent slows and runoff tapers off. The concentration of ions leaving the depression storage is also dependent on the intensity of the rainfall, as at the onset of precipitation residuals are flushed out of the pores on the paved surface. For storm events with steady precipitation, the peak runoff specific conductivity is in the beginning of the runoff. If precipitation intensifies, then the specific conductivities may increase with the intensity of the precipitation.

6.2 Chemistry

It is seen that sodium and chloride dominate the soluble ionic species in the runoff for the water samples taken at discrete times by the automated sampler throughout 2004. To a lesser extent calcium, magnesium, bicarbonate and sulfate ions are present in the runoff but do not persist in the same fashion as Na^+ and Cl^- ions over the year. Ions associated with CMA rapidly disappear after the road salting season, with acetate values dropping from 8000 mg/L in February to less than 1 mg/L by May. The impact of collecting samples immediately after storm events cannot be understated, as acetate degrades quickly in the sample which affects the concentration being measured in the recovered runoff sample versus the concentration entering the groundwater in the basin.

The conservative anions and cations were able to be traced to their sources, and the maximum concentrations of deicing agent observed by sample collection during each event are presented in Figure 5.27. As expected, evidence of the applied deicing agents persists over the year, and shows a decreasing trend with time. Bicarbonate concentrations tend to remain within the same order of magnitude (~50 mg/L) with higher concentrations (170 mg/L) observed during the winter events. Bicarbonate is generated from the degradation of acetate, but as shown in Figure 5.4, the bicarbonate which is expected does not match well with the observed values for the beginning of the event. This could possibly be due to carbonate fractions forming with the metal species of the deicing agents.

6.3 Hydrographs and Loadographs

The Nash (1957) instantaneous unit hydrograph (IUH) model was validated for a small watershed. The calibrated parameter values indicate a quick response time with one linear reservoir and a storage coefficient of 7.79×10^{-4} s^{-1}. The depression storage layer depth was found to be 2.7 mm which is related to the roughness of pavement (pavement texture) and is similar to the 3 mm depth relative to the pavement texture found by Ostendorf et al. (2001) for a study site in Cohasset, MA. The model was run for data collected for 2004 storm events. Typically, the model predicted flow matches the observed flow. Storms with sharp peaks in the hydrographs are not accurately modeled as the predicted runoff peak was generally less than the observed runoff peaks. Predicted runoff had many sharp peaks of flow rates within each event due to a precipitation input to the model. The predicted flow responded rapidly to new inputs which is an explanation for the jagged peaks.

The results of the loadograph for the chloride flux model did not match the observed flux as well as the hydrograph modeled flow when optimizing for one value, the source strength. Storms with one peak in the flux were accurately predicted by the model. The chloride flux model consistently under-predicted flux during for events with more than one flux peak. The first peak in flux was typically missed while successive smaller peaks were better predicted by the loadograph model. Smaller peaks later in an event may have driven the source term to be low as more points were in the latter part of the model lowering the overall error but missing the peaks. The source term in the model was decreased with successive events during 2004, with a source strength of 2.93 x 10^{-7} kg/m^2-s in April and reaching a value of 2.7 x 10^{-9} kg/m^2-s on December 10, 2004. These values are comparable to the source strengths (range: 7.21 x 10^{-8} to 2 x 10^{-9} kg/m^2-s) for a site studied by Ostendorf et al. (2001) where salt is the only deicing agent applied. The comparable values for the source strength indicate that salt is the primary deicing agent being applied at the research site.

6.4 Results of Sampler Analysis

The maximum specific conductivity occurred in the first 10% of the event captured during the month of February for both 2004 and 2005and for the other two events graphed occurred at 20% of the event captured in July and November 2004. This indicates that a greater concentration of ions is observed more quickly in the winter, quickly dropping to a steady specific conductivity value after the frozen precipitation has reached a melting point. During the winter months it was shown that there is an initially high rate of loading with the first flush followed by a more gradual linear loading later in the event. A quick input of ions occurs during the first 20% of the event which then levels off for the remainder of the event. This trend is also observed in July, 2004 and is related with trends in the specific conductivity. The maximum specific conductivity is not related to the time of maximum flow.

6.5 Recommendations

The sampling strategy developed for the Plymouth site was developed based on four years of data collected from the site. As more data is collected, they should be added to the database and evaluated to compare the results of the optimal rule with more events. While the sampling rule might provide the best results with a more drawn out sampling of the latter portions of the event, it is possible for the tail end of the event to have little impact on the more significant mass loading in the initial stages of the event.

The analysis of the chemistry of the runoff water samples leaves many open questions which were not studied for this research. The concentration of conservative ions sodium, chloride, calcium and magnesium were evaluated and compare favorably with predicted levels based on deicing agent sources. Concentration of bicarbonate could be better studied to understand the bicarbonate chemistry and other possible sources to better simulate the observed values. The influence of temperature on the dissolution of CMA could also be studied to evaluate CMA's impact on water chemistry as a function of time, pH and temperature. Another method of evaluating the water chemistry would be to compare runoff collected from this site against a control site with no deicing agent application for the same event. Manual collection of samples from storm events during the spring, summer and fall should also be conducted to check the agreement of the manual sample chemistry with those collected by the automated sampler.

Further evaluation of storm events for other years would provide a more encompassing decay constant for the watershed. The source strengths should be determined for other ions (Ca^{+2}, Mg^{+2}, Na^{+}) which are measured and changes in the C_K values in the water samples can be evaluated for different seasons. A model should be developed based on the measurements of specific conductivity for other ions and compared with the water samples collected during the event. The loadograph model should further be tested with true flux values from measured ion concentrations in the collected water samples. With the continual addition of data for runoff chemistry it is possible to create a model that will successfully predict the concentration of ions in the runoff knowing the inputs (precipitation, deicing agent application) to the site's control volume.

CHAPTER 7

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APPENDIX A

VISUAL BASIC PROGRAMS

1) Seasonal Programming of Sampler
2) Seasonal Programming of Sampler (December to April)
3) Seasonal Programming of Sampler (May to November)
4) IUH Model
5) Chloride Flux Model : Loadograph

```
'Shem Stygar
'June 2004
'Yearly Sampling Strategy


Const nn = 65000       '# of data points
Const mS = 1000        'mS to micro Siemens conversion
Const TolRise = 0.1    'DLevel to start program(ft)
Const DeltaA = 15      'Time step for Part A (min)
Const DeltaB = 60      'Time step for Part B (min)
Const NoA = 5          '# Bottles in Part A
Const NoB = 24 - NoA   '# Bottles in Part B

Dim DeltaT        'Time
Dim Qm(nn)        'Measured flow (gpm)
Dim Cm(nn)        'Measured conductivity, West Weir (uS/cm)
Dim QP(100)       'Measured Flow - rule (gpm)
Dim CP(100)       'Measured Conductivity - rule(uS/cm)
Dim EndA          'End Time of part A (integer)
Dim FluxA         'Measured Storm Flux Part A
Dim FluxB         'Measured Storm Flux Part B
Dim Hacc(nn)      'Total Accumulated head in weir, (ft)
Dim Hrise(nn)     'Difference between successive level measurements
(ft)
Dim Hm(nn)        'Measured head (ft)
Dim CmMax         'Measured Max. Concentration (uS/cm)
Dim QMax          'Measured Max. Flow (gpm)
Dim CPMax         'Max. Conc. predicuted by rule (uS/cm)
Dim TCPMax        'Time of Max. Conc. using rule (integer)
Dim TCMax         'Max Obs Conc during storm (uS/cm)
Dim StormStart    'Start of Storm (integer not time)
Dim StormEnd      'End of the storm (integer)
Dim StormAvg      'Avg Cond for the storm (needs units); not rule
Dim Ihour         '# of data points in an hour dependent on DeltaT
Dim JumpA         'When DeltaA does not equal DeltaT, moves program to
read Cond & Flow from appropriate cells
Dim JumpB         'When DeltaB does not equal DeltaT, moves program to
read Cond & Flow from appropriate cells
Dim Cstart        'Conc @ Start time (uS/cm)
Dim TimeB         'Start of Part B of program
Dim EndB          'End of sampler program
Dim DurP          'Predicted Length of storm (by program)
Dim Volume        'Tot Vol going over the weir during the storm
(gallons)
Dim RuleVol       'Rule Vol for the storm (gallons)
Dim StormTV       'Storm Total Volume (not program)
Dim RuleAvg       'Avg Cond passing over the weir (uS/cm)/gallon for
the rule
Dim FluxSum       'Sum of Flux A and Flux B, (Cond * Flow)
Dim PDur          'Predicted storm duration
Dim TRuleVA       'Total Vol from Rule A, (gallons)
Dim TRuleVB       'Total Vol from Rule B, (gallons)
Dim FluxRule      'Flux of the Rule (uS/cm/gallon)
Dim FluxStorm     'Flux of the Storm (uS/cm/gallon)
Dim CondA
Dim CondB
Dim FlowA
Dim FlowB

Sub Main()
```

```
    For Each sh In ThisWorkbook.Worksheets
    sh.Activate
        Readdata
        StormDef
        StartA
        StartB
        Average
        Output
    Next sh
End Sub

Sub Readdata()
    DeltaT = Cells(3, 8)
    For iread = 1 To nn
        Cm(iread) = Cells(iread + 3, 5)
        Hm(iread) = Cells(iread + 3, 2)
        Qm(iread) = 1122 * (Hm(iread)) ^ 2.5
    Next iread
End Sub

Sub StormDef()    'Defines duration of the storm
    Ihour = 60 / DeltaT
    eps = 0
    Hrise(1) = 0
    Hacc(1) = Hm(1)
    For istart = 2 To nn
       Hrise(istart) = Hm(istart) - Hm(istart - 1)
       Hacc(istart) = Hacc(istart - 1) + Hrise(istart)
    Next istart
    jstart = 0   'Start Time Algorithm
    Volume = 0
    Do While eps < TolRise And jstart < nn    'Finds the predicted
beginning of the storm
       jstart = jstart + 1
       eps = Hacc(jstart + Ihour) - Hacc(jstart)
    Loop
    StormStart = jstart + Ihour
    Cstart = Cells(StormStart + 3, 5)
    StormEnd = StormStart              'Defines predicted End of the
storm
    Do While Qm(StormEnd) > 1 And StormEnd < nn
        StormEnd = StormEnd + 1
    Loop

    CmMax = 0
    TCMax = 0
    QMax = 0
    For lstart = StormStart To StormEnd     'Finds Max Concentration
during the storm (not rule)
        If CmMax < Cm(lstart) Then
           CmMax = Cm(lstart)
           TCMax = lstart
        Else
        End If
    Next lstart
    For mstart = StormStart To StormEnd     'Finds Max Flow during the
storm (not rule)
        If QMax < Qm(mstart) Then
        QMax = Qm(mstart)
        Else
        End If
```

```
    Next mstart
    PDur = StormEnd - StormStart 'Predicted Duration of the Storm

End Sub

Sub StartA()                    'sums Cond * Flow, Maximum, and time of
Maximum occurrence
    QP(0) = Qm(StormStart - 1)
    JumpA = DeltaA / DeltaT
    FlowA = 0
    CondA = 0
    FluxA = 0
    TRuleVA = 0
    CPMax = 0
    For PartA = 1 To NoA
        CP(PartA) = Cm(StormStart + JumpA * (PartA - 1))  'Note CP -
concentration predicted, same notation used in subprogram part B
        QP(PartA) = Qm(StormStart + JumpA * (PartA - 1))
        FluxA = FluxA + (CP(PartA) * QP(PartA))
        EndA = StormStart + JumpA * (PartA - 1)
        CondA = CondA + CP(PartA)   'Sums up the cond. from part B of
the rule
        FlowA = FlowA + QP(PartA)
        RuleVA = ((QP(PartA) + QP(PartA - 1)) / 2) * DeltaA 'Finds the
Volume flowing between rule events
        TRuleVA = TRuleVA + RuleVA        'sums up the volume
intervals

        If CP(PartA) > CPMax Then   'Finds the Max. concentration &
time of max. for the rule
            CPMax = CP(PartA)
            TCPMax = PartA
        Else
        End If
    Next PartA
End Sub

Sub StartB()
    EndB = 0
    FluxB = 0
    CondB = 0
    FlowB = 0
    FluxRule = 0
    TRuleVB = 0
    RuleVol = 0
    JumpB = DeltaB / DeltaT
    For PartB = NoA + 1 To 24
        CP(PartB) = Cm((EndA + 1) + JumpB * (PartB - (NoA + 1)))
'Note the '+1' moves it from the endA sequence to a next event sample
time later on, i.e. adds five minutes to the previously taken sample
        QP(PartB) = Qm((EndA + 1) + JumpB * (PartB - (NoA + 1)))
        FluxB = FluxB + (CP(PartB) * QP(PartB))
        RuleVB = ((QP(PartB) + QP(PartB - 1)) / 2) * DeltaB 'Finds the
Volume flowing between rule events
        TRuleVB = RuleVB + TRuleVB
        CondB = CondB + CP(PartB)   'Sums up the cond. from part B of
the rule
        FlowB = FlowB + QP(PartB)
        If CP(PartB) > CPMax Then 'Finds the Max. Conc. if it occurs
in Part B
            CPMax = CP(PartB)
```

```
            TCPMax = PartB + NoA
            Else
        End If
    Next PartB
    RuleVol = TRuleVA + TRuleVB
    EndB = EndA + JumpB * (PartB - (NoA + 1))
    RuleAvg = (CondA + CondB) / (FlowA + FlowB)    'Average = Sum of
the Conductivity / Sum of the flow (Both multiplied by time interval
so time drops out)
    FTRule = (FluxA + FluxB) * mS     'sum of Fluxes, used to find a
rule Average *NOTE: MULT. BY 1,000 TO GET uS
    TVRule = TRuleVA + TRuleVB
    FluxRule = FTRule / TVRule            'average flux sampled from
the storm (rule)
End Sub
Sub Average()    'Finds the Avg. Cond. & Flux for the Entire Storm
    TCond = 0
    TFlow = 0
    FluxStorm = 0
    StormAvg = 0
    StormTV = 0
    For nstart = StormStart To StormEnd                   'Finds the
Volume of water, used to find an average conductivity per gallon of
water for the storm
        TCond = TCond + Cm(nstart) 'Total Conductivity of the storm
        TFlow = TFlow + Qm(nstart) 'Total Flow for the storm
        FTStorm = FTStorm + (Cm(nstart) * Qm(nstart))   'Flux occuring
over the entire storm (not rule)
        StormV = ((Qm(nstart - 1) + Qm(nstart)) / 2) * DeltaT
'Volume of water per each time step (gallons)
        StormTV = StormTV + StormV                    'Sums the volumes
of water for the storm
    Next nstart
    StormAvg = TCond / TFlow      'Average Conductivity per unit
volume
    FluxStorm = (FTStorm / StormTV) * mS     'Note multiplication to
change to uS
End Sub
Sub Output()
    For iout = 1 To 24
        Cells(iout + 3, 10) = QP(iout)
        Cells(iout + 3, 11) = CP(iout)
    Next iout
    Cells(4, 8) = StormStart
    Cells(5, 8) = StormEnd
    Cells(6, 8) = CPMax
    Cells(7, 8) = RuleAvg
    Cells(8, 8) = StormAvg
    Cells(9, 8) = RuleVol
    Cells(10, 8) = StormTV
    Cells(11, 8) = TRuleVA
    Cells(12, 8) = TRuleVB
    Cells(13, 8) = FluxRule
    Cells(14, 8) = FluxStorm
    Cells(4, 13) = FluxA
    Cells(5, 13) = FluxB
    Cells(6, 13) = CmMax
    Cells(7, 13) = QMax
    Cells(8, 13) = TCMax
    Cells(9, 13) = PDur
End Sub
```

```
'Shem Stygar
'June 2004
'Seasonal Sampling Strategy (December to April)


Const nn = 65000         '# of data points
Const mS = 1             'Milli-Siemens to Micro-Siemens conversion
Const TolRise = 0.1      'DLevel to start program(ft)
Const DeltaA = 20        'Time step for Part A (min)
Const DeltaB = 85        'Time step for Part B (min)
Const NoA = 9            '# Bottles in Part A
Const NoB = 24 - NoA     '# Bottles in Part B

Dim DeltaT          'Time
Dim Qm(nn)          'Measured flow gpm)
Dim Cm(nn)          'Measured conductivity, West weir (uS/cm)
Dim QP(100)         'Measured Flow for the rule (gpm)
Dim CP(100)         'Measured Conductivity for the rule(uS/cm)
Dim EndA            'End Time of part A (integer)
Dim FluxA           'Measured Storm Flux Part A
Dim FluxB           'Measured Storm Flux Part B
Dim Hacc(nn)        'Total Accumulated head in weir, (ft)
Dim Hrise(nn)       'Difference between successive level measurements
(ft)
Dim Hm(nn)          'Measured head {actual}(ft)
Dim CmMax           'Measured Maximum Concentration (uS/cm)
Dim QMax            'Measured Maximum Flow (gpm)
Dim CPMax           'Maximum Conc. predicuted by rule (uS/cm)
Dim TCPMax          'Time of Max. Conc. using rule (integer)
Dim StormStart      'Start of Storm (integer not time)
Dim StormAvg        'Avg Cond for the storm (needs units); not rule
Dim Ihour           '# of data points in an hour dependent on DeltaT
Dim JumpA           'When DeltaA does not equal DeltaT, moves program to
read Cond & Flow from appropriate cells
Dim JumpB           'When DeltaB does not equal DeltaT, moves program to
read Cond & Flow from appropriate cells
Dim Cstart          'Conc @ Start time (uS/cm)
Dim TimeB           'Start of Part B of program, after end of Part A
Dim EndB            'End of Part B : end of program
Dim TCMax           'Max Obs Conc during storm (uS/cm)
Dim StormEnd        'End of the storm (integer)
Dim DurP            'Predicted Length of storm (by program)
Dim Volume          'Tot Vol going over the weir during the storm
(gallons)
Dim RuleVol         'Rule Vol for the storm (gallons)
Dim StormTV         'Storm Total Volume (not program)
Dim RuleAvg         'Avg Cond passing over the weir (uS/cm)/gallon for
the rule
Dim FluxSum         'Sum of Flux A and Flux B, (Cond * Flow)
Dim PDur            'Predicted storm duration
Dim TRuleVA         'Total Vol from Rule A, (gallons)
Dim TRuleVB         'Total Vol from Rule B, (gallons)
Dim FluxRule        'Flux of the Rule (uS/cm/gallon)
Dim FluxStorm       'Flux of the Storm (uS/cm/gallon)
Dim CondA
Dim CondB
Dim FlowA
Dim FlowB

Dim sh As Worksheet
```

```
Dim DestSh As Worksheet
Dim last As Long


Sub Main()
    For Each sh In ThisWorkbook.Worksheets
    sh.Activate
        Readdata
        StormDef
        StartA
        StartB
        Average
        Output
    Next sh
End Sub

Sub Readdata()
    DeltaT = Cells(3, 8)
    For iread = 1 To nn
        Cm(iread) = Cells(iread + 3, 5)
        Hm(iread) = Cells(iread + 3, 2)
        Qm(iread) = 1122 * (Hm(iread)) ^ 2.5
        Next iread
End Sub

Sub StormDef()     'Defines the duration of the storm
    Ihour = 60 / DeltaT
    eps = 0
    Hrise(1) = 0
    Hacc(1) = Hm(1)
    For istart = 2 To nn
       Hrise(istart) = Hm(istart) - Hm(istart - 1)
       Hacc(istart) = Hacc(istart - 1) + Hrise(istart)
    Next istart
    jstart = 0   'Start Time Algorithm
    Volume = 0
    Do While eps < TolRise And jstart < nn    'Finds the predicted
beginning of the storm
       jstart = jstart + 1
       eps = Hacc(jstart + Ihour) - Hacc(jstart)
    Loop
    StormStart = jstart + Ihour
    Cstart = Cells(StormStart + 3, 5)
    StormEnd = StormStart             'Defines the predicted End of
the storm
    Do While Qm(StormEnd) > 1 And StormEnd < nn
        StormEnd = StormEnd + 1
    Loop

    CmMax = 0
    TCMax = 0
    QMax = 0

    For lstart = StormStart To StormEnd     'Finds the Max
Concentration during the storm (not rule)
        If CmMax < Cm(lstart) Then
           CmMax = Cm(lstart)
           TCMax = lstart
        Else
        End If
    Next lstart
```

```
    For mstart = StormStart To StormEnd     'Finds the Max Flow during
the storm (not rule)
        If QMax < Qm(mstart) Then
        QMax = Qm(mstart)
        Else
        End If
    Next mstart
    PDur = StormEnd - StormStart 'Predicted Duration of the Storm


End Sub

Sub StartA()                  'sums Cond * Flow, Maximum, and time of
Maximum occurrence

    QP(0) = Qm(StormStart - 1)
    JumpA = DeltaA / DeltaT
    FlowA = 0
    CondA = 0
    FluxA = 0
    TRuleVA = 0
    CPMax = 0
    For PartA = 1 To NoA
        CP(PartA) = Cm(StormStart + JumpA * (PartA - 1))   'Note CP -
concentration predicted, same notation used in subprogram part B
        QP(PartA) = Qm(StormStart + JumpA * (PartA - 1))
        FluxA = FluxA + (CP(PartA) * QP(PartA))

        EndA = StormStart + JumpA * (PartA - 1)
        CondA = CondA + CP(PartA)    'Sums up the cond. from part B of
the rule
        FlowA = FlowA + QP(PartA)
        RuleVA = ((QP(PartA) + QP(PartA - 1)) / 2) * DeltaA 'Finds the
Volume flowing between rule events
        TRuleVA = TRuleVA + RuleVA        'sums up the volume
intervals

        If CP(PartA) > CPMax Then   'Finds the Max. concentration &
time of max. for the rule
            CPMax = CP(PartA)
            TCPMax = PartA
        Else
        End If
    Next PartA
End Sub

Sub StartB()
    EndB = 0
    FluxB = 0
    CondB = 0
    FlowB = 0
    FluxRule = 0
    TRuleVB = 0
    RuleVol = 0
    JumpB = DeltaB / DeltaT
    For PartB = NoA + 1 To 24
        CP(PartB) = Cm((EndA + 1) + JumpB * (PartB - (NoA + 1)))
'Note the '+1' moves it from the endA sequence to a next event sample
time later on, i.e. adds five minutes to the previously taken sample
        QP(PartB) = Qm((EndA + 1) + JumpB * (PartB - (NoA + 1)))
```

```
        FluxB = FluxB + (CP(PartB) * QP(PartB))
        RuleVB = ((QP(PartB) + QP(PartB - 1)) / 2) * DeltaB 'Finds the
Volume flowing between rule events
        TRuleVB = RuleVB + TRuleVB
        CondB = CondB + CP(PartB)   'Sums up the cond. from part B of
the rule
        FlowB = FlowB + QP(PartB)
        If CP(PartB) > CPMax Then 'Finds the Max. Conc. if it occurs
in Part B
            CPMax = CP(PartB)
            TCPMax = PartB + NoA
            Else
        End If
    Next PartB
    RuleVol = TRuleVA + TRuleVB
    EndB = EndA + JumpB * (PartB - (NoA + 1))
    RuleAvg = (CondA + CondB) / (FlowA + FlowB)    'Average = Sum of
the Conductivity / Sum of the flow (Both multiplied by time interval
so time drops out)
    FTRule = (FluxA + FluxB) * mS     'sum of Fluxes, used to find a
rule Average *NOTE: MULT. BY 1,000 TO GET uS
    TVRule = TRuleVA + TRuleVB
    FluxRule = FTRule / TVRule            'average flux sampled from
the storm (rule)
End Sub
Sub Average()    'Finds the Avg. Cond. & Flux for the Entire Storm
    TCond = 0
    TFlow = 0
    FluxStorm = 0
    StormAvg = 0
    StormTV = 0
    For nstart = StormStart To StormEnd                    'Finds the
Volume of water, used to find an average conductivity per gallon of
water for the storm
        TCond = TCond + Cm(nstart) 'Total Conductivity of the storm
        TFlow = TFlow + Qm(nstart) 'Total Flow for the storm
        FTStorm = FTStorm + (Cm(nstart) * Qm(nstart))   'Flux occuring
over the entire storm (not rule)
        StormV = ((Qm(nstart - 1) + Qm(nstart)) / 2) * DeltaT
'Volume of water per each time step (gallons)
        StormTV = StormTV + StormV                        'Sums the volumes
of water for the storm
    Next nstart
    StormAvg = TCond / TFlow      'Average Conductivity per unit
volume
    FluxStorm = (FTStorm / StormTV) * mS               'Note
multiplication to change to uS
End Sub
Sub Output()
    For iout = 1 To 24
        Cells(iout + 3, 10) = QP(iout)
        Cells(iout + 3, 11) = CP(iout)
    Next iout
    Cells(4, 8) = StormStart
    Cells(5, 8) = StormEnd
    Cells(6, 8) = CPMax
    Cells(7, 8) = RuleAvg
    Cells(8, 8) = StormAvg
    Cells(9, 8) = RuleVol
    Cells(10, 8) = StormTV
    Cells(11, 8) = TRuleVA
```

```
    Cells(12, 8) = TRuleVB
    Cells(13, 8) = FluxRule
    Cells(14, 8) = FluxStorm
    Cells(4, 13) = FluxA
    Cells(5, 13) = FluxB
    Cells(6, 13) = CmMax
    Cells(7, 13) = QMax
    Cells(8, 13) = TCMax
    Cells(9, 13) = PDur
End Sub
```

```
'Shem Stygar
'June 2004
'Seasonal Sampling Strategy (May to November)

Const nn = 65000        '# of data points
Const mS = 1            'Milli-Siemens to Micro-Siemens conversion
Const TolRise = 0.1     'DLevel to start program(ft)
Const DeltaA = 15       'Time step for Part A (min)
Const DeltaB = 65       'Time step for Part B (min)
Const NoA = 6           '# Bottles in Part A
Const NoB = 24 - NoA    '# Bottles in Part B

Dim DeltaT          'Time
Dim Qm(nn)          'Measured flow gpm)
Dim Cm(nn)          'Measured conductivity, West weir (uS/cm)
Dim QP(100)         'Measured Flow for the rule (gpm)
Dim CP(100)         'Measured Conductivity for the rule(uS/cm)
Dim EndA            'End Time of part A (integer)
Dim FluxA           'Measured Storm Flux Part A
Dim FluxB           'Measured Storm Flux Part B
Dim Hacc(nn)        'Total Accumulated head in weir, (ft)
Dim Hrise(nn)       'Difference between successive level measurements
(ft)
Dim Hm(nn)          'Measured head {actual}(ft)
Dim CmMax           'Measured Maximum Concentration (uS/cm)
Dim QMax            'Measured Maximum Flow (gpm)
Dim CPMax           'Maximum Conc. predicuted by rule (uS/cm)
Dim TCPMax          'Time of Max. Conc. using rule (integer)
Dim StormStart      'Start of Storm (integer not time)
Dim StormAvg        'Avg Cond for the storm (needs units); not rule
Dim Ihour           '# of data points in an hour dependent on DeltaT
Dim JumpA           'When DeltaA does not equal DeltaT, moves program to
read Cond & Flow from appropriate cells
Dim JumpB           'When DeltaB does not equal DeltaT, moves program to
read Cond & Flow from appropriate cells
Dim Cstart          'Conc @ Start time (uS/cm)
Dim TimeB           'Start of Part B of program, after end of Part A
Dim EndB            'End of Part B : end of program
Dim TCMax           'Max Obs Conc during storm (uS/cm)
Dim StormEnd        'End of the storm (integer)
Dim DurP            'Predicted Length of storm (by program)
Dim Volume          'Tot Vol going over the weir during the storm
(gallons)
Dim RuleVol         'Rule Vol for the storm (gallons)
Dim StormTV         'Storm Total Volume (not program)
Dim RuleAvg         'Avg Cond passing over the weir (uS/cm)/gallon for
the rule
Dim FluxSum         'Sum of Flux A and Flux B, (Cond * Flow)
Dim PDur            'Predicted storm duration
Dim TRuleVA         'Total Vol from Rule A, (gallons)
Dim TRuleVB         'Total Vol from Rule B, (gallons)
Dim FluxRule        'Flux of the Rule (uS/cm/gallon)
Dim FluxStorm       'Flux of the Storm (uS/cm/gallon)
Dim CondA
Dim CondB
Dim FlowA
Dim FlowB
Dim sh As Worksheet
Dim DestSh As Worksheet
Dim Last As Long
```

```
Sub Main()
    For Each sh In ThisWorkbook.Worksheets
    sh.Activate
        Readdata
        StormDef
        StartA
        StartB
        Average
        Output
    Next sh
End Sub

Sub Readdata()
    DeltaT = Cells(3, 8)
    For iread = 1 To nn
        Cm(iread) = Cells(iread + 3, 5)
        Hm(iread) = Cells(iread + 3, 2)
        Qm(iread) = 1122 * (Hm(iread)) ^ 2.5
    Next iread
End Sub

Sub StormDef()     'Defines the duration of the storm
    Ihour = 60 / DeltaT
    eps = 0
    Hrise(1) = 0
    Hacc(1) = Hm(1)
    For istart = 2 To nn
       Hrise(istart) = Hm(istart) - Hm(istart - 1)
       Hacc(istart) = Hacc(istart - 1) + Hrise(istart)
    Next istart
    jstart = 0    'Start Time Algorithm
    Volume = 0
    Do While eps < TolRise And jstart < nn    'Finds the predicted
beginning of the storm
        jstart = jstart + 1
        eps = Hacc(jstart + Ihour) - Hacc(jstart)
    Loop
    StormStart = jstart + Ihour
    Cstart = Cells(StormStart + 3, 5)
    StormEnd = StormStart              'Defines the predicted End of
the storm
    Do While Qm(StormEnd) > 1 And StormEnd < nn
        StormEnd = StormEnd + 1
    Loop

    CmMax = 0
    TCMax = 0
    QMax = 0
    For lstart = StormStart To StormEnd     'Finds the Max
Concentration during the storm (not rule)
        If CmMax < Cm(lstart) Then
           CmMax = Cm(lstart)
           TCMax = lstart
        Else
        End If
    Next lstart
    For mstart = StormStart To StormEnd     'Finds the Max Flow during
the storm (not rule)
        If QMax < Qm(mstart) Then
        QMax = Qm(mstart)
        Else
```

```
        End If
    Next mstart
    PDur = StormEnd - StormStart 'Predicted Duration of the Storm

End Sub

Sub StartA()                    'sums Cond * Flow, Maximum, and time of
Maximum occurrence
    QP(0) = Qm(StormStart - 1)
    JumpA = DeltaA / DeltaT
    FlowA = 0
    CondA = 0
    FluxA = 0
    TRuleVA = 0
    CPMax = 0
    For PartA = 1 To NoA
        CP(PartA) = Cm(StormStart + JumpA * (PartA - 1))  'Note CP -
concentration predicted, same notation used in subprogram part B
        QP(PartA) = Qm(StormStart + JumpA * (PartA - 1))
        FluxA = FluxA + (CP(PartA) * QP(PartA))

        EndA = StormStart + JumpA * (PartA - 1)
        CondA = CondA + CP(PartA)   'Sums up the cond. from part B of
the rule
        FlowA = FlowA + QP(PartA)
        RuleVA = ((QP(PartA) + QP(PartA - 1)) / 2) * DeltaA 'Finds the
Volume flowing between rule events
        TRuleVA = TRuleVA + RuleVA        'sums up the volume
intervals

        If CP(PartA) > CPMax Then   'Finds the Max. concentration &
time of max. for the rule
            CPMax = CP(PartA)
            TCPMax = PartA
        Else
        End If
    Next PartA
End Sub
Sub StartB()
    EndB = 0
    FluxB = 0
    CondB = 0
    FlowB = 0
    FluxRule = 0
    TRuleVB = 0
    RuleVol = 0
    JumpB = DeltaB / DeltaT
    For PartB = NoA + 1 To 24
        CP(PartB) = Cm((EndA + 1) + JumpB * (PartB - (NoA + 1)))
'Note the '+1' moves it from the endA sequence to a next event sample
time later on, i.e. adds five minutes to the previously taken sample
        QP(PartB) = Qm((EndA + 1) + JumpB * (PartB - (NoA + 1)))

        FluxB = FluxB + (CP(PartB) * QP(PartB))
        RuleVB = ((QP(PartB) + QP(PartB - 1)) / 2) * DeltaB 'Finds the
Volume flowing between rule events
        TRuleVB = RuleVB + TRuleVB
        CondB = CondB + CP(PartB)   'Sums up the cond. from part B of
the rule
        FlowB = FlowB + QP(PartB)
```

```
        If CP(PartB) > CPMax Then 'Finds the Max. Conc. if it occurs
in Part B
            CPMax = CP(PartB)
            TCPMax = PartB + NoA
            Else
        End If
    Next PartB
    RuleVol = TRuleVA + TRuleVB
    EndB = EndA + JumpB * (PartB - (NoA + 1))
    RuleAvg = (CondA + CondB) / (FlowA + FlowB)    'Average = Sum of
the Conductivity / Sum of the flow (Both multiplied by time interval
so time drops out)
    FTRule = (FluxA + FluxB) * mS     'sum of Fluxes, used to find a
rule Average *NOTE: MULT. BY 1,000 TO GET uS
    TVRule = TRuleVA + TRuleVB
    FluxRule = FTRule / TVRule             'average flux sampled from
the storm (rule)
End Sub
Sub Average()    'Finds the Avg. Cond. & Flux for the Entire Storm
    TCond = 0
    TFlow = 0
    FluxStorm = 0
    StormAvg = 0
    StormTV = 0
    For nstart = StormStart To StormEnd                  'Finds the
Volume of water, used to find an average conductivity per gallon of
water for the storm
        TCond = TCond + Cm(nstart) 'Total Conductivity of the storm
        TFlow = TFlow + Qm(nstart) 'Total Flow for the storm
        FTStorm = FTStorm + (Cm(nstart) * Qm(nstart))   'Flux occuring
over the entire storm (not rule)
        StormV = ((Qm(nstart - 1) + Qm(nstart)) / 2) * DeltaT
'Volume of water per each time step (gallons)
        StormTV = StormTV + StormV                    'Sums the volumes
of water for the storm
    Next nstart
    StormAvg = TCond / TFlow      'Average Conductivity per unit
volume
    FluxStorm = (FTStorm / StormTV) * mS               'Note
multiplication to change to uS
End Sub
Sub Output()
    For iout = 1 To 24
        Cells(iout + 3, 10) = QP(iout)
        Cells(iout + 3, 11) = CP(iout)
    Next iout
    Cells(4, 8) = StormStart
    Cells(5, 8) = StormEnd
    Cells(6, 8) = CPMax
    Cells(7, 8) = RuleAvg
    Cells(8, 8) = StormAvg
    Cells(9, 8) = RuleVol
    Cells(10, 8) = StormTV
    Cells(11, 8) = TRuleVA
    Cells(12, 8) = TRuleVB
    Cells(13, 8) = FluxRule
    Cells(14, 8) = FluxStorm
    Cells(4, 13) = FluxA
    Cells(5, 13) = FluxB
    Cells(6, 13) = CmMax
    Cells(7, 13) = QMax
```

```
    Cells(8, 13) = TCMax
    Cells(9, 13) = PDur
End Sub


IUH Model with depression storage term
'Spring 2005
'Shem Stygar

Dim M                   '# of linear reservoirs (1)
Dim Sum                 'Summing up of the Eqn.
Dim iread               'counter in 2 subs
Dim ierr                'counter used in 2 subs
Dim Observe             'Storm progressor
Dim T(10000)            'Measured time (min)
Dim P_m(10000)          'Measured precipitation (in/hr)
Dim Q_m(10000)          'Measured flow (gpm)
Dim Q_p(10000)          'Predicted flow (gpm)
Dim Delta(10000)        'Error
Dim A_eff               'Calculated Effective Area - Diff. for each storm
Dim delt                'mean error (Fibonacci)
Dim M_opt               'optimum # of m reservoirs
Dim Om_opt              'optimum omega
Dim Gamma               'Depression storage layer
Dim nn                  '# of data points
Dim nne                 'effective # of Data points
Dim i_s                 'Sampling pt. when runoff starts
Dim Sum_p
Dim Sum_q

Const dt = 300
Const g = 9.81

Sub Main()
    For Each sh In ThisWorkbook.Worksheets
        sh.Activate
        ReadData
        InnerSearch
        Output
    Next sh
End Sub

Sub ReadData()
    Sum_q = 0
    Sum_p = 0
    Gamma = 0
    M_opt = 1
    i_s = 0
    nn = Cells(7, "i")
    For iread = 1 To nn    'reads in measured values
        T(iread) = Cells(iread + 1, "b") * 60                     'Time
(min to sec)
        P_m(iread) = Cells(iread + 1, "c") * (0.0254 / 3600)
'Precip measured (in/hr to m/s)
        Q_m(iread) = Cells(iread + 1, "d") * (0.003785411 / 60)   'Flow
(gpm to m3/s)
        If Q_m(iread) < 0.00004 And iread < 40 Then
            Gamma = Gamma + P_m(iread) * dt  'Depression Storage
depth(m)
            i_s = iread          'start time of storm after storage
is filled
```

```
        Else
        End If
        Sum_p = Sum_p + P_m(iread) * dt
        Sum_q = Sum_q + Q_m(iread) * dt
    Next iread
    Sum_p = Sum_p - Gamma
    nne = nn - i_s
    A_eff = Sum_q / Sum_p  'Effective Area {m3/m}
End Sub

Sub InnerSearch()  'Searches for Optimum Omega
    xmin = Cells(5, "i")
    xmax = Cells(6, "i")
    x1 = xmin + 0.382 * (xmax - xmin)
    Om_opt = x1
    Err
    del1 = delt
    x2 = xmin + 0.618 * (xmax - xmin)
    Om_opt = x2
    Err
    del2 = delt
    For Iin = 1 To 100
        If del2 > del1 Then
            xmax = x2
            x2 = x1
            del2 = del1
            x1 = xmin + 0.382 * (xmax - xmin)
            Om_opt = x1
            Err
            del1 = delt
        Else
            xmin = x1
            x1 = x2
            del1 = del2
            x2 = xmin + 0.618 * (xmax - xmin)
            Om_opt = x2
            Err
            del2 = delt
        End If
    Next Iin
    Om_opt = (x1 + x2) / 2
    Err
End Sub

Sub Err()
delt = 0
For ierr = i_s To nn
    Observe = T(ierr)
    Convolution
    Delta(ierr) = Abs(Q_m(ierr) - Q_p(ierr))
    delt = delt + Delta(ierr)
Next ierr
delt = Abs(delt) / nne   'note division by nne
End Sub

Sub Convolution()
    Eqn = 0
    Sum = 0
    t_star = i_s * dt       'time of runoff: note the multiplication
    t_star_eq = t_star + dt  'Influence of rain on runoff
    While t_star < Observe Or t_star_eq = Observe
```

```
        counter = t_star_eq / dt    'Influence of first - last rain
drop on runoff measured
        RT = Observe - t_star         'Routing Time, refers to time of
app. to watershed
        Eqn = P_m(counter) * Exp(-Om_opt * RT) * dt    'Main convln
eqn.
        Sum = Sum + Eqn   'Sums up the eqn (makes VB less messy)
        t_star_eq = t_star_eq + dt   'moves the counter forward 1
        t_star = t_star + dt    'time increases from beg. of storm to
time of interest
    Wend
    Q_p(ierr) = Sum * Om_opt * A_eff 'predicted outflow
End Sub

Sub Output()
    Cells(4, "m") = M_opt      'verifies input
    Cells(5, "m") = Om_opt
    Cells(6, "m") = Cons
    Cells(4, "o") = A_eff
    Cells(5, "o") = delt       'shows error
    Cells(6, "o") = Observe    'Observed end of storm (sec)
    Cells(7, "o") = Gamma      'Depression Storage layer depth
    Cells(8, "o") = nne
    Cells(4, "q") = Sum_p
    Cells(5, "q") = Sum_q
    For iout = i_s To nn
        Cells(iout + 1, "e") = Q_p(iout)
    Next iout
End Sub
```

```
'Chloride Flux model added to IUH
'Summer 2005
'Shem Stygar

Dim M                   '# of linear reservoirs (1)
Dim Sum                 'Summing up of the Eqn.
Dim iread               'counter in 2 subs
Dim ierr                'counter used in 2 subs
Dim Observe             'Storm progressor
Dim T(10000)            'Measured time (min)
Dim P_m(10000)          'Measured precipitation (in/hr)
Dim Q_m(10000)          'Measured flow (gpm)
Dim Q_p(10000)          'Predicted flow (gpm)
Dim Delta(10000)        'Error
Dim A_eff               'Calculated Effective Area - Diff. for each storm
Dim delt                'mean error (Fibonacci)
Dim M_opt               'optimum # of m reservoirs
Dim Om_opt              'optimum omega
Dim nn                  '# of data points
Dim nne                 'effective # of Data points
Dim i_s                 'Sampling pt. when runoff starts

Dim F_m(10000)          'Measured Flux
Dim F_p(10000)          'Predicted Flux
Dim C_pi(10000)         'Concentration leaving dep. storage
Dim zeta                'depression storage depth
Dim Source              'omega * Sn (Source Strength * Solid Cl load)

Const n = 0.4           'Pavement Porosity (assumed)
Const dt = 300
Const g = 9.81
Const pi = 3.14159265359

Sub Main()
For Each sh In ThisWorkbook.Worksheets
sh.Activate
    ReadData
    outerSearch
    Output
Next sh
End Sub

Sub ReadData()
    Gamma = 0
    M_opt = 1
    Fmax = 0
    i_s = 0
    nn = Cells(7, "m")
    zeta = Cells(7, "s")   'dep. storage
    A_eff = Cells(4, "s") 'Effective Area {m3/m}
    For iread = 1 To nn   'reads in measured values
        T(iread) = Cells(iread + 1, "b") * 60                            'Time
(min to sec)
        P_m(iread) = Cells(iread + 1, "c") * (0.0254 / 3600)
'Precip measured (in/hr to m/s)
        Q_m(iread) = Cells(iread + 1, "d") * (0.003785411 / 60)  'Flow
(gpm to m3/s)
        F_m(iread) = Cells(iread + 1, "h") 'predicted from Spec Cond
values
        If Q_m(iread) <= 0.00006 And iread < 40 Then
```

```
            i_s = iread          'start time of storm after storage is
filled
        Else
        End If
    Next iread
    nne = nn - i_s
End Sub

Sub outerSearch()  'Searches for Optimum Source term
    xmin = Cells(8, "m")
    xmax = Cells(9, "m")
    x1 = xmin + 0.382 * (xmax - xmin)
    Om_opt = x1
    InnerSearch
    del1 = delt
    x2 = xmin + 0.618 * (xmax - xmin)
    Om_opt = x2
    InnerSearch
    del2 = delt
    For Iin = 1 To 50
        If del2 > del1 Then
            xmax = x2
            x2 = x1
            del2 = del1
            x1 = xmin + 0.382 * (xmax - xmin)
            Om_opt = x1
            InnerSearch
            del1 = delt
        Else
            xmin = x1
            x1 = x2
            del1 = del2
            x2 = xmin + 0.618 * (xmax - xmin)
            Om_opt = x2
            InnerSearch
            del2 = delt
        End If
    Next Iin
    Om_opt = (x1 + x2) / 2
    InnerSearch
End Sub

Sub InnerSearch()  'Searches for Optimum Source term
    xmin = Cells(5, "m")
    xmax = Cells(6, "m")
    x1 = xmin + 0.382 * (xmax - xmin)
    Source = x1
    Err
    del1 = delt
    x2 = xmin + 0.618 * (xmax - xmin)
    Source = x2
    Err
    del2 = delt
    For Iin = 1 To 50
        If del2 > del1 Then
            xmax = x2
            x2 = x1
            del2 = del1
            x1 = xmin + 0.382 * (xmax - xmin)
            Source = x1
            Err
```

```
            del1 = delt
        Else
            xmin = x1
            x1 = x2
            del1 = del2
            x2 = xmin + 0.618 * (xmax - xmin)
            Source = x2
            Err
            del2 = delt
        End If
    Next Iin
    Source = (x1 + x2) / 2
    Err
End Sub
Sub Err()
    delt = 0
    For ierr = i_s To nn
        Observe = T(ierr)
        Convolution
        Delta(ierr) = Abs(F_m(ierr) - F_p(ierr))
        delt = delt + Delta(ierr)
    Next ierr
    delt = delt / nne   'note division by nne
End Sub

Sub Convolution()
    Eqn = 0
    Sum = 0
    t_star = i_s * dt      'time of runoff: note the multiplication
    t_star_eq = t_star + dt  'Influence of rain on runoff
    C_pi(i_s) = F_m(i_s + 1) / Q_m(i_s + 1)  'set first value for C_pi
    While t_star_eq < Observe Or t_star_eq = Observe
        counter = t_star_eq / dt     'Influence of first - last rain
drop on runoff measured
        RT = Observe - t_star_eq         'Routing TimeP
        C_pi(counter) = (Source / (n * zeta) + C_pi(counter - 1) / dt)
/ (P_m(counter) / (n * zeta) + 1 / dt)
        Eqn = C_pi(counter) * P_m(counter) * Exp(-Om_opt * RT) * dt
'Main convln eqn.
        Sum = Sum + Eqn   'Sums up the eqn (makes VB less messy)
        t_star_eq = t_star_eq + dt   'moves the counter forward 1
        t_star = t_star + dt  'time increases from beg. of storm to
time of interest
    Wend
    F_p(ierr) = Sum * Om_opt * A_eff 'predicted outflow
End Sub

Sub Output()
    Cells(12, "q") = delt      'shows error
    Cells(13, "q") = Source
    Cells(14, "q") = Om_opt
    For iout = i_s To nn
        Cells(iout + 1, "i") = F_p(iout)
    Next iout
End Sub
```

APPENDIX B

INPUT FOR THE SAMPLING STRATEGY

1) Yearly Sampling Strategy
2) Seasonal Strategy (May to November)
3) Seasonal Strategy (December to April)

Yearly Sampling Strategy: March 2001

Delta Time (min)	5
StormStart	30
Storm End	492
C_P Max (µS/cm)	6310
Rule Average (kg - µS/cm/s)	4.50
Storm Average (kg - µS/cm/s)	10.75
Rule Volume (gal)	304472
Storm Total Vol. (gal)	290569
Volume A (gal)	14714
Volume B (gal)	289758
Flux Rule (kg - µS/cm/s)	15.17
Flux Storm (kg - µS/cm/s)	108.00

Flux A (kg - µS/cm/s)	2.54E+06
Flux B (kg - mS/cm/s)	2.08E+06
C_M Max (µS/cm)	6310
Q Max (gpm)	646
TC Max	30
Storm Length	462
Manual Length	467
Storm Duration Err.	1.08E-02
Concentration Err.	0.00E+00

Bottle #	Flow (gpm)	Cond. (µS/cm)
1	36	6310
2	254	3696
3	325	2298
4	253	1496
5	223	1112
6	219	1070
7	242	896
8	229	648
9	393	596
10	409	342
11	485	328
12	287	286
13	569	256
14	482	276
15	220	352
16	199	404
17	355	564
18	426	292
19	146	366
20	16	494
21	14	594
22	7	904
23	16	1044
24	8	1504

Date/Time	Level (ft)	Flow (GPM)	Flow Volume (gal)	Cond (uS/cm)
3/21/2001 17:30	0	0	0	0
3/21/2001 17:35	0	0	0	0
3/21/2001 17:40	0	0	0	0
3/21/2001 17:45	0	0	0	0
3/21/2001 17:50	0	0	0	0
3/21/2001 17:55	0	0	0	0
3/21/2001 18:00	0	0	0	0
3/21/2001 18:05	0	0	0	0
3/21/2001 18:10	0	0	0	0
3/21/2001 18:15	0	0	0	0
3/21/2001 18:20	0	0	0	0
3/21/2001 18:25	0	0	0	0
3/21/2001 18:30	0	0	0	0
3/21/2001 18:35	0	0	0	0
3/21/2001 18:40	0	0	0	0
3/21/2001 18:45	0	0	0	0
3/21/2001 18:50	0	0	0	0
3/21/2001 18:55	0	0	0	0
3/21/2001 19:00	0	0	0	0
3/21/2001 19:05	0	0	0	0
3/21/2001 19:10	0	0	0	0
3/21/2001 19:15	0	0	0	0
3/21/2001 19:20	0	0	0	0
3/21/2001 19:25	0	0	0	0
3/21/2001 19:30	0	0	0	0
3/21/2001 19:35	0	0	0	0
3/21/2001 19:40	0	0	0	0
3/21/2001 19:45	0	0.0	0	6434
3/21/2001 19:50	0.098	3.4	8	6450
3/21/2001 19:55	0.253	36.1	99	6310
3/21/2001 20:00	0.421	129.0	413	3688
3/21/2001 20:05	0.52	218.8	870	2870
3/21/2001 20:10	0.552	254.0	1182	3696
3/21/2001 20:15	0.558	261.0	1287	3818
3/21/2001 20:20	0.588	297.5	1396	3230
3/21/2001 20:25	0.609	324.7	1556	2298
3/21/2001 20:30	0.604	318.1	1607	1948
3/21/2001 20:35	0.581	288.7	1517	1692
3/21/2001 20:40	0.551	252.9	1354	1496
3/21/2001 20:45	0.537	237.1	1225	1344
3/21/2001 20:50	0.531	230.5	1169	1200
3/21/2001 20:55	0.524	223.0	1134	1112
3/21/2001 21:00	0.52	218.8	1104	1070
3/21/2001 21:05	0.515	213.6	1081	1012
3/21/2001 21:10	0.508	206.4	1050	990
3/21/2001 21:15	0.497	195.4	1004	978
3/21/2001 21:20	0.503	201.3	992	972
3/21/2001 21:25	0.508	206.4	1019	970
3/21/2001 21:30	0.505	203.3	1024	954
3/21/2001 21:35	0.507	205.4	1022	946
3/21/2001 21:40	0.517	215.6	1052	952
3/21/2001 21:45	0.533	232.7	1121	932
3/21/2001 21:50	0.539	239.3	1180	908
3/21/2001 21:55	0.541	241.5	1202	906
3/21/2001 22:00	0.541	241.5	1208	896
3/21/2001 22:05	0.533	232.7	1186	876
3/21/2001 22:10	0.518	216.7	1123	860
3/21/2001 22:15	0.504	202.3	1048	848
3/21/2001 22:20	0.497	195.4	994	840
3/21/2001 22:25	0.507	205.4	1002	824
3/21/2001 22:30	0.555	257.5	1157	804
3/21/2001 22:35	0.606	320.8	1446	756
3/21/2001 22:40	0.627	349.3	1675	720
3/21/2001 22:45	0.615	332.8	1705	718
3/21/2001 22:50	0.589	298.7	1579	702
3/21/2001 22:55	0.558	261.0	1399	676
3/21/2001 23:00	0.53	229.4	1226	648
3/21/2001 23:05	0.509	207.4	1092	636
3/21/2001 23:10	0.496	194.4	1004	632
3/21/2001 23:15	0.494	192.4	967	632
3/21/2001 23:20	0.497	195.4	970	634
3/21/2001 23:25	0.497	195.4	977	644
3/21/2001 23:30	0.506	204.3	999	660
3/21/2001 23:35	0.533	232.7	1093	674
3/21/2001 23:40	0.587	296.2	1322	668
3/21/2001 23:45	0.612	328.8	1562	630
3/21/2001 23:50	0.598	310.3	1598	628

3/21/2001 23:55	0.607	322.1	1581	648
3/22/2001	0.657	392.6	1787	596
3/22/2001 0:05	0.671	413.8	2016	520
3/22/2001 0:10	0.703	464.9	2197	516
3/22/2001 0:15	0.752	550.2	2538	454
3/22/2001 0:20	0.771	585.6	2840	406
3/22/2001 0:25	0.754	553.9	2849	378
3/22/2001 0:30	0.72	493.5	2619	350
3/22/2001 0:35	0.669	410.7	2261	332
3/22/2001 0:40	0.657	392.6	2008	324
3/22/2001 0:45	0.62	339.6	1830	316
3/22/2001 0:50	0.585	293.7	1583	316
3/22/2001 0:55	0.587	296.2	1475	330
3/22/2001 1:00	0.668	409.2	1764	342
3/22/2001 1:05	0.742	532.1	2353	322
3/22/2001 1:10	0.753	552.1	2710	332
3/22/2001 1:15	0.692	446.9	2498	344
3/22/2001 1:20	0.614	331.4	1946	344
3/22/2001 1:25	0.552	254.0	1464	342
3/22/2001 1:30	0.505	203.3	1143	340
3/22/2001 1:35	0.55	251.7	1138	342
3/22/2001 1:40	0.637	363.4	1538	344
3/22/2001 1:45	0.731	512.6	2190	328
3/22/2001 1:50	0.747	541.1	2634	348
3/22/2001 1:55	0.73	510.9	2630	348
3/22/2001 2:00	0.715	485.0	2490	328
3/22/2001 2:05	0.719	491.8	2442	306
3/22/2001 2:10	0.754	553.9	2614	282
3/22/2001 2:15	0.802	646.3	3000	262
3/22/2001 2:20	0.783	608.7	3137	252
3/22/2001 2:25	0.746	539.3	2870	250
3/22/2001 2:30	0.713	481.6	2552	242
3/22/2001 2:35	0.682	431.0	2282	240
3/22/2001 2:40	0.689	442.1	2183	244
3/22/2001 2:45	0.676	421.6	2159	250
3/22/2001 2:50	0.636	361.9	1959	258
3/22/2001 2:55	0.59	300.0	1655	272
3/22/2001 3:00	0.58	287.5	1469	286
3/22/2001 3:05	0.596	307.7	1488	300
3/22/2001 3:10	0.628	350.7	1646	296
3/22/2001 3:15	0.678	424.7	1938	310
3/22/2001 3:20	0.726	503.9	2321	310
3/22/2001 3:25	0.741	530.3	2586	304
3/22/2001 3:30	0.736	521.4	2629	300
3/22/2001 3:35	0.713	481.6	2508	286
3/22/2001 3:40	0.686	437.3	2297	276
3/22/2001 3:45	0.669	410.7	2120	270
3/22/2001 3:50	0.687	438.9	2124	262
3/22/2001 3:55	0.724	500.4	2348	258
3/22/2001 4:00	0.762	568.7	2673	256
3/22/2001 4:05	0.762	568.7	2843	256
3/22/2001 4:10	0.739	526.7	2739	250
3/22/2001 4:15	0.68	427.8	2386	246
3/22/2001 4:20	0.62	339.6	1919	248
3/22/2001 4:25	0.59	300.0	1599	250
3/22/2001 4:30	0.589	298.7	1497	256
3/22/2001 4:35	0.603	316.8	1539	260
3/22/2001 4:40	0.656	391.1	1770	272
3/22/2001 4:45	0.713	481.6	2182	276
3/22/2001 4:50	0.735	519.7	2503	278
3/22/2001 4:55	0.726	503.9	2559	282
3/22/2001 5:00	0.713	481.6	2464	276
3/22/2001 5:05	0.689	442.1	2309	266
3/22/2001 5:10	0.663	401.6	2109	262
3/22/2001 5:15	0.626	347.9	1874	260
3/22/2001 5:20	0.593	303.8	1629	266
3/22/2001 5:25	0.58	287.5	1478	272
3/22/2001 5:30	0.585	293.7	1453	280
3/22/2001 5:35	0.594	305.1	1497	290
3/22/2001 5:40	0.594	305.1	1526	296
3/22/2001 5:45	0.562	265.7	1427	310
3/22/2001 5:50	0.537	237.1	1257	326
3/22/2001 5:55	0.518	216.7	1134	340
3/22/2001 6:00	0.521	219.8	1091	352
3/22/2001 6:05	0.526	225.1	1112	358
3/22/2001 6:10	0.52	218.8	1110	362
3/22/2001 6:15	0.518	216.7	1089	380
3/22/2001 6:20	0.528	227.3	1110	402
3/22/2001 6:25	0.554	256.3	1209	412
3/22/2001 6:30	0.589	298.7	1388	408

3/22/2001 6:35	0.619	338.2	1592	400
3/22/2001 6:40	0.621	341.0	1698	408
3/22/2001 6:45	0.603	316.8	1644	410
3/22/2001 6:50	0.567	271.6	1471	408
3/22/2001 6:55	0.542	242.7	1286	406
3/22/2001 7:00	0.501	199.3	1105	404
3/22/2001 7:05	0.467	167.2	916	404
3/22/2001 7:10	0.425	132.1	748	410
3/22/2001 7:15	0.389	105.9	595	414
3/22/2001 7:20	0.356	84.8	477	422
3/22/2001 7:25	0.332	71.3	390	430
3/22/2001 7:30	0.32	65.0	341	438
3/22/2001 7:35	0.312	61.0	315	452
3/22/2001 7:40	0.328	69.1	325	464
3/22/2001 7:45	0.384	102.5	429	490
3/22/2001 7:50	0.437	141.6	610	536
3/22/2001 7:55	0.52	218.8	901	552
3/22/2001 8:00	0.631	354.9	1434	564
3/22/2001 8:05	0.692	446.9	2005	526
3/22/2001 8:10	0.707	471.6	2296	526
3/22/2001 8:15	0.697	455.1	2317	488
3/22/2001 8:20	0.694	450.2	2263	440
3/22/2001 8:25	0.715	485.0	2338	390
3/22/2001 8:30	0.747	541.1	2565	336
3/22/2001 8:35	0.74	528.5	2674	312
3/22/2001 8:40	0.734	517.9	2616	306
3/22/2001 8:45	0.722	497.0	2537	300
3/22/2001 8:50	0.696	453.4	2376	296
3/22/2001 8:55	0.661	398.6	2130	294
3/22/2001 9:00	0.679	426.3	2062	292
3/22/2001 9:05	0.694	450.2	2191	278
3/22/2001 9:10	0.665	404.6	2137	278
3/22/2001 9:15	0.64	367.7	1931	296
3/22/2001 9:20	0.642	370.5	1845	300
3/22/2001 9:25	0.616	334.2	1762	296
3/22/2001 9:30	0.583	291.2	1563	302
3/22/2001 9:35	0.546	247.2	1346	312
3/22/2001 9:40	0.516	214.6	1154	318
3/22/2001 9:45	0.495	193.4	1020	322
3/22/2001 9:50	0.482	181.0	936	332
3/22/2001 9:55	0.465	165.4	866	348
3/22/2001 10:00	0.442	145.7	778	366
3/22/2001 10:05	0.413	123.0	672	378
3/22/2001 10:10	0.382	101.2	560	390
3/22/2001 10:15	0.35	81.3	456	404
3/22/2001 10:20	0.327	68.6	375	416
3/22/2001 10:25	0.301	55.8	311	430
3/22/2001 10:30	0.27	42.5	246	448
3/22/2001 10:35	0.253	36.1	197	458
3/22/2001 10:40	0.236	30.4	166	466
3/22/2001 10:45	0.219	25.2	139	472
3/22/2001 10:50	0.209	22.4	119	480
3/22/2001 10:55	0.196	19.1	104	486
3/22/2001 11:00	0.184	16.3	88	494
3/22/2001 11:05	0.177	14.8	78	500
3/22/2001 11:10	0.173	14.0	72	504
3/22/2001 11:15	0.17	13.4	68	510
3/22/2001 11:20	0.173	14.0	68	518
3/22/2001 11:25	0.173	14.0	70	526
3/22/2001 11:30	0.175	14.4	71	534
3/22/2001 11:35	0.178	15.0	73	544
3/22/2001 11:40	0.177	14.8	74	550
3/22/2001 11:45	0.18	15.4	76	562
3/22/2001 11:50	0.181	15.6	78	574
3/22/2001 11:55	0.18	15.4	78	584
3/22/2001 12:00	0.175	14.4	74	594
3/22/2001 12:05	0.171	13.6	70	614
3/22/2001 12:10	0.166	12.6	65	624
3/22/2001 12:15	0.163	12.0	62	628
3/22/2001 12:20	0.156	10.8	57	664
3/22/2001 12:25	0.154	10.4	53	716
3/22/2001 12:30	0.15	9.8	51	756
3/22/2001 12:35	0.145	9.0	47	772
3/22/2001 12:40	0.142	8.5	44	790
3/22/2001 12:45	0.138	7.9	41	818
3/22/2001 12:50	0.137	7.8	39	840
3/22/2001 12:55	0.134	7.4	38	874
3/22/2001 13:00	0.131	7.0	36	904
3/22/2001 13:05	0.127	6.4	34	928
3/22/2001 13:10	0.13	6.8	33	946

3/22/2001 13:15	0.132	7.1	35	962
3/22/2001 13:20	0.135	7.5	37	976
3/22/2001 13:25	0.143	8.7	40	988
3/22/2001 13:30	0.159	11.3	50	1000
3/22/2001 13:35	0.17	13.4	62	1016
3/22/2001 13:40	0.175	14.4	69	1032
3/22/2001 13:45	0.192	18.1	81	1038
3/22/2001 13:50	0.187	17.0	88	1040
3/22/2001 13:55	0.184	16.3	83	1042
3/22/2001 14:00	0.183	16.1	81	1044
3/22/2001 14:05	0.175	14.4	76	1048
3/22/2001 14:10	0.169	13.2	69	1054
3/22/2001 14:15	0.174	14.2	68	1064
3/22/2001 14:20	0.167	12.8	67	1158
3/22/2001 14:25	0.163	12.0	62	1300
3/22/2001 14:30	0.156	10.8	57	1380
3/22/2001 14:35	0.147	9.3	50	1426
3/22/2001 14:40	0.148	9.5	47	1450
3/22/2001 14:45	0.142	8.5	45	1468
3/22/2001 14:50	0.14	8.2	42	1484
3/22/2001 14:55	0.139	8.1	41	1494
3/22/2001 15:00	0.135	7.5	39	1504
3/22/2001 15:05	0.133	7.2	37	1510
3/22/2001 15:10	0.13	6.8	35	1518
3/22/2001 15:15	0.128	6.6	34	1524
3/22/2001 15:20	0.133	7.2	35	1528
3/22/2001 15:25	0.154	10.4	44	1536
3/22/2001 15:30	0.189	17.4	70	1544
3/22/2001 15:35	0.22	25.5	107	1558
3/22/2001 15:40	0.241	32.0	144	1570
3/22/2001 15:45	0.25	35.1	168	1540
3/22/2001 15:50	0.255	36.8	180	1430
3/22/2001 15:55	0.249	34.7	179	1396
3/22/2001 16:00	0.241	32.0	167	1420
3/22/2001 16:05	0.232	29.1	153	1558
3/22/2001 16:10	0.221	25.8	137	1678
3/22/2001 16:15	0.209	22.4	120	1774
3/22/2001 16:20	0.201	20.3	107	1802
3/22/2001 16:25	0.189	17.4	94	1822
3/22/2001 16:30	0.183	16.1	84	1840
3/22/2001 16:35	0.177	14.8	77	1852
3/22/2001 16:40	0.169	13.2	70	1854
3/22/2001 16:45	0.165	12.4	64	1864
3/22/2001 16:50	0.159	11.3	59	1878
3/22/2001 16:55	0.152	10.1	54	1898
3/22/2001 17:00	0.15	9.8	50	1916
3/22/2001 17:05	0.148	9.5	48	1922
3/22/2001 17:10	0.144	8.8	46	1928
3/22/2001 17:15	0.141	8.4	43	1946
3/22/2001 17:20	0.139	8.1	41	1964
3/22/2001 17:25	0.136	7.7	39	1976
3/22/2001 17:30	0.135	7.5	38	1984
3/22/2001 17:35	0.134	7.4	37	1992
3/22/2001 17:40	0.131	7.0	36	2000
3/22/2001 17:45	0.129	6.7	34	2006
3/22/2001 17:50	0.127	6.4	33	2008
3/22/2001 17:55	0.125	6.2	32	2012
3/22/2001 18:00	0.124	6.1	31	2012
3/22/2001 18:05	0.123	6.0	30	2016
3/22/2001 18:10	0.118	5.4	28	2016
3/22/2001 18:15	0.118	5.4	27	2014
3/22/2001 18:20	0.118	5.4	27	2012
3/22/2001 18:25	0.115	5.0	26	2010
3/22/2001 18:30	0.115	5.0	25	2008
3/22/2001 18:35	0.114	4.9	25	2012
3/22/2001 18:40	0.11	4.5	24	2010
3/22/2001 18:45	0.111	4.6	23	2008
3/22/2001 18:50	0.112	4.7	23	2008
3/22/2001 18:55	0.11	4.5	23	2006
3/22/2001 19:00	0.11	4.5	23	2004
3/22/2001 19:05	0.11	4.5	23	2002
3/22/2001 19:10	0.108	4.3	22	2002
3/22/2001 19:15	0.108	4.3	22	1996
3/22/2001 19:20	0.108	4.3	22	1992
3/22/2001 19:25	0.107	4.2	21	1986
3/22/2001 19:30	0.106	4.1	21	1982
3/22/2001 19:35	0.107	4.2	21	1982
3/22/2001 19:40	0.106	4.1	21	1978
3/22/2001 19:45	0.104	3.9	20	1972
3/22/2001 19:50	0.106	4.1	20	1964

3/22/2001 19:55	0.102	3.7	20	1956
3/22/2001 20:00	0.104	3.9	19	1948
3/22/2001 20:05	0.102	3.7	19	1940
3/22/2001 20:10	0.1	3.5	18	1932
3/22/2001 20:15	0.101	3.6	18	1924
3/22/2001 20:20	0.102	3.7	18	1916
3/22/2001 20:25	0.102	3.7	19	1908
3/22/2001 20:30	0.1	3.5	18	1898
3/22/2001 20:35	0.1	3.5	18	1890
3/22/2001 20:40	0.098	3.4	17	1860
3/22/2001 20:45	0.1	3.5	17	1870
3/22/2001 20:50	0.1	3.5	18	1858
3/22/2001 20:55	0.098	3.4	17	1848
3/22/2001 21:00	0.098	3.4	17	1838
3/22/2001 21:05	0.099	3.5	17	1830
3/22/2001 21:10	0.099	3.5	17	1826
3/22/2001 21:15	0.098	3.4	17	1828
3/22/2001 21:20	0.098	3.4	17	1822
3/22/2001 21:25	0.098	3.4	17	1816
3/22/2001 21:30	0.096	3.2	16	1814
3/22/2001 21:35	0.096	3.2	16	1812
3/22/2001 21:40	0.095	3.1	16	1812
3/22/2001 21:45	0.094	3.0	15	1812
3/22/2001 21:50	0.094	3.0	15	1810
3/22/2001 21:55	0.093	3.0	15	1812
3/22/2001 22:00	0.091	2.8	14	1810
3/22/2001 22:05	0.091	2.8	14	1810
3/22/2001 22:10	0.09	2.7	14	1808
3/22/2001 22:15	0.089	2.7	13	1806
3/22/2001 22:20	0.089	2.7	13	1806
3/22/2001 22:25	0.089	2.7	13	1804
3/22/2001 22:30	0.088	2.6	13	1804
3/22/2001 22:35	0.087	2.5	13	1804
3/22/2001 22:40	0.085	2.4	12	1804
3/22/2001 22:45	0.087	2.5	12	1802
3/22/2001 22:50	0.086	2.4	12	1798
3/22/2001 22:55	0.083	2.2	12	1800
3/22/2001 23:00	0.084	2.3	11	1796
3/22/2001 23:05	0.084	2.3	11	1794
3/22/2001 23:10	0.083	2.2	11	1794
3/22/2001 23:15	0.083	2.2	11	1790
3/22/2001 23:20	0.083	2.2	11	1786
3/22/2001 23:25	0.081	2.1	11	1782
3/22/2001 23:30	0.082	2.2	11	1780
3/22/2001 23:35	0.082	2.2	11	1776
3/22/2001 23:40	0.081	2.1	11	1776
3/22/2001 23:45	0.081	2.1	10	1772
3/22/2001 23:50	0.081	2.1	10	1770
3/22/2001 23:55	0.079	2.0	10	1768
3/23/2001	0.08	2.0	10	1768
3/23/2001 0:05	0.081	2.1	10	1766
3/23/2001 0:10	0.081	2.1	10	1762
3/23/2001 0:15	0.079	2.0	10	1760
3/23/2001 0:20	0.081	2.1	10	1762
3/23/2001 0:25	0.078	1.9	10	1762
3/23/2001 0:30	0.08	2.0	10	1764
3/23/2001 0:35	0.081	2.1	10	1766
3/23/2001 0:40	0.081	2.1	10	1772
3/23/2001 0:45	0.081	2.1	10	1774
3/23/2001 0:50	0.083	2.2	11	1776
3/23/2001 0:55	0.083	2.2	11	1776
3/23/2001 1:00	0.084	2.3	11	1778
3/23/2001 1:05	0.086	2.4	12	1780
3/23/2001 1:10	0.087	2.5	12	1782
3/23/2001 1:15	0.087	2.5	13	1786
3/23/2001 1:20	0.089	2.7	13	1788
3/23/2001 1:25	0.086	2.4	13	1790
3/23/2001 1:30	0.089	2.7	13	1792
3/23/2001 1:35	0.089	2.7	13	1788
3/23/2001 1:40	0.089	2.7	13	1786
3/23/2001 1:45	0.089	2.7	13	1782
3/23/2001 1:50	0.089	2.7	13	1780
3/23/2001 1:55	0.088	2.6	13	1780
3/23/2001 2:00	0.086	2.4	13	1776
3/23/2001 2:05	0.087	2.5	12	1770
3/23/2001 2:10	0.087	2.5	13	1768
3/23/2001 2:15	0.085	2.4	12	1764
3/23/2001 2:20	0.087	2.5	12	1758
3/23/2001 2:25	0.085	2.4	12	1752
3/23/2001 2:30	0.085	2.4	12	1748

3/23/2001 2:35	0.085	2.4	12	1740
3/23/2001 2:40	0.083	2.2	11	1734
3/23/2001 2:45	0.084	2.3	11	1734
3/23/2001 2:50	0.083	2.2	11	1730
3/23/2001 2:55	0.082	2.2	11	1728
3/23/2001 3:00	0.081	2.1	11	1728
3/23/2001 3:05	0.079	2.0	10	1732
3/23/2001 3:10	0.078	1.9	10	1736
3/23/2001 3:15	0.081	2.1	10	1740
3/23/2001 3:20	0.083	2.2	11	1742
3/23/2001 3:25	0.083	2.2	11	1750
3/23/2001 3:30	0.085	2.4	11	1754
3/23/2001 3:35	0.086	2.4	12	1756
3/23/2001 3:40	0.087	2.5	12	1762
3/23/2001 3:45	0.089	2.7	13	1766
3/23/2001 3:50	0.085	2.4	13	1768
3/23/2001 3:55	0.08	2.0	11	1770
3/23/2001 4:00	0.089	2.7	12	1766
3/23/2001 4:05	0.087	2.5	13	1758
3/23/2001 4:10	0.087	2.5	13	1736
3/23/2001 4:15	0.087	2.5	13	1724
3/23/2001 4:20	0.084	2.3	12	1692
3/23/2001 4:25	0.084	2.3	11	1648
3/23/2001 4:30	0.083	2.2	11	1620
3/23/2001 4:35	0.085	2.4	11	1594
3/23/2001 4:40	0.085	2.4	12	1578
3/23/2001 4:45	0.083	2.2	11	1606
3/23/2001 4:50	0.077	1.8	10	1582
3/23/2001 4:55	0.076	1.8	9	1568
3/23/2001 5:00	0.077	1.8	9	1564
3/23/2001 5:05	0.077	1.8	9	1566
3/23/2001 5:10	0.077	1.8	9	1566
3/23/2001 5:15	0.085	2.4	11	1566
3/23/2001 5:20	0.084	2.3	12	1566
3/23/2001 5:25	0.085	2.4	12	1564
3/23/2001 5:30	0.089	2.7	13	1564
3/23/2001 5:35	0.091	2.8	14	1562
3/23/2001 5:40	0.096	3.2	15	1562
3/23/2001 5:45	0.1	3.5	17	1562
3/23/2001 5:50	0.099	3.5	18	1562
3/23/2001 5:55	0.095	3.1	16	1580
3/23/2001 6:00	0.106	4.1	18	1694
3/23/2001 6:05	0.103	3.8	20	1848
3/23/2001 6:10	0.105	4.0	20	1982
3/23/2001 6:15	0.11	4.5	21	2080
3/23/2001 6:20	0.102	3.7	21	2140
3/23/2001 6:25	0.106	4.1	20	2180
3/23/2001 6:30	0.099	3.5	19	2204
3/23/2001 6:35	0.102	3.7	18	2220
3/23/2001 6:40	0.106	4.1	20	2234
3/23/2001 6:45	0.105	4.0	20	2246
3/23/2001 6:50	0.102	3.7	19	2256
3/23/2001 6:55	0.099	3.5	18	2268
3/23/2001 7:00	0.099	3.5	17	2294
3/23/2001 7:05	0.093	3.0	16	2340
3/23/2001 7:10	0.094	3.0	15	2450
3/23/2001 7:15	0.096	3.2	16	2562
3/23/2001 7:20	0.095	3.1	16	2656
3/23/2001 7:25	0.094	3.0	15	2726
3/23/2001 7:30	0.092	2.9	15	2778
3/23/2001 7:35	0.091	2.8	14	2816
3/23/2001 7:40	0.089	2.7	14	2848
3/23/2001 7:45	0.088	2.6	13	2870
3/23/2001 7:50	0.082	2.2	12	2890
3/23/2001 7:55	0.079	2.0	10	2904
3/23/2001 8:00	0.083	2.2	10	2916
3/23/2001 8:05	0.083	2.2	11	2930
3/23/2001 8:10	0.082	2.2	11	2942
3/23/2001 8:15	0.08	2.0	10	2966
3/23/2001 8:20	0.079	2.0	10	2988
3/23/2001 8:25	0.077	1.8	10	3012
3/23/2001 8:30	0.077	1.8	9	3036
3/23/2001 8:35	0.076	1.8	9	3060
3/23/2001 8:40	0.074	1.7	9	3080
3/23/2001 8:45	0.073	1.6	8	3096
3/23/2001 8:50	0.073	1.6	8	3112
3/23/2001 8:55	0.07	1.5	8	3124
3/23/2001 9:00	0.071	1.5	7	3134
3/23/2001 9:05	0.071	1.5	8	3144
3/23/2001 9:10	0.07	1.5	7	3150

3/23/2001 9:15	0.069	1.4	7	3150
3/23/2001 9:20	0.068	1.4	7	3154
3/23/2001 9:25	0.067	1.3	7	3158
3/23/2001 9:30	0.067	1.3	7	3162
3/23/2001 9:35	0.066	1.3	6	3166
3/23/2001 9:40	0.066	1.3	6	3168
3/23/2001 9:45	0.064	1.2	6	3172
3/23/2001 9:50	0.064	1.2	6	3174
3/23/2001 9:55	0.063	1.1	6	3176
3/23/2001 10:00	0.064	1.2	6	3180
3/23/2001 10:05	0.064	1.2	6	3188
3/23/2001 10:10	0.062	1.1	6	3190
3/23/2001 10:15	0.062	1.1	5	3192
3/23/2001 10:20	0.062	1.1	5	3192
3/23/2001 10:25	0.06	1.0	5	3194
3/23/2001 10:30	0.061	1.0	5	3194
3/23/2001 10:35	0.061	1.0	5	3196
3/23/2001 10:40	0.06	1.0	5	3196
3/23/2001 10:45	0.059	0.9	5	3196
3/23/2001 10:50	0.059	0.9	5	3196
3/23/2001 10:55	0.058	0.9	5	3198
3/23/2001 11:00	0.058	0.9	5	3200
3/23/2001 11:05	0.058	0.9	5	3202
3/23/2001 11:10	0.058	0.9	5	3202
3/23/2001 11:15	0.057	0.9	4	3206
3/23/2001 11:20	0.058	0.9	4	3208
3/23/2001 11:25	0.058	0.9	5	3210
3/23/2001 11:30	0.056	0.8	4	3214
3/23/2001 11:35	0.057	0.9	4	3218
3/23/2001 11:40	0.056	0.8	4	3222
3/23/2001 11:45	0.055	0.8	4	3224
3/23/2001 11:50	0.055	0.8	4	3228
3/23/2001 11:55	0.054	0.8	4	3232
3/23/2001 12:00	0.055	0.8	4	3234
3/23/2001 12:05	0.056	0.8	4	3236
3/23/2001 12:10	0.053	0.7	4	3238
3/23/2001 12:15	0.054	0.8	4	3242
3/23/2001 12:20	0.055	0.8	4	3244
3/23/2001 12:25	0.054	0.8	4	3246
3/23/2001 12:30	0.054	0.8	4	3248
3/23/2001 12:35	0.054	0.8	4	3248
3/23/2001 12:40	0.053	0.7	4	3250
3/23/2001 12:45	0.053	0.7	4	3252
3/23/2001 12:50	0.053	0.7	4	3252
3/23/2001 12:55	0.053	0.7	4	3254
3/23/2001 13:00	0.052	0.7	4	3254
3/23/2001 13:05	0.053	0.7	4	3256
3/23/2001 13:10	0.051	0.7	3	3248
3/23/2001 13:15	0.052	0.7	3	3248
3/23/2001 13:20	0.052	0.7	3	3248
3/23/2001 13:25	0.052	0.7	3	3248
3/23/2001 13:30	0.051	0.7	3	3250
3/23/2001 13:35	0.052	0.7	3	3250
3/23/2001 13:40	0.052	0.7	3	3250
3/23/2001 13:45	0.052	0.7	3	3250
3/23/2001 13:50	0.051	0.7	3	3250
3/23/2001 13:55	0.052	0.7	3	3248
3/23/2001 14:00	0.051	0.7	3	3246
3/23/2001 14:05	0.052	0.7	3	3244
3/23/2001 14:10	0.048	0.6	3	3242
3/23/2001 14:15	0.049	0.6	3	3240
3/23/2001 14:20	0.049	0.6	3	3238
3/23/2001 14:25	0.05	0.6	3	3238
3/23/2001 14:30	0.05	0.6	3	3232
3/23/2001 14:35	0.051	0.7	3	3226
3/23/2001 14:40	0.051	0.7	3	3218
3/23/2001 14:45	0.051	0.7	3	3212
3/23/2001 14:50	0.051	0.7	3	3216
3/23/2001 14:55	0.049	0.6	3	3214
3/23/2001 15:00	0.049	0.6	3	3212
3/23/2001 15:05	0.049	0.6	3	3212
3/23/2001 15:10	0.046	0.5	3	3208
3/23/2001 15:15	0.049	0.6	3	3204
3/23/2001 15:20	0.05	0.6	3	3202
3/23/2001 15:25	0.046	0.5	3	3190
3/23/2001 15:30	0.049	0.6	3	3190
3/23/2001 15:35	0.05	0.6	3	3188
3/23/2001 15:40	0.047	0.5	3	3186
3/23/2001 15:45	0.049	0.6	3	3182
3/23/2001 15:50	0.049	0.6	3	3178

3/23/2001 15:55	0.046	0.5	3	3172
3/23/2001 16:00	0.048	0.6	3	3168
3/23/2001 16:05	0.049	0.6	3	3170
3/23/2001 16:10	0.049	0.6	3	3168
3/23/2001 16:15	0.048	0.6	3	3170
3/23/2001 16:20	0.049	0.6	3	3170
3/23/2001 16:25	0.047	0.5	3	3166
3/23/2001 16:30	0.047	0.5	3	3162
3/23/2001 16:35	0.048	0.6	3	3158
3/23/2001 16:40	0.048	0.6	3	3154
3/23/2001 16:45	0.047	0.5	3	3150
3/23/2001 16:50	0.047	0.5	3	3144
3/23/2001 16:55	0.046	0.5	3	3136
3/23/2001 17:00	0.047	0.5	3	3134
3/23/2001 17:05	0.047	0.5	3	3136
3/23/2001 17:10	0.046	0.5	3	3134
3/23/2001 17:15	0.046	0.5	3	3132
3/23/2001 17:20	0.047	0.5	3	3132
3/23/2001 17:25	0.046	0.5	3	3128
3/23/2001 17:30	0.045	0.5	2	3126
3/23/2001 17:35	0.046	0.5	2	3118
3/23/2001 17:40	0.047	0.5	3	3112
3/23/2001 17:45	0.045	0.5	3	3106
3/23/2001 17:50	0.047	0.5	3	3102
3/23/2001 17:55	0.044	0.5	2	3098
3/23/2001 18:00	0.046	0.5	2	3094
3/23/2001 18:05	0.046	0.5	3	3090
3/23/2001 18:10	0.045	0.5	2	3092
3/23/2001 18:15	0.045	0.5	2	3084
3/23/2001 18:20	0.045	0.5	2	3074
3/23/2001 18:25	0.044	0.5	2	3070
3/23/2001 18:30	0.045	0.5	2	3066
3/23/2001 18:35	0.045	0.5	2	3062
3/23/2001 18:40	0.045	0.5	2	3060
3/23/2001 18:45	0.041	0.4	2	3058
3/23/2001 18:50	0.041	0.4	2	3012
3/23/2001 18:55	0.041	0.4	2	2944
3/23/2001 19:00	0.045	0.5	2	2908
3/23/2001 19:05	0.044	0.5	2	2876
3/23/2001 19:10	0.044	0.5	2	2870
3/23/2001 19:15	0.043	0.4	2	2832
3/23/2001 19:20	0.039	0.3	2	2806
3/23/2001 19:25	0.043	0.4	2	2790
3/23/2001 19:30	0.041	0.4	2	2786
3/23/2001 19:35	0.039	0.3	2	2776
3/23/2001 19:40	0.04	0.4	2	2768
3/23/2001 19:45	0.043	0.4	2	2762
3/23/2001 19:50	0.041	0.4	2	2756
3/23/2001 19:55	0.037	0.3	2	2752
3/23/2001 20:00	0.041	0.4	2	2748
3/23/2001 20:05	0.038	0.3	2	2744
3/23/2001 20:10	0.037	0.3	2	2740
3/23/2001 20:15	0.041	0.4	2	2734
3/23/2001 20:20	0.041	0.4	2	2730
3/23/2001 20:25	0.036	0.3	2	2726
3/23/2001 20:30	0.042	0.4	2	2722
3/23/2001 20:35	0.035	0.3	2	2716
3/23/2001 20:40	0.043	0.4	2	2712
3/23/2001 20:45	0.042	0.4	2	2708
3/23/2001 20:50	0.042	0.4	2	2704
3/23/2001 20:55	0.039	0.3	2	2700
3/23/2001 21:00	0.041	0.4	2	2696
3/23/2001 21:05	0.04	0.4	2	2692
3/23/2001 21:10	0.042	0.4	2	2688
3/23/2001 21:15	0.043	0.4	2	2684
3/23/2001 21:20	0.04	0.4	2	2682
3/23/2001 21:25	0.043	0.4	2	2678
3/23/2001 21:30	0.037	0.3	2	2672
3/23/2001 21:35	0.042	0.4	2	2668
3/23/2001 21:40	0.041	0.4	2	2662
3/23/2001 21:45	0.041	0.4	2	2660
3/23/2001 21:50	0.038	0.3	2	2656
3/23/2001 21:55	0.04	0.4	2	2650
3/23/2001 22:00	0.039	0.3	2	2646
3/23/2001 22:05	0.035	0.3	1	2642
3/23/2001 22:10	0.037	0.3	1	2636
3/23/2001 22:15	0.035	0.3	1	2632
3/23/2001 22:20	0.035	0.3	1	2630
3/23/2001 22:25	0.033	0.2	1	2626
3/23/2001 22:30	0.033	0.2	1	2626

3/23/2001 22:35	0.035	0.3	1	2624
3/23/2001 22:40	0.031	0.2	1	2620
3/23/2001 22:45	0.04	0.4	1	2622
3/23/2001 22:50	0.03	0.2	1	2622
3/23/2001 22:55	0.033	0.2	1	2620
3/23/2001 23:00	0.039	0.3	1	2612
3/23/2001 23:05	0.035	0.3	1	2606
3/23/2001 23:10	0.031	0.2	1	2600
3/23/2001 23:15	0.03	0.2	1	2598
3/23/2001 23:20	0.03	0.2	1	2592
3/23/2001 23:25	0.027	0.1	1	2588
3/23/2001 23:30	0.031	0.2	1	2584
3/23/2001 23:35	0.03	0.2	1	2578
3/23/2001 23:40	0.034	0.2	1	2574
3/23/2001 23:45	0.039	0.3	1	2572
3/23/2001 23:50	0.027	0.1	1	2570
3/23/2001 23:55	0.028	0.1	1	2566
3/24/2001	0.033	0.2	1	2564
3/24/2001 0:05	0.024	0.1	1	2560
3/24/2001 0:10	0.03	0.2	1	2560
3/24/2001 0:15	0.03	0.2	1	2556
3/24/2001 0:20	0.024	0.1	1	2554
3/24/2001 0:25	0.028	0.1	1	2550
3/24/2001 0:30	0.029	0.2	1	2548
3/24/2001 0:35	0.027	0.1	1	2546
3/24/2001 0:40	0.027	0.1	1	2544
3/24/2001 0:45	0.027	0.1	1	2542
3/24/2001 0:50	0.026	0.1	1	2540
3/24/2001 0:55	0.032	0.2	1	2538
3/24/2001 1:00	0.029	0.2	1	2536
3/24/2001 1:05	0.024	0.1	1	2534
3/24/2001 1:10	0.03	0.2	1	2530
3/24/2001 1:15	0.028	0.1	1	2528
3/24/2001 1:20	0.024	0.1	1	2526
3/24/2001 1:25	0.026	0.1	1	2524
3/24/2001 1:30	0.026	0.1	1	2522
3/24/2001 1:35	0.026	0.1	1	2518
3/24/2001 1:40	0.027	0.1	1	2514
3/24/2001 1:45	0.027	0.1	1	2510
3/24/2001 1:50	0.022	0.1	1	2504
3/24/2001 1:55	0.029	0.2	1	2500
3/24/2001 2:00	0.028	0.1	1	2498
3/24/2001 2:05	0.025	0.1	1	2494
3/24/2001 2:10	0.02	0.1	0	2492

Seasonal Sampling (May - Nov) June 2001

Delta Time	5
StormStart	31
Storm End	185
CP Max	270
Rule Average	0.66
Storm Average	1.09
Rule Volume	196117
Storm Total Vol.	141752
Volume A	83002
Volume B	113114
Flux Rule	4.41
Flux Storm	26.24

Flux A	6.78E+05
Flux B	1.88E+05
Cm Max	270
Q Max	2394
TC Max	31
Storm Length	154
Manual Length	239

Storm Duration Err.	5.52E-01
Concentration Err.	0.00E+00

Bottle #	Flow	Cond.
1	50	270
2	2031	158
3	1170	90
4	1335	84
5	578	86
6	734	104
7	792	106
8	187	128
9	202	196
10	142	204
11	21	210
12	7	216
13	3	222
14	3	228
15	2	234
16	2	240
17	1	244
18	1	250
19	1	250
20	2	250
21	1	248
22	2	250
23	3	252
24	0	252

Date/Time	Level (ft)	Flow (GPM)	Flow Volume (gal)	Cond (uS/cm)
6/17/2001 15:40	0	0	0	0
6/17/2001 15:45	0	0	0	0
6/17/2001 15:50	0	0	0	0
6/17/2001 15:55	0	0	0	0
6/17/2001 16:00	0	0	0	0
6/17/2001 16:05	0	0	0	0
6/17/2001 16:10	0	0	0	0
6/17/2001 16:15	0	0	0	0
6/17/2001 16:20	0	0	0	0
6/17/2001 16:25	0	0	0	0
6/17/2001 16:30	0	0	0	0
6/17/2001 16:35	0	0	0	0
6/17/2001 16:40	0	0	0	0
6/17/2001 16:45	0	0	0	0
6/17/2001 16:50	0	0	0	0
6/17/2001 16:55	0	0	0	0
6/17/2001 17:00	0	0	0	0
6/17/2001 17:05	0	0	0	0
6/17/2001 17:10	0	0	0	0
6/17/2001 17:15	0	0	0	0
6/17/2001 17:20	0	0	0	0
6/17/2001 17:25	0	0	0	0
6/17/2001 17:30	0	0	0	0
6/17/2001 17:35	0	0	0	0
6/17/2001 17:40	0	0	0	0
6/17/2001 17:45	0	0	0	0
6/17/2001 17:50	0	0	0	0
6/17/2001 17:55	0.014	0.0	0	272
6/17/2001 18:00	0.057	0.9	2	272
6/17/2001 18:05	0.098	3.4	11	272
6/17/2001 18:10	0.288	49.9	133	270
6/17/2001 18:15	0.8	642.3	1731	256
6/17/2001 18:20	1.354	2393.5	7590	196
6/17/2001 18:25	1.268	2031.4	11062	158
6/17/2001 18:30	1.051	1270.6	8255	118
6/17/2001 18:35	1.025	1193.4	6160	96
6/17/2001 18:40	1.017	1170.3	5909	90
6/17/2001 18:45	1.039	1234.6	6012	94
6/17/2001 18:50	1.133	1533.1	6919	86
6/17/2001 18:55	1.072	1335.0	7170	84
6/17/2001 19:00	0.951	989.6	5811	82
6/17/2001 19:05	0.837	719.1	4272	84
6/17/2001 19:10	0.767	578.1	3243	86
6/17/2001 19:15	0.802	646.3	3061	90
6/17/2001 19:20	0.848	743.0	3473	96
6/17/2001 19:25	0.844	734.3	3693	104
6/17/2001 19:30	0.87	792.1	3816	106
6/17/2001 19:35	0.864	778.5	3927	102
6/17/2001 19:40	0.808	658.4	3592	100
6/17/2001 19:45	0.744	535.7	2985	100
6/17/2001 19:50	0.736	521.4	2643	100
6/17/2001 19:55	0.715	485.0	2516	100
6/17/2001 20:00	0.683	432.6	2294	100
6/17/2001 20:05	0.644	373.4	2015	104
6/17/2001 20:10	0.609	324.7	1745	108
6/17/2001 20:15	0.573	278.9	1509	112
6/17/2001 20:20	0.547	248.3	1318	114
6/17/2001 20:25	0.529	228.4	1192	120
6/17/2001 20:30	0.505	203.3	1079	124
6/17/2001 20:35	0.488	186.7	975	128
6/17/2001 20:40	0.459	160.1	867	132
6/17/2001 20:45	0.428	134.5	737	136
6/17/2001 20:50	0.401	114.2	622	140
6/17/2001 20:55	0.381	100.5	537	144
6/17/2001 21:00	0.364	89.7	476	148
6/17/2001 21:05	0.36	87.2	442	152
6/17/2001 21:10	0.356	84.8	430	156
6/17/2001 21:15	0.356	84.8	424	158
6/17/2001 21:20	0.389	105.9	477	162
6/17/2001 21:25	0.435	140.0	615	168
6/17/2001 21:30	0.473	172.6	782	178
6/17/2001 21:35	0.499	197.4	925	188
6/17/2001 21:40	0.504	202.3	999	196
6/17/2001 21:45	0.497	195.4	994	202
6/17/2001 21:50	0.499	197.4	982	210
6/17/2001 21:55	0.496	194.4	979	216
6/17/2001 22:00	0.495	193.4	970	222

6/17/2001 22:05	0.495	193.4	967	224
6/17/2001 22:10	0.484	182.9	941	224
6/17/2001 22:15	0.476	175.4	896	222
6/17/2001 22:20	0.471	170.8	866	220
6/17/2001 22:25	0.477	176.3	868	218
6/17/2001 22:30	0.472	171.7	870	214
6/17/2001 22:35	0.47	169.9	854	210
6/17/2001 22:40	0.459	160.1	825	206
6/17/2001 22:45	0.438	142.5	757	204
6/17/2001 22:50	0.409	120.0	656	202
6/17/2001 22:55	0.386	103.9	560	202
6/17/2001 23:00	0.361	87.9	479	202
6/17/2001 23:05	0.331	70.7	396	202
6/17/2001 23:10	0.315	62.5	333	204
6/17/2001 23:15	0.292	51.7	285	204
6/17/2001 23:20	0.274	44.1	239	204
6/17/2001 23:25	0.258	37.9	205	206
6/17/2001 23:30	0.243	32.7	176	206
6/17/2001 23:35	0.23	28.5	153	208
6/17/2001 23:40	0.219	25.2	134	208
6/17/2001 23:45	0.209	22.4	119	210
6/17/2001 23:50	0.203	20.8	108	210
6/17/2001 23:55	0.196	19.1	100	210
6/18/2001	0.189	17.4	91	212
6/18/2001 0:05	0.184	16.3	84	212
6/18/2001 0:10	0.178	15.0	78	212
6/18/2001 0:15	0.171	13.6	71	212
6/18/2001 0:20	0.163	12.0	64	212
6/18/2001 0:25	0.16	11.5	59	214
6/18/2001 0:30	0.151	9.9	54	214
6/18/2001 0:35	0.139	8.1	45	214
6/18/2001 0:40	0.136	7.7	39	214
6/18/2001 0:45	0.127	6.4	35	214
6/18/2001 0:50	0.126	6.3	32	216
6/18/2001 0:55	0.128	6.6	32	216
6/18/2001 1:00	0.119	5.5	30	216
6/18/2001 1:05	0.116	5.1	27	216
6/18/2001 1:10	0.115	5.0	25	216
6/18/2001 1:15	0.113	4.8	25	218
6/18/2001 1:20	0.112	4.7	24	218
6/18/2001 1:25	0.11	4.5	23	218
6/18/2001 1:30	0.11	4.5	23	220
6/18/2001 1:35	0.106	4.1	22	220
6/18/2001 1:40	0.104	3.9	20	220
6/18/2001 1:45	0.098	3.4	18	220
6/18/2001 1:50	0.097	3.3	17	222
6/18/2001 1:55	0.096	3.2	16	222
6/18/2001 2:00	0.096	3.2	16	222
6/18/2001 2:05	0.094	3.0	16	222
6/18/2001 2:10	0.091	2.8	15	222
6/18/2001 2:15	0.093	3.0	14	224
6/18/2001 2:20	0.089	2.7	14	224
6/18/2001 2:25	0.093	3.0	14	224
6/18/2001 2:30	0.087	2.5	14	224
6/18/2001 2:35	0.086	2.4	12	224
6/18/2001 2:40	0.091	2.8	13	226
6/18/2001 2:45	0.089	2.7	14	226
6/18/2001 2:50	0.091	2.8	14	226
6/18/2001 2:55	0.09	2.7	14	226
6/18/2001 3:00	0.089	2.7	13	226
6/18/2001 3:05	0.092	2.9	14	228
6/18/2001 3:10	0.09	2.7	14	228
6/18/2001 3:15	0.089	2.7	13	228
6/18/2001 3:20	0.082	2.2	12	230
6/18/2001 3:25	0.086	2.4	11	230
6/18/2001 3:30	0.091	2.8	13	230
6/18/2001 3:35	0.092	2.9	14	230
6/18/2001 3:40	0.091	2.8	14	232
6/18/2001 3:45	0.087	2.5	13	232
6/18/2001 3:50	0.089	2.7	13	232
6/18/2001 3:55	0.087	2.5	13	232
6/18/2001 4:00	0.081	2.1	12	234
6/18/2001 4:05	0.083	2.2	11	234
6/18/2001 4:10	0.081	2.1	11	234
6/18/2001 4:15	0.081	2.1	10	236
6/18/2001 4:20	0.079	2.0	10	236
6/18/2001 4:25	0.082	2.2	10	236
6/18/2001 4:30	0.079	2.0	10	236
6/18/2001 4:35	0.079	2.0	10	236
6/18/2001 4:40	0.079	2.0	10	236

6/18/2001 4:45	0.077	1.8	10	238
6/18/2001 4:50	0.079	2.0	10	238
6/18/2001 4:55	0.076	1.8	9	238
6/18/2001 5:00	0.079	2.0	9	238
6/18/2001 5:05	0.084	2.3	11	240
6/18/2001 5:10	0.079	2.0	11	240
6/18/2001 5:15	0.083	2.2	10	240
6/18/2001 5:20	0.078	1.9	10	240
6/18/2001 5:25	0.079	2.0	10	240
6/18/2001 5:30	0.082	2.2	10	242
6/18/2001 5:35	0.082	2.2	11	242
6/18/2001 5:40	0.08	2.0	10	242
6/18/2001 5:45	0.075	1.7	9	242
6/18/2001 5:50	0.07	1.5	8	242
6/18/2001 5:55	0.07	1.5	7	244
6/18/2001 6:00	0.071	1.5	7	244
6/18/2001 6:05	0.071	1.5	8	244
6/18/2001 6:10	0.07	1.5	7	244
6/18/2001 6:15	0.068	1.4	7	244
6/18/2001 6:20	0.07	1.5	7	244
6/18/2001 6:25	0.068	1.4	7	244
6/18/2001 6:30	0.066	1.3	7	244
6/18/2001 6:35	0.064	1.2	6	244
6/18/2001 6:40	0.065	1.2	6	246
6/18/2001 6:45	0.063	1.1	6	246
6/18/2001 6:50	0.064	1.2	6	248
6/18/2001 6:55	0.062	1.1	6	248
6/18/2001 7:00	0.054	0.8	5	248
6/18/2001 7:05	0.056	0.8	4	248
6/18/2001 7:10	0.062	1.1	5	250
6/18/2001 7:15	0.06	1.0	5	250
6/18/2001 7:20	0.06	1.0	5	250
6/18/2001 7:25	0.062	1.1	5	250
6/18/2001 7:30	0.056	0.8	5	250
6/18/2001 7:35	0.059	0.9	4	250
6/18/2001 7:40	0.06	1.0	5	250
6/18/2001 7:45	0.055	0.8	4	250
6/18/2001 7:50	0.056	0.8	4	252
6/18/2001 7:55	0.06	1.0	5	252
6/18/2001 8:00	0.058	0.9	5	252
6/18/2001 8:05	0.058	0.9	5	252
6/18/2001 8:10	0.058	0.9	5	252
6/18/2001 8:15	0.072	1.6	6	252
6/18/2001 8:20	0.06	1.0	6	252
6/18/2001 8:25	0.062	1.1	5	252
6/18/2001 8:30	0.058	0.9	5	250
6/18/2001 8:35	0.056	0.8	4	250
6/18/2001 8:40	0.057	0.9	4	250
6/18/2001 8:45	0.077	1.8	7	250
6/18/2001 8:50	0.059	0.9	7	250
6/18/2001 8:55	0.064	1.2	5	250
6/18/2001 9:00	0.095	3.1	11	250
6/18/2001 9:05	0.07	1.5	11	250
6/18/2001 9:10	0.062	1.1	6	250
6/18/2001 9:15	0.096	3.2	11	250
6/18/2001 9:20	0.058	0.9	10	250
6/18/2001 9:25	0.06	1.0	5	250
6/18/2001 9:30	0.1	3.5	11	250
6/18/2001 9:35	0.076	1.8	13	250
6/18/2001 9:40	0.068	1.4	8	250
6/18/2001 9:45	0.075	1.7	8	250
6/18/2001 9:50	0.061	1.0	7	250
6/18/2001 9:55	0.062	1.1	5	250
6/18/2001 10:00	0.098	3.4	11	250
6/18/2001 10:05	0.06	1.0	11	250
6/18/2001 10:10	0.064	1.2	5	250
6/18/2001 10:15	0.1	3.5	12	250
6/18/2001 10:20	0.063	1.1	12	248
6/18/2001 10:25	0.056	0.8	5	248
6/18/2001 10:30	0.106	4.1	12	248
6/18/2001 10:35	0.064	1.2	13	248
6/18/2001 10:40	0.06	1.0	5	248
6/18/2001 10:45	0.092	2.9	10	250
6/18/2001 10:50	0.102	3.7	17	250
6/18/2001 10:55	0.056	0.8	11	248
6/18/2001 11:00	0.089	2.7	9	248
6/18/2001 11:05	0.096	3.2	15	248
6/18/2001 11:10	0.056	0.8	10	250
6/18/2001 11:15	0.1	3.5	11	250
6/18/2001 11:20	0.112	4.7	21	250

6/18/2001 11:25	0.061	1.0	14	250
6/18/2001 11:30	0.087	2.5	9	250
6/18/2001 11:35	0.097	3.3	14	250
6/18/2001 11:40	0.049	0.6	10	250
6/18/2001 11:45	0.084	2.3	7	250
6/18/2001 11:50	0.053	0.7	8	250
6/18/2001 11:55	0.051	0.7	3	250
6/18/2001 12:00	0.093	3.0	9	250
6/18/2001 12:05	0.046	0.5	9	250
6/18/2001 12:10	0.045	0.5	2	250
6/18/2001 12:15	0.044	0.5	2	250
6/18/2001 12:20	0.043	0.4	2	250
6/18/2001 12:25	0.045	0.5	2	250
6/18/2001 12:30	0.08	2.0	6	250
6/18/2001 12:35	0.053	0.7	7	250
6/18/2001 12:40	0.05	0.6	3	252
6/18/2001 12:45	0.051	0.7	3	252
6/18/2001 12:50	0.096	3.2	10	252
6/18/2001 12:55	0.043	0.4	9	252
6/18/2001 13:00	0.065	1.2	4	252
6/18/2001 13:05	0.044	0.5	4	252
6/18/2001 13:10	0.043	0.4	2	252
6/18/2001 13:15	0.085	2.4	7	252
6/18/2001 13:20	0.079	2.0	11	252
6/18/2001 13:25	0.041	0.4	6	252
6/18/2001 13:30	0.08	2.0	6	252
6/18/2001 13:35	0.043	0.4	6	252
6/18/2001 13:40	0.041	0.4	2	252
6/18/2001 13:45	0.077	1.8	6	252
6/18/2001 13:50	0.02	0.1	5	252
6/18/2001 13:55	0	0.0	0	252

Seasonal Sampling (December through April) March 2001

Delta Time	5
StormStart	30
Storm End	492
CP Max	6310
Rule Average	6.08
Storm Average	10.75
Rule Volume	284368
Storm Total Vol.	290569
Volume A	36309
Volume B	248059
Flux Rule	14.57
Flux Storm	108.00
Flux A	2.98E+06
Flux B	1.16E+06
Cm Max	6310
Q Max	646
TC Max	30
Storm Length	462
Manual Length	467
Storm Duration Err.	1.08E-02
Concentration Err.	0.00E+00

Bottle #	Flow	Cond.
1	36	6310
2	261	3818
3	289	1692
4	223	1112
5	195	978
6	205	946
7	242	906
8	202	848
9	321	756
10	349	720
11	414	520
12	203	340
13	300	272
14	340	248
15	266	310
16	132	410
17	529	312
18	146	366
19	14	526
20	8	840
21	14	1064
22	32	1570
23	9	1922
24	5	2008

Date/Time	Level (ft)	Flow (GPM)	Flow Volume (gal)	Cond (uS/cm)
3/21/2001 17:30	0	0	0	0
3/21/2001 17:35	0	0	0	0
3/21/2001 17:40	0	0	0	0
3/21/2001 17:45	0	0	0	0
3/21/2001 17:50	0	0	0	0
3/21/2001 17:55	0	0	0	0
3/21/2001 18:00	0	0	0	0
3/21/2001 18:05	0	0	0	0
3/21/2001 18:10	0	0	0	0
3/21/2001 18:15	0	0	0	0
3/21/2001 18:20	0	0	0	0
3/21/2001 18:25	0	0	0	0
3/21/2001 18:30	0	0	0	0
3/21/2001 18:35	0	0	0	0
3/21/2001 18:40	0	0	0	0
3/21/2001 18:45	0	0	0	0
3/21/2001 18:50	0	0	0	0
3/21/2001 18:55	0	0	0	0
3/21/2001 19:00	0	0	0	0
3/21/2001 19:05	0	0	0	0
3/21/2001 19:10	0	0	0	0
3/21/2001 19:15	0	0	0	0
3/21/2001 19:20	0	0	0	0
3/21/2001 19:25	0	0	0	0
3/21/2001 19:30	0	0	0	0
3/21/2001 19:35	0	0	0	0
3/21/2001 19:40	0	0	0	0
3/21/2001 19:45	0	0.0	0	6434
3/21/2001 19:50	0.098	3.4	8	6450
3/21/2001 19:55	0.253	36.1	99	6310
3/21/2001 20:00	0.421	129.0	413	3688
3/21/2001 20:05	0.52	218.8	870	2870
3/21/2001 20:10	0.552	254.0	1182	3696
3/21/2001 20:15	0.558	261.0	1287	3818
3/21/2001 20:20	0.588	297.5	1396	3230
3/21/2001 20:25	0.609	324.7	1556	2298
3/21/2001 20:30	0.604	318.1	1607	1948
3/21/2001 20:35	0.581	288.7	1517	1692
3/21/2001 20:40	0.551	252.9	1354	1496
3/21/2001 20:45	0.537	237.1	1225	1344
3/21/2001 20:50	0.531	230.5	1169	1200
3/21/2001 20:55	0.524	223.0	1134	1112
3/21/2001 21:00	0.52	218.8	1104	1070
3/21/2001 21:05	0.515	213.6	1081	1012
3/21/2001 21:10	0.508	206.4	1050	990
3/21/2001 21:15	0.497	195.4	1004	978
3/21/2001 21:20	0.503	201.3	992	972
3/21/2001 21:25	0.508	206.4	1019	970
3/21/2001 21:30	0.505	203.3	1024	954
3/21/2001 21:35	0.507	205.4	1022	946
3/21/2001 21:40	0.517	215.6	1052	952
3/21/2001 21:45	0.533	232.7	1121	932
3/21/2001 21:50	0.539	239.3	1180	908
3/21/2001 21:55	0.541	241.5	1202	906
3/21/2001 22:00	0.541	241.5	1208	896
3/21/2001 22:05	0.533	232.7	1186	876
3/21/2001 22:10	0.518	216.7	1123	860
3/21/2001 22:15	0.504	202.3	1048	848
3/21/2001 22:20	0.497	195.4	994	840
3/21/2001 22:25	0.507	205.4	1002	824
3/21/2001 22:30	0.555	257.5	1157	804
3/21/2001 22:35	0.606	320.8	1446	756
3/21/2001 22:40	0.627	349.3	1675	720
3/21/2001 22:45	0.615	332.8	1705	718
3/21/2001 22:50	0.589	298.7	1579	702
3/21/2001 22:55	0.558	261.0	1399	676
3/21/2001 23:00	0.53	229.4	1226	648
3/21/2001 23:05	0.509	207.4	1092	636
3/21/2001 23:10	0.496	194.4	1004	632
3/21/2001 23:15	0.494	192.4	967	632
3/21/2001 23:20	0.497	195.4	970	634
3/21/2001 23:25	0.497	195.4	977	644
3/21/2001 23:30	0.506	204.3	999	660
3/21/2001 23:35	0.533	232.7	1093	674
3/21/2001 23:40	0.587	296.2	1322	668
3/21/2001 23:45	0.612	328.8	1562	630
3/21/2001 23:50	0.598	310.3	1598	628

3/21/2001 23:55	0.607	322.1	1581	648
3/22/2001	0.657	392.6	1787	596
3/22/2001 0:05	0.671	413.8	2016	520
3/22/2001 0:10	0.703	464.9	2197	516
3/22/2001 0:15	0.752	550.2	2538	454
3/22/2001 0:20	0.771	585.6	2840	406
3/22/2001 0:25	0.754	553.9	2849	378
3/22/2001 0:30	0.72	493.5	2619	350
3/22/2001 0:35	0.669	410.7	2261	332
3/22/2001 0:40	0.657	392.6	2008	324
3/22/2001 0:45	0.62	339.6	1830	316
3/22/2001 0:50	0.585	293.7	1583	316
3/22/2001 0:55	0.587	296.2	1475	330
3/22/2001 1:00	0.668	409.2	1764	342
3/22/2001 1:05	0.742	532.1	2353	322
3/22/2001 1:10	0.753	552.1	2710	332
3/22/2001 1:15	0.692	446.9	2498	344
3/22/2001 1:20	0.614	331.4	1946	344
3/22/2001 1:25	0.552	254.0	1464	342
3/22/2001 1:30	0.505	203.3	1143	340
3/22/2001 1:35	0.55	251.7	1138	342
3/22/2001 1:40	0.637	363.4	1538	344
3/22/2001 1:45	0.731	512.6	2190	328
3/22/2001 1:50	0.747	541.1	2634	348
3/22/2001 1:55	0.73	510.9	2630	348
3/22/2001 2:00	0.715	485.0	2490	328
3/22/2001 2:05	0.719	491.8	2442	306
3/22/2001 2:10	0.754	553.9	2614	282
3/22/2001 2:15	0.802	646.3	3000	262
3/22/2001 2:20	0.783	608.7	3137	252
3/22/2001 2:25	0.746	539.3	2870	250
3/22/2001 2:30	0.713	481.6	2552	242
3/22/2001 2:35	0.682	431.0	2282	240
3/22/2001 2:40	0.689	442.1	2183	244
3/22/2001 2:45	0.676	421.6	2159	250
3/22/2001 2:50	0.636	361.9	1959	258
3/22/2001 2:55	0.59	300.0	1655	272
3/22/2001 3:00	0.58	287.5	1469	286
3/22/2001 3:05	0.596	307.7	1488	300
3/22/2001 3:10	0.628	350.7	1646	296
3/22/2001 3:15	0.678	424.7	1938	310
3/22/2001 3:20	0.726	503.9	2321	310
3/22/2001 3:25	0.741	530.3	2586	304
3/22/2001 3:30	0.736	521.4	2629	300
3/22/2001 3:35	0.713	481.6	2508	286
3/22/2001 3:40	0.686	437.3	2297	276
3/22/2001 3:45	0.669	410.7	2120	270
3/22/2001 3:50	0.687	438.9	2124	262
3/22/2001 3:55	0.724	500.4	2348	258
3/22/2001 4:00	0.762	568.7	2673	256
3/22/2001 4:05	0.762	568.7	2843	256
3/22/2001 4:10	0.739	526.7	2739	250
3/22/2001 4:15	0.68	427.8	2386	246
3/22/2001 4:20	0.62	339.6	1919	248
3/22/2001 4:25	0.59	300.0	1599	250
3/22/2001 4:30	0.589	298.7	1497	256
3/22/2001 4:35	0.603	316.8	1539	260
3/22/2001 4:40	0.656	391.1	1770	272
3/22/2001 4:45	0.713	481.6	2182	276
3/22/2001 4:50	0.735	519.7	2503	278
3/22/2001 4:55	0.726	503.9	2559	282
3/22/2001 5:00	0.713	481.6	2464	276
3/22/2001 5:05	0.689	442.1	2309	266
3/22/2001 5:10	0.663	401.6	2109	262
3/22/2001 5:15	0.626	347.9	1874	260
3/22/2001 5:20	0.593	303.8	1629	266
3/22/2001 5:25	0.58	287.5	1478	272
3/22/2001 5:30	0.585	293.7	1453	280
3/22/2001 5:35	0.594	305.1	1497	290
3/22/2001 5:40	0.594	305.1	1526	296
3/22/2001 5:45	0.562	265.7	1427	310
3/22/2001 5:50	0.537	237.1	1257	326
3/22/2001 5:55	0.518	216.7	1134	340
3/22/2001 6:00	0.521	219.8	1091	352
3/22/2001 6:05	0.526	225.1	1112	358
3/22/2001 6:10	0.52	218.8	1110	362
3/22/2001 6:15	0.518	216.7	1089	380
3/22/2001 6:20	0.528	227.3	1110	402
3/22/2001 6:25	0.554	256.3	1209	412
3/22/2001 6:30	0.589	298.7	1388	408

3/22/2001 6:35	0.619	338.2	1592	400
3/22/2001 6:40	0.621	341.0	1698	408
3/22/2001 6:45	0.603	316.8	1644	410
3/22/2001 6:50	0.567	271.6	1471	408
3/22/2001 6:55	0.542	242.7	1286	406
3/22/2001 7:00	0.501	199.3	1105	404
3/22/2001 7:05	0.467	167.2	916	404
3/22/2001 7:10	0.425	132.1	748	410
3/22/2001 7:15	0.389	105.9	595	414
3/22/2001 7:20	0.356	84.8	477	422
3/22/2001 7:25	0.332	71.3	390	430
3/22/2001 7:30	0.32	65.0	341	438
3/22/2001 7:35	0.312	61.0	315	452
3/22/2001 7:40	0.328	69.1	325	464
3/22/2001 7:45	0.384	102.5	429	490
3/22/2001 7:50	0.437	141.6	610	536
3/22/2001 7:55	0.52	218.8	901	552
3/22/2001 8:00	0.631	354.9	1434	564
3/22/2001 8:05	0.692	446.9	2005	526
3/22/2001 8:10	0.707	471.6	2296	526
3/22/2001 8:15	0.697	455.1	2317	488
3/22/2001 8:20	0.694	450.2	2263	440
3/22/2001 8:25	0.715	485.0	2338	390
3/22/2001 8:30	0.747	541.1	2565	336
3/22/2001 8:35	0.74	528.5	2674	312
3/22/2001 8:40	0.734	517.9	2616	306
3/22/2001 8:45	0.722	497.0	2537	300
3/22/2001 8:50	0.696	453.4	2376	296
3/22/2001 8:55	0.661	398.6	2130	294
3/22/2001 9:00	0.679	426.3	2062	292
3/22/2001 9:05	0.694	450.2	2191	278
3/22/2001 9:10	0.665	404.6	2137	278
3/22/2001 9:15	0.64	367.7	1931	296
3/22/2001 9:20	0.642	370.5	1845	300
3/22/2001 9:25	0.616	334.2	1762	296
3/22/2001 9:30	0.583	291.2	1563	302
3/22/2001 9:35	0.546	247.2	1346	312
3/22/2001 9:40	0.516	214.6	1154	318
3/22/2001 9:45	0.495	193.4	1020	322
3/22/2001 9:50	0.482	181.0	936	332
3/22/2001 9:55	0.465	165.4	866	348
3/22/2001 10:00	0.442	145.7	778	366
3/22/2001 10:05	0.413	123.0	672	378
3/22/2001 10:10	0.382	101.2	560	390
3/22/2001 10:15	0.35	81.3	456	404
3/22/2001 10:20	0.327	68.6	375	416
3/22/2001 10:25	0.301	55.8	311	430
3/22/2001 10:30	0.27	42.5	246	448
3/22/2001 10:35	0.253	36.1	197	458
3/22/2001 10:40	0.236	30.4	166	466
3/22/2001 10:45	0.219	25.2	139	472
3/22/2001 10:50	0.209	22.4	119	480
3/22/2001 10:55	0.196	19.1	104	486
3/22/2001 11:00	0.184	16.3	88	494
3/22/2001 11:05	0.177	14.8	78	500
3/22/2001 11:10	0.173	14.0	72	504
3/22/2001 11:15	0.17	13.4	68	510
3/22/2001 11:20	0.173	14.0	68	518
3/22/2001 11:25	0.173	14.0	70	526
3/22/2001 11:30	0.175	14.4	71	534
3/22/2001 11:35	0.178	15.0	73	544
3/22/2001 11:40	0.177	14.8	74	550
3/22/2001 11:45	0.18	15.4	76	562
3/22/2001 11:50	0.181	15.6	78	574
3/22/2001 11:55	0.18	15.4	78	584
3/22/2001 12:00	0.175	14.4	74	594
3/22/2001 12:05	0.171	13.6	70	614
3/22/2001 12:10	0.166	12.6	65	624
3/22/2001 12:15	0.163	12.0	62	628
3/22/2001 12:20	0.156	10.8	57	664
3/22/2001 12:25	0.154	10.4	53	716
3/22/2001 12:30	0.15	9.8	51	756
3/22/2001 12:35	0.145	9.0	47	772
3/22/2001 12:40	0.142	8.5	44	790
3/22/2001 12:45	0.138	7.9	41	818
3/22/2001 12:50	0.137	7.8	39	840
3/22/2001 12:55	0.134	7.4	38	874
3/22/2001 13:00	0.131	7.0	36	904
3/22/2001 13:05	0.127	6.4	34	928
3/22/2001 13:10	0.13	6.8	33	946

3/22/2001 13:15	0.132	7.1	35	962
3/22/2001 13:20	0.135	7.5	37	976
3/22/2001 13:25	0.143	8.7	40	988
3/22/2001 13:30	0.159	11.3	50	1000
3/22/2001 13:35	0.17	13.4	62	1016
3/22/2001 13:40	0.175	14.4	69	1032
3/22/2001 13:45	0.192	18.1	81	1038
3/22/2001 13:50	0.187	17.0	88	1040
3/22/2001 13:55	0.184	16.3	83	1042
3/22/2001 14:00	0.183	16.1	81	1044
3/22/2001 14:05	0.175	14.4	76	1048
3/22/2001 14:10	0.169	13.2	69	1054
3/22/2001 14:15	0.174	14.2	68	1064
3/22/2001 14:20	0.167	12.8	67	1158
3/22/2001 14:25	0.163	12.0	62	1300
3/22/2001 14:30	0.156	10.8	57	1380
3/22/2001 14:35	0.147	9.3	50	1426
3/22/2001 14:40	0.148	9.5	47	1450
3/22/2001 14:45	0.142	8.5	45	1468
3/22/2001 14:50	0.14	8.2	42	1484
3/22/2001 14:55	0.139	8.1	41	1494
3/22/2001 15:00	0.135	7.5	39	1504
3/22/2001 15:05	0.133	7.2	37	1510
3/22/2001 15:10	0.13	6.8	35	1518
3/22/2001 15:15	0.128	6.6	34	1524
3/22/2001 15:20	0.133	7.2	35	1528
3/22/2001 15:25	0.154	10.4	44	1536
3/22/2001 15:30	0.189	17.4	70	1544
3/22/2001 15:35	0.22	25.5	107	1558
3/22/2001 15:40	0.241	32.0	144	1570
3/22/2001 15:45	0.25	35.1	168	1540
3/22/2001 15:50	0.255	36.8	180	1430
3/22/2001 15:55	0.249	34.7	179	1396
3/22/2001 16:00	0.241	32.0	167	1420
3/22/2001 16:05	0.232	29.1	153	1558
3/22/2001 16:10	0.221	25.8	137	1678
3/22/2001 16:15	0.209	22.4	120	1774
3/22/2001 16:20	0.201	20.3	107	1802
3/22/2001 16:25	0.189	17.4	94	1822
3/22/2001 16:30	0.183	16.1	84	1840
3/22/2001 16:35	0.177	14.8	77	1852
3/22/2001 16:40	0.169	13.2	70	1854
3/22/2001 16:45	0.165	12.4	64	1864
3/22/2001 16:50	0.159	11.3	59	1878
3/22/2001 16:55	0.152	10.1	54	1898
3/22/2001 17:00	0.15	9.8	50	1916
3/22/2001 17:05	0.148	9.5	48	1922
3/22/2001 17:10	0.144	8.8	46	1928
3/22/2001 17:15	0.141	8.4	43	1946
3/22/2001 17:20	0.139	8.1	41	1964
3/22/2001 17:25	0.136	7.7	39	1976
3/22/2001 17:30	0.135	7.5	38	1984
3/22/2001 17:35	0.134	7.4	37	1992
3/22/2001 17:40	0.131	7.0	36	2000
3/22/2001 17:45	0.129	6.7	34	2006
3/22/2001 17:50	0.127	6.4	33	2008
3/22/2001 17:55	0.125	6.2	32	2012
3/22/2001 18:00	0.124	6.1	31	2012
3/22/2001 18:05	0.123	6.0	30	2016
3/22/2001 18:10	0.118	5.4	28	2016
3/22/2001 18:15	0.118	5.4	27	2014
3/22/2001 18:20	0.118	5.4	27	2012
3/22/2001 18:25	0.115	5.0	26	2010
3/22/2001 18:30	0.115	5.0	25	2008
3/22/2001 18:35	0.114	4.9	25	2012
3/22/2001 18:40	0.11	4.5	24	2010
3/22/2001 18:45	0.111	4.6	23	2008
3/22/2001 18:50	0.112	4.7	23	2008
3/22/2001 18:55	0.11	4.5	23	2006
3/22/2001 19:00	0.11	4.5	23	2004
3/22/2001 19:05	0.11	4.5	23	2002
3/22/2001 19:10	0.108	4.3	22	2002
3/22/2001 19:15	0.108	4.3	22	1996
3/22/2001 19:20	0.108	4.3	22	1992
3/22/2001 19:25	0.107	4.2	21	1986
3/22/2001 19:30	0.106	4.1	21	1982
3/22/2001 19:35	0.107	4.2	21	1982
3/22/2001 19:40	0.106	4.1	21	1978
3/22/2001 19:45	0.104	3.9	20	1972
3/22/2001 19:50	0.106	4.1	20	1964

3/22/2001 19:55	0.102	3.7	20	1956
3/22/2001 20:00	0.104	3.9	19	1948
3/22/2001 20:05	0.102	3.7	19	1940
3/22/2001 20:10	0.1	3.5	18	1932
3/22/2001 20:15	0.101	3.6	18	1924
3/22/2001 20:20	0.102	3.7	18	1916
3/22/2001 20:25	0.102	3.7	19	1908
3/22/2001 20:30	0.1	3.5	18	1898
3/22/2001 20:35	0.1	3.5	18	1890
3/22/2001 20:40	0.098	3.4	17	1880
3/22/2001 20:45	0.1	3.5	17	1870
3/22/2001 20:50	0.1	3.5	18	1858
3/22/2001 20:55	0.098	3.4	17	1848
3/22/2001 21:00	0.098	3.4	17	1838
3/22/2001 21:05	0.099	3.5	17	1830
3/22/2001 21:10	0.099	3.5	17	1826
3/22/2001 21:15	0.098	3.4	17	1828
3/22/2001 21:20	0.098	3.4	17	1822
3/22/2001 21:25	0.098	3.4	17	1816
3/22/2001 21:30	0.096	3.2	16	1814
3/22/2001 21:35	0.096	3.2	16	1812
3/22/2001 21:40	0.095	3.1	16	1812
3/22/2001 21:45	0.094	3.0	15	1812
3/22/2001 21:50	0.094	3.0	15	1810
3/22/2001 21:55	0.093	3.0	15	1812
3/22/2001 22:00	0.091	2.8	14	1810
3/22/2001 22:05	0.091	2.8	14	1810
3/22/2001 22:10	0.09	2.7	14	1808
3/22/2001 22:15	0.089	2.7	13	1806
3/22/2001 22:20	0.089	2.7	13	1806
3/22/2001 22:25	0.089	2.7	13	1804
3/22/2001 22:30	0.088	2.6	13	1804
3/22/2001 22:35	0.087	2.5	13	1804
3/22/2001 22:40	0.085	2.4	12	1804
3/22/2001 22:45	0.087	2.5	12	1802
3/22/2001 22:50	0.086	2.4	12	1798
3/22/2001 22:55	0.083	2.2	12	1800
3/22/2001 23:00	0.084	2.3	11	1796
3/22/2001 23:05	0.084	2.3	11	1794
3/22/2001 23:10	0.083	2.2	11	1794
3/22/2001 23:15	0.083	2.2	11	1790
3/22/2001 23:20	0.083	2.2	11	1786
3/22/2001 23:25	0.081	2.1	11	1782
3/22/2001 23:30	0.082	2.2	11	1780
3/22/2001 23:35	0.082	2.2	11	1776
3/22/2001 23:40	0.081	2.1	11	1776
3/22/2001 23:45	0.081	2.1	10	1772
3/22/2001 23:50	0.081	2.1	10	1770
3/22/2001 23:55	0.079	2.0	10	1768
3/23/2001	0.08	2.0	10	1768
3/23/2001 0:05	0.081	2.1	10	1766
3/23/2001 0:10	0.081	2.1	10	1762
3/23/2001 0:15	0.079	2.0	10	1760
3/23/2001 0:20	0.081	2.1	10	1762
3/23/2001 0:25	0.078	1.9	10	1762
3/23/2001 0:30	0.08	2.0	10	1764
3/23/2001 0:35	0.081	2.1	10	1766
3/23/2001 0:40	0.081	2.1	10	1772
3/23/2001 0:45	0.081	2.1	10	1774
3/23/2001 0:50	0.083	2.2	11	1776
3/23/2001 0:55	0.083	2.2	11	1776
3/23/2001 1:00	0.084	2.3	11	1778
3/23/2001 1:05	0.086	2.4	12	1780
3/23/2001 1:10	0.087	2.5	12	1782
3/23/2001 1:15	0.087	2.5	13	1786
3/23/2001 1:20	0.089	2.7	13	1788
3/23/2001 1:25	0.086	2.4	13	1790
3/23/2001 1:30	0.089	2.7	13	1792
3/23/2001 1:35	0.089	2.7	13	1788
3/23/2001 1:40	0.089	2.7	13	1786
3/23/2001 1:45	0.089	2.7	13	1782
3/23/2001 1:50	0.089	2.7	13	1780
3/23/2001 1:55	0.088	2.6	13	1780
3/23/2001 2:00	0.086	2.4	13	1776
3/23/2001 2:05	0.087	2.5	12	1770
3/23/2001 2:10	0.087	2.5	13	1768
3/23/2001 2:15	0.085	2.4	12	1764
3/23/2001 2:20	0.087	2.5	12	1758
3/23/2001 2:25	0.085	2.4	12	1752
3/23/2001 2:30	0.085	2.4	12	1748

3/23/2001 2:35	0.085	2.4	12	1740
3/23/2001 2:40	0.083	2.2	11	1734
3/23/2001 2:45	0.084	2.3	11	1734
3/23/2001 2:50	0.083	2.2	11	1730
3/23/2001 2:55	0.082	2.2	11	1728
3/23/2001 3:00	0.081	2.1	11	1728
3/23/2001 3:05	0.079	2.0	10	1732
3/23/2001 3:10	0.078	1.9	10	1736
3/23/2001 3:15	0.081	2.1	10	1740
3/23/2001 3:20	0.083	2.2	11	1742
3/23/2001 3:25	0.083	2.2	11	1750
3/23/2001 3:30	0.085	2.4	11	1754
3/23/2001 3:35	0.086	2.4	12	1756
3/23/2001 3:40	0.087	2.5	12	1762
3/23/2001 3:45	0.089	2.7	13	1766
3/23/2001 3:50	0.085	2.4	13	1768
3/23/2001 3:55	0.08	2.0	11	1770
3/23/2001 4:00	0.089	2.7	12	1766
3/23/2001 4:05	0.087	2.5	13	1758
3/23/2001 4:10	0.087	2.5	13	1736
3/23/2001 4:15	0.087	2.5	13	1724
3/23/2001 4:20	0.084	2.3	12	1692
3/23/2001 4:25	0.084	2.3	11	1648
3/23/2001 4:30	0.083	2.2	11	1620
3/23/2001 4:35	0.085	2.4	11	1594
3/23/2001 4:40	0.085	2.4	12	1578
3/23/2001 4:45	0.083	2.2	11	1606
3/23/2001 4:50	0.077	1.8	10	1582
3/23/2001 4:55	0.076	1.8	9	1568
3/23/2001 5:00	0.077	1.8	9	1564
3/23/2001 5:05	0.077	1.8	9	1566
3/23/2001 5:10	0.077	1.8	9	1566
3/23/2001 5:15	0.085	2.4	11	1566
3/23/2001 5:20	0.084	2.3	12	1566
3/23/2001 5:25	0.085	2.4	12	1564
3/23/2001 5:30	0.089	2.7	13	1564
3/23/2001 5:35	0.091	2.8	14	1562
3/23/2001 5:40	0.096	3.2	15	1562
3/23/2001 5:45	0.1	3.5	17	1562
3/23/2001 5:50	0.099	3.5	18	1562
3/23/2001 5:55	0.095	3.1	16	1580
3/23/2001 6:00	0.106	4.1	18	1694
3/23/2001 6:05	0.103	3.8	20	1848
3/23/2001 6:10	0.105	4.0	20	1982
3/23/2001 6:15	0.11	4.5	21	2080
3/23/2001 6:20	0.102	3.7	21	2140
3/23/2001 6:25	0.106	4.1	20	2180
3/23/2001 6:30	0.099	3.5	19	2204
3/23/2001 6:35	0.102	3.7	18	2220
3/23/2001 6:40	0.106	4.1	20	2234
3/23/2001 6:45	0.105	4.0	20	2246
3/23/2001 6:50	0.102	3.7	19	2256
3/23/2001 6:55	0.099	3.5	18	2268
3/23/2001 7:00	0.099	3.5	17	2294
3/23/2001 7:05	0.093	3.0	16	2340
3/23/2001 7:10	0.094	3.0	15	2450
3/23/2001 7:15	0.096	3.2	16	2562
3/23/2001 7:20	0.095	3.1	16	2656
3/23/2001 7:25	0.094	3.0	15	2726
3/23/2001 7:30	0.092	2.9	15	2778
3/23/2001 7:35	0.091	2.8	14	2816
3/23/2001 7:40	0.089	2.7	14	2848
3/23/2001 7:45	0.088	2.6	13	2870
3/23/2001 7:50	0.082	2.2	12	2890
3/23/2001 7:55	0.079	2.0	10	2904
3/23/2001 8:00	0.083	2.2	10	2916
3/23/2001 8:05	0.083	2.2	11	2930
3/23/2001 8:10	0.082	2.2	11	2942
3/23/2001 8:15	0.08	2.0	10	2966
3/23/2001 8:20	0.079	2.0	10	2988
3/23/2001 8:25	0.077	1.8	10	3012
3/23/2001 8:30	0.077	1.8	9	3036
3/23/2001 8:35	0.076	1.8	9	3060
3/23/2001 8:40	0.074	1.7	9	3080
3/23/2001 8:45	0.073	1.6	8	3096
3/23/2001 8:50	0.073	1.6	8	3112
3/23/2001 8:55	0.07	1.5	8	3124
3/23/2001 9:00	0.071	1.5	7	3134
3/23/2001 9:05	0.071	1.5	8	3144
3/23/2001 9:10	0.07	1.5	7	3150

3/23/2001 9:15	0.069	1.4	7	3150
3/23/2001 9:20	0.068	1.4	7	3154
3/23/2001 9:25	0.067	1.3	7	3158
3/23/2001 9:30	0.067	1.3	7	3162
3/23/2001 9:35	0.066	1.3	6	3166
3/23/2001 9:40	0.066	1.3	6	3168
3/23/2001 9:45	0.064	1.2	6	3172
3/23/2001 9:50	0.064	1.2	6	3174
3/23/2001 9:55	0.063	1.1	6	3176
3/23/2001 10:00	0.064	1.2	6	3180
3/23/2001 10:05	0.064	1.2	6	3188
3/23/2001 10:10	0.062	1.1	6	3190
3/23/2001 10:15	0.062	1.1	5	3192
3/23/2001 10:20	0.062	1.1	5	3192
3/23/2001 10:25	0.06	1.0	5	3194
3/23/2001 10:30	0.061	1.0	5	3194
3/23/2001 10:35	0.061	1.0	5	3196
3/23/2001 10:40	0.06	1.0	5	3196
3/23/2001 10:45	0.059	0.9	5	3196
3/23/2001 10:50	0.059	0.9	5	3196
3/23/2001 10:55	0.058	0.9	5	3198
3/23/2001 11:00	0.058	0.9	5	3200
3/23/2001 11:05	0.058	0.9	5	3202
3/23/2001 11:10	0.058	0.9	5	3202
3/23/2001 11:15	0.057	0.9	4	3206
3/23/2001 11:20	0.058	0.9	4	3208
3/23/2001 11:25	0.058	0.9	5	3210
3/23/2001 11:30	0.056	0.8	4	3214
3/23/2001 11:35	0.057	0.9	4	3218
3/23/2001 11:40	0.056	0.8	4	3222
3/23/2001 11:45	0.055	0.8	4	3224
3/23/2001 11:50	0.055	0.8	4	3228
3/23/2001 11:55	0.054	0.8	4	3232
3/23/2001 12:00	0.055	0.8	4	3234
3/23/2001 12:05	0.056	0.8	4	3236
3/23/2001 12:10	0.053	0.7	4	3238
3/23/2001 12:15	0.054	0.8	4	3242
3/23/2001 12:20	0.055	0.8	4	3244
3/23/2001 12:25	0.054	0.8	4	3246
3/23/2001 12:30	0.054	0.8	4	3248
3/23/2001 12:35	0.054	0.8	4	3248
3/23/2001 12:40	0.053	0.7	4	3250
3/23/2001 12:45	0.053	0.7	4	3252
3/23/2001 12:50	0.053	0.7	4	3252
3/23/2001 12:55	0.053	0.7	4	3254
3/23/2001 13:00	0.052	0.7	4	3254
3/23/2001 13:05	0.053	0.7	4	3256
3/23/2001 13:10	0.051	0.7	3	3248
3/23/2001 13:15	0.052	0.7	3	3248
3/23/2001 13:20	0.052	0.7	3	3248
3/23/2001 13:25	0.052	0.7	3	3248
3/23/2001 13:30	0.051	0.7	3	3250
3/23/2001 13:35	0.052	0.7	3	3250
3/23/2001 13:40	0.052	0.7	3	3250
3/23/2001 13:45	0.052	0.7	3	3250
3/23/2001 13:50	0.051	0.7	3	3250
3/23/2001 13:55	0.052	0.7	3	3248
3/23/2001 14:00	0.051	0.7	3	3246
3/23/2001 14:05	0.052	0.7	3	3244
3/23/2001 14:10	0.048	0.6	3	3242
3/23/2001 14:15	0.049	0.6	3	3240
3/23/2001 14:20	0.049	0.6	3	3238
3/23/2001 14:25	0.05	0.6	3	3238
3/23/2001 14:30	0.05	0.6	3	3232
3/23/2001 14:35	0.051	0.7	3	3226
3/23/2001 14:40	0.051	0.7	3	3218
3/23/2001 14:45	0.051	0.7	3	3212
3/23/2001 14:50	0.051	0.7	3	3216
3/23/2001 14:55	0.049	0.6	3	3214
3/23/2001 15:00	0.049	0.6	3	3212
3/23/2001 15:05	0.049	0.6	3	3212
3/23/2001 15:10	0.046	0.5	3	3208
3/23/2001 15:15	0.049	0.6	3	3204
3/23/2001 15:20	0.05	0.6	3	3202
3/23/2001 15:25	0.046	0.5	3	3190
3/23/2001 15:30	0.049	0.6	3	3190
3/23/2001 15:35	0.05	0.6	3	3188
3/23/2001 15:40	0.047	0.5	3	3186
3/23/2001 15:45	0.049	0.6	3	3182
3/23/2001 15:50	0.049	0.6	3	3178

3/23/2001 15:55	0.046	0.5	3	3172
3/23/2001 16:00	0.048	0.6	3	3168
3/23/2001 16:05	0.049	0.6	3	3170
3/23/2001 16:10	0.049	0.6	3	3168
3/23/2001 16:15	0.048	0.6	3	3170
3/23/2001 16:20	0.049	0.6	3	3170
3/23/2001 16:25	0.047	0.5	3	3166
3/23/2001 16:30	0.047	0.5	3	3162
3/23/2001 16:35	0.048	0.6	3	3158
3/23/2001 16:40	0.048	0.6	3	3154
3/23/2001 16:45	0.047	0.5	3	3150
3/23/2001 16:50	0.047	0.5	3	3144
3/23/2001 16:55	0.046	0.5	3	3136
3/23/2001 17:00	0.047	0.5	3	3134
3/23/2001 17:05	0.047	0.5	3	3136
3/23/2001 17:10	0.046	0.5	3	3134
3/23/2001 17:15	0.046	0.5	3	3132
3/23/2001 17:20	0.047	0.5	3	3132
3/23/2001 17:25	0.046	0.5	3	3128
3/23/2001 17:30	0.045	0.5	2	3126
3/23/2001 17:35	0.046	0.5	2	3118
3/23/2001 17:40	0.047	0.5	3	3112
3/23/2001 17:45	0.045	0.5	3	3106
3/23/2001 17:50	0.047	0.5	3	3102
3/23/2001 17:55	0.044	0.5	2	3098
3/23/2001 18:00	0.046	0.5	2	3094
3/23/2001 18:05	0.046	0.5	3	3090
3/23/2001 18:10	0.045	0.5	2	3092
3/23/2001 18:15	0.045	0.5	2	3084
3/23/2001 18:20	0.045	0.5	2	3074
3/23/2001 18:25	0.044	0.5	2	3070
3/23/2001 18:30	0.045	0.5	2	3066
3/23/2001 18:35	0.045	0.5	2	3062
3/23/2001 18:40	0.045	0.5	2	3060
3/23/2001 18:45	0.041	0.4	2	3058
3/23/2001 18:50	0.041	0.4	2	3012
3/23/2001 18:55	0.041	0.4	2	2944
3/23/2001 19:00	0.045	0.5	2	2908
3/23/2001 19:05	0.044	0.5	2	2876
3/23/2001 19:10	0.044	0.5	2	2870
3/23/2001 19:15	0.043	0.4	2	2832
3/23/2001 19:20	0.039	0.3	2	2806
3/23/2001 19:25	0.043	0.4	2	2790
3/23/2001 19:30	0.041	0.4	2	2786
3/23/2001 19:35	0.039	0.3	2	2776
3/23/2001 19:40	0.04	0.4	2	2768
3/23/2001 19:45	0.043	0.4	2	2762
3/23/2001 19:50	0.041	0.4	2	2756
3/23/2001 19:55	0.037	0.3	2	2752
3/23/2001 20:00	0.041	0.4	2	2748
3/23/2001 20:05	0.038	0.3	2	2744
3/23/2001 20:10	0.037	0.3	2	2740
3/23/2001 20:15	0.041	0.4	2	2734
3/23/2001 20:20	0.041	0.4	2	2730
3/23/2001 20:25	0.036	0.3	2	2726
3/23/2001 20:30	0.042	0.4	2	2722
3/23/2001 20:35	0.035	0.3	2	2716
3/23/2001 20:40	0.043	0.4	2	2712
3/23/2001 20:45	0.042	0.4	2	2708
3/23/2001 20:50	0.042	0.4	2	2704
3/23/2001 20:55	0.039	0.3	2	2700
3/23/2001 21:00	0.041	0.4	2	2696
3/23/2001 21:05	0.04	0.4	2	2692
3/23/2001 21:10	0.042	0.4	2	2688
3/23/2001 21:15	0.043	0.4	2	2684
3/23/2001 21:20	0.04	0.4	2	2682
3/23/2001 21:25	0.043	0.4	2	2678
3/23/2001 21:30	0.037	0.3	2	2672
3/23/2001 21:35	0.042	0.4	2	2668
3/23/2001 21:40	0.041	0.4	2	2662
3/23/2001 21:45	0.041	0.4	2	2660
3/23/2001 21:50	0.038	0.3	2	2656
3/23/2001 21:55	0.04	0.4	2	2650
3/23/2001 22:00	0.039	0.3	2	2646
3/23/2001 22:05	0.035	0.3	1	2642
3/23/2001 22:10	0.037	0.3	1	2636
3/23/2001 22:15	0.035	0.3	1	2632
3/23/2001 22:20	0.035	0.3	1	2630
3/23/2001 22:25	0.033	0.2	1	2626
3/23/2001 22:30	0.033	0.2	1	2626

3/23/2001 22:35	0.035	0.3	1	2624
3/23/2001 22:40	0.031	0.2	1	2620
3/23/2001 22:45	0.04	0.4	1	2622
3/23/2001 22:50	0.03	0.2	1	2622
3/23/2001 22:55	0.033	0.2	1	2620
3/23/2001 23:00	0.039	0.3	1	2612
3/23/2001 23:05	0.035	0.3	1	2606
3/23/2001 23:10	0.031	0.2	1	2600
3/23/2001 23:15	0.03	0.2	1	2598
3/23/2001 23:20	0.03	0.2	1	2592
3/23/2001 23:25	0.027	0.1	1	2588
3/23/2001 23:30	0.031	0.2	1	2584
3/23/2001 23:35	0.03	0.2	1	2578
3/23/2001 23:40	0.034	0.2	1	2574
3/23/2001 23:45	0.039	0.3	1	2572
3/23/2001 23:50	0.027	0.1	1	2570
3/23/2001 23:55	0.028	0.1	1	2566
3/24/2001	0.033	0.2	1	2564
3/24/2001 0:05	0.024	0.1	1	2560
3/24/2001 0:10	0.03	0.2	1	2560
3/24/2001 0:15	0.03	0.2	1	2556
3/24/2001 0:20	0.024	0.1	1	2554
3/24/2001 0:25	0.028	0.1	1	2550
3/24/2001 0:30	0.029	0.2	1	2548
3/24/2001 0:35	0.027	0.1	1	2546
3/24/2001 0:40	0.027	0.1	1	2544
3/24/2001 0:45	0.027	0.1	1	2542
3/24/2001 0:50	0.026	0.1	1	2540
3/24/2001 0:55	0.032	0.2	1	2538
3/24/2001 1:00	0.029	0.2	1	2536
3/24/2001 1:05	0.024	0.1	1	2534
3/24/2001 1:10	0.03	0.2	1	2530
3/24/2001 1:15	0.028	0.1	1	2528
3/24/2001 1:20	0.024	0.1	1	2526
3/24/2001 1:25	0.026	0.1	1	2524
3/24/2001 1:30	0.026	0.1	1	2522
3/24/2001 1:35	0.026	0.1	1	2518
3/24/2001 1:40	0.027	0.1	1	2514
3/24/2001 1:45	0.027	0.1	1	2510
3/24/2001 1:50	0.022	0.1	1	2504
3/24/2001 1:55	0.029	0.2	1	2500
3/24/2001 2:00	0.028	0.1	1	2498
3/24/2001 2:05	0.025	0.1	1	2494
3/24/2001 2:10	0.02	0.1	0	2492

APPENDIX C

HYDROGRAPH

1) Input/Output for Hydrograph on 9/18/04

For Storm on 9/18/04 8:50 a.m.

Date of Storm:	End of Storm : Date	Q Total (gal)
9/18/04 8:50 AM	9/18/04 11:45 PM	162357

Date of Storm:	End of Storm : Date
9/18/04 6:00 AM	9/18/04 3:55 PM
M opt	1
Ω opt (s^{-1})	7.38E-04

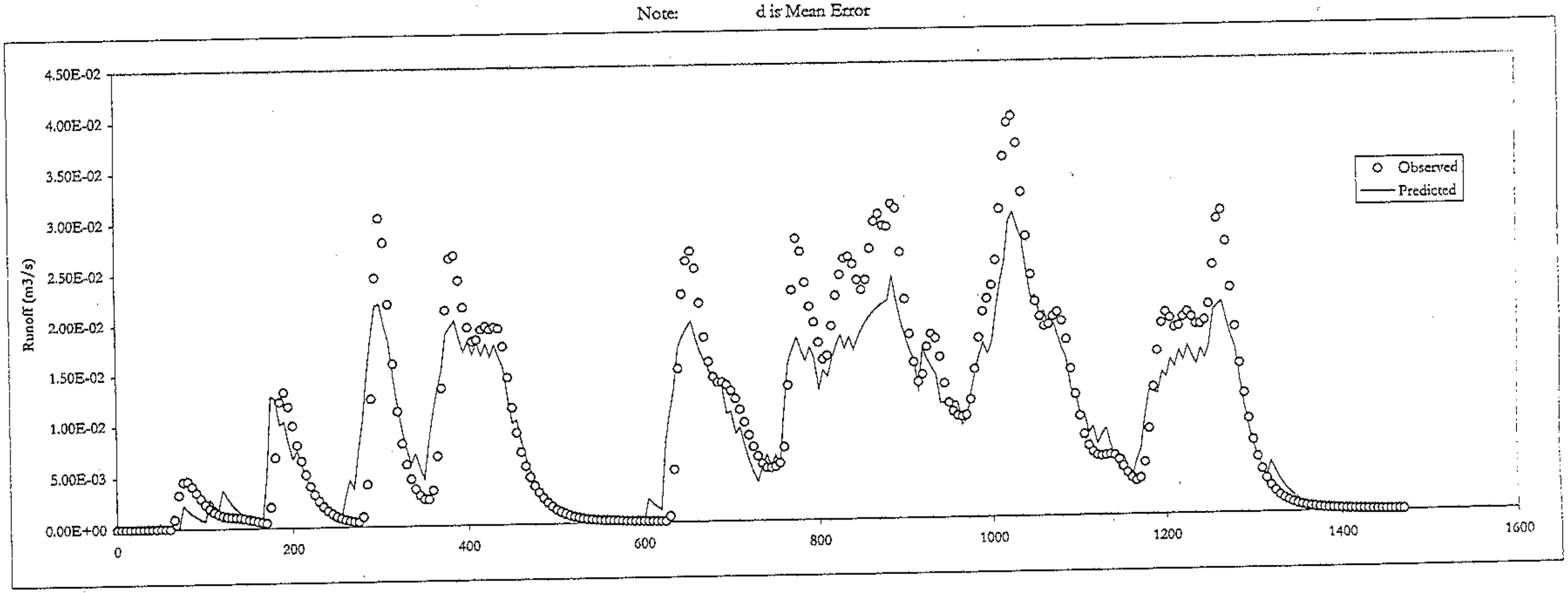
Precip. Meas. (in.)	Precip. Meas. (m.)
1.77	0.044958
A Eff.	1.49E+04
δ (m^3/s)	2.29E-03
t_S	0
Dep. Storage (m)	2.54E-03
Eff. # of Pts.	319

A Eff. (m^2)	A Eff. (%)
13670.3	58.73%
sum P (m)	6.15E-02
Sum Q (m^3)	914.35

Input:

Ω min (s^{-1})	5.0E-04
Ω max (s^{-1})	1.00E-03
nn	295

Note: d is Mean Error



Time (min)	Precipitation$_{Meas}$ (in/hr)	Flow$_{Meas}$ (gpm)	*Flow Pred. (m^3/s)*	Flow$_{Meas}$ (m^3/s)
0	0.12	0.0		0.00E+00
5	0	0.0		0.00E+00
10	0.12	0.0		0.00E+00
15	0	0.0		0.00E+00
20	0	0.0		0.00E+00
25	0.12	0.0		0.00E+00
30	0.12	0.0		0.00E+00
35	0.12	0.0		0.00E+00
40	0.12	0.0		0.00E+00
45	0.12	0.0		0.00E+00
50	0.12	0.0		0.00E+00
55	0.24	0.0		0.00E+00
60	0	0.0	0.00E+00	5.44E-07
65	0	15.0	0.00E+00	9.46E-04
70	0.12	51.7	0.00E+00	3.26E-03
75	0	71.8	2.23E-03	4.53E-03
80	0	72.9	1.79E-03	4.60E-03
85	0	64.5	1.44E-03	4.07E-03
90	0	54.8	1.15E-03	3.46E-03
95	0	45.7	9.22E-04	2.88E-03
100	0.12	36.8	7.39E-04	2.32E-03
105	0	30.4	2.83E-03	1.92E-03
110	0	25.2	2.27E-03	1.59E-03
115	0.12	21.6	1.82E-03	1.36E-03
120	0	19.3	3.69E-03	1.22E-03
125	0	17.9	2.96E-03	1.13E-03
130	0	17.2	2.37E-03	1.08E-03
135	0	16.5	1.90E-03	1.04E-03
140	0	15.9	1.52E-03	1.00E-03
145	0	14.8	1.22E-03	9.33E-04
150	0	13.2	9.77E-04	8.31E-04
155	0	11.7	7.83E-04	7.36E-04
160	0	10.1	6.28E-04	6.38E-04
165	0.24	8.8	5.03E-04	5.57E-04
170	0.48	7.8	4.87E-03	4.92E-04
175	0.12	31.7	1.28E-02	2.00E-03
180	0	107.9	1.25E-02	6.81E-03
185	0.12	194.4	1.00E-02	1.23E-02
190	0	209.4	1.03E-02	1.32E-02
195	0	186.7	8.24E-03	1.18E-02
200	0.12	156.7	6.60E-03	9.89E-03
205	0	126.7	7.53E-03	8.00E-03
210	0	101.9	6.03E-03	6.43E-03
215	0	80.7	4.83E-03	5.09E-03
220	0	63.0	3.87E-03	3.97E-03
225	0	49.5	3.10E-03	3.12E-03
230	0	39.4	2.49E-03	2.49E-03
235	0	31.0	1.99E-03	1.96E-03
240	0	24.6	1.60E-03	1.55E-03
245	0	19.8	1.28E-03	1.25E-03
250	0	15.9	1.03E-03	1.00E-03
255	0.12	13.2	8.22E-04	8.31E-04
260	0.12	10.8	2.89E-03	6.80E-04
265	0	9.0	4.55E-03	5.67E-04
270	0.24	7.7	3.65E-03	4.83E-04
275	0.24	7.2	7.39E-03	4.57E-04
280	0.36	15.2	1.04E-02	9.60E-04
285	0.36	64.5	1.50E-02	4.07E-03
290	0.36	197.4	1.88E-02	1.25E-02
295	0.24	388.1	2.17E-02	2.45E-02
300	0.12	481.6	2.19E-02	3.04E-02
305	0.12	443.7	1.98E-02	2.80E-02
310	0	346.5	1.81E-02	2.19E-02
315	0	251.7	1.45E-02	1.59E-02
320	0	177.2	1.16E-02	1.12E-02
325	0	126.7	9.31E-03	8.00E-03
330	0	94.1	7.46E-03	5.93E-03
335	0.12	71.8	5.98E-03	4.53E-03
340	0	56.2	7.02E-03	3.55E-03
345	0	46.1	5.63E-03	2.91E-03
350	0.24	40.2	4.51E-03	2.53E-03
355	0.24	39.8	8.08E-03	2.51E-03
360	0.24	53.9	1.09E-02	3.40E-03
365	0.24	106.6	1.32E-02	6.72E-03
370	0.36	212.5	1.51E-02	1.34E-02
375	0.24	335.5	1.88E-02	2.12E-02
380	0.24	416.9	1.95E-02	2.63E-02
385	0.12	421.6	2.01E-02	2.66E-02
390	0.12	382.2	1.84E-02	2.41E-02
395	0.24	339.6	1.69E-02	2.14E-02
400	0.12	307.7	1.80E-02	1.94E-02
405	0.24	285.0	1.67E-02	1.80E-02
410	0.12	287.5	1.79E-02	1.81E-02
415	0.24	303.8	1.65E-02	1.92E-02
420	0.12	309.0	1.77E-02	1.95E-02
425	0.24	303.8	1.64E-02	1.92E-02

430	0.12	307.7	1.76E-02	1.94E-02
435	0.12	305.1	1.64E-02	1.92E-02
440	0	276.4	1.54E-02	1.74E-02
445	0	227.3	1.23E-02	1.43E-02
450	0.12	180.0	9.86E-03	1.14E-02
455	0	140.8	1.01E-02	8.89E-03
460	0	110.7	8.12E-03	6.99E-03
465	0	88.5	6.51E-03	5.58E-03
470	0	71.8	5.22E-03	4.53E-03
475	0	58.1	4.18E-03	3.67E-03
480	0	47.8	3.35E-03	3.02E-03
485	0	38.7	2.69E-03	2.44E-03
490	0	31.7	2.15E-03	2.00E-03
495	0	25.8	1.72E-03	1.63E-03
500	0	20.8	1.38E-03	1.31E-03
505	0	17.2	1.11E-03	1.08E-03
510	0	14.4	8.87E-04	9.07E-04
515	0	11.9	7.11E-04	7.48E-04
520	0	9.9	5.70E-04	6.27E-04
525	0	8.5	4.57E-04	5.38E-04
530	0	7.2	3.66E-04	4.57E-04
535	0	6.2	2.93E-04	3.91E-04
540	0	5.5	2.35E-04	3.46E-04
545	0	4.8	1.88E-04	3.04E-04
550	0	4.3	1.51E-04	2.71E-04
555	0	3.9	1.21E-04	2.47E-04
560	0	3.5	9.69E-05	2.24E-04
565	0	3.2	7.77E-05	2.02E-04
570	0	2.9	6.23E-05	1.82E-04
575	0	2.5	4.99E-05	1.58E-04
580	0	2.2	4.00E-05	1.40E-04
585	0	2.0	3.20E-05	1.28E-04
590	0	1.8	2.57E-05	1.16E-04
595	0	1.7	2.06E-05	1.05E-04
600	0.12	1.6	1.65E-05	9.85E-05
605	0	1.4	2.25E-03	8.85E-05
610	0	1.3	1.80E-03	7.92E-05
615	0	1.2	1.44E-03	7.34E-05
620	0.36	1.0	1.16E-03	6.51E-05
625	0.24	1.0	7.63E-03	6.24E-05
630	0.24	8.4	1.06E-02	5.28E-04
635	0.36	79.6	1.30E-02	5.02E-03
640	0.24	237.1	1.71E-02	1.50E-02
645	0.24	354.9	1.82E-02	2.24E-02
650	0.24	407.7	1.90E-02	2.57E-02
655	0.12	423.1	1.97E-02	2.67E-02
660	0.12	395.6	1.80E-02	2.50E-02
665	0.12	341.0	1.67E-02	2.15E-02
670	0.12	286.2	1.56E-02	1.81E-02
675	0.12	247.2	1.47E-02	1.56E-02
680	0.12	223.0	1.40E-02	1.41E-02
685	0.12	214.6	1.35E-02	1.35E-02
690	0	214.6	1.30E-02	1.35E-02
695	0.12	210.5	1.05E-02	1.33E-02
700	0	201.3	1.06E-02	1.27E-02
705	0.12	188.6	8.51E-03	1.19E-02
710	0	171.7	9.05E-03	1.08E-02
715	0	151.6	7.25E-03	9.56E-03
720	0	131.3	5.81E-03	8.29E-03
725	0	113.5	4.66E-03	7.16E-03
730	0.12	98.6	3.73E-03	6.22E-03
735	0.12	86.6	5.23E-03	5.47E-03
740	0	80.2	6.42E-03	5.06E-03
745	0.12	80.2	5.15E-03	5.06E-03
750	0	81.9	6.36E-03	5.17E-03
755	0.36	87.2	5.10E-03	5.50E-03
760	0.36	112.1	1.08E-02	7.07E-03
765	0.24	208.4	1.54E-02	1.31E-02
770	0.24	359.1	1.68E-02	2.27E-02
775	0.12	440.5	1.79E-02	2.78E-02
780	0.12	420.0	1.66E-02	2.65E-02
785	0.24	370.5	1.55E-02	2.34E-02
790	0.12	332.8	1.69E-02	2.10E-02
795	0	307.7	1.58E-02	1.94E-02
800	0.24	275.2	1.27E-02	1.74E-02
805	0.12	248.3	1.46E-02	1.57E-02
810	0.24	254.0	1.39E-02	1.60E-02
815	0.24	301.3	1.56E-02	1.90E-02
820	0.24	349.3	1.70E-02	2.20E-02
825	0.12	382.2	1.81E-02	2.41E-02
830	0.24	407.7	1.67E-02	2.57E-02
835	0.12	410.7	1.79E-02	2.59E-02
840	0.24	398.6	1.66E-02	2.51E-02
845	0.24	373.4	1.77E-02	2.36E-02
850	0.24	357.7	1.87E-02	2.26E-02
855	0.24	373.4	1.94E-02	2.36E-02
860	0.24	423.1	2.01E-02	2.67E-02
865	0.24	464.9	2.05E-02	2.93E-02

870	0.24	476.6	2.09E-02	3.01E-02
875	0.24	458.3	2.12E-02	2.89E-02
880	0.36	456.7	2.15E-02	2.88E-02
885	0.12	491.8	2.39E-02	3.10E-02
890	0.12	485.0	2.14E-02	3.06E-02
895	0.12	416.9	1.94E-02	2.63E-02
900	0.12	342.3	1.78E-02	2.16E-02
905	0.12	286.2	1.65E-02	1.81E-02
910	0	241.5	1.54E-02	1.52E-02
915	0.36	210.5	1.24E-02	1.33E-02
920	0.12	221.9	1.66E-02	1.40E-02
925	0.12	265.7	1.56E-02	1.68E-02
930	0.12	286.2	1.47E-02	1.81E-02
935	0	278.9	1.40E-02	1.76E-02
940	0.12	249.4	1.12E-02	1.57E-02
945	0.12	207.4	1.12E-02	1.31E-02
950	0.12	177.2	1.12E-02	1.12E-02
955	0.12	163.7	1.12E-02	1.03E-02
960	0	156.7	1.12E-02	9.89E-03
965	0.12	155.0	9.01E-03	9.78E-03
970	0.24	157.5	9.46E-03	9.94E-03
975	0.24	181.9	1.20E-02	1.15E-02
980	0.24	229.4	1.41E-02	1.45E-02
985	0.24	278.9	1.58E-02	1.76E-02
990	0.12	320.8	1.71E-02	2.02E-02
995	0.24	341.0	1.60E-02	2.15E-02
1000	0.36	361.9	1.73E-02	2.28E-02
1005	0.36	401.6	2.05E-02	2.53E-02
1010	0.36	481.6	2.32E-02	3.04E-02
1015	0.48	563.1	2.53E-02	3.55E-02
1020	0.36	616.5	2.92E-02	3.89E-02
1025	0.24	626.3	3.01E-02	3.95E-02
1030	0.24	583.7	2.86E-02	3.68E-02
1035	0.12	507.4	2.74E-02	3.20E-02
1040	0.12	438.9	2.42E-02	2.77E-02
1045	0.24	377.8	2.16E-02	2.38E-02
1050	0.12	335.5	2.18E-02	2.12E-02
1055	0.24	311.6	1.97E-02	1.97E-02
1060	0.12	296.2	2.03E-02	1.87E-02
1065	0.24	298.7	1.85E-02	1.88E-02
1070	0.12	311.6	1.93E-02	1.97E-02
1075	0.12	318.1	1.77E-02	2.01E-02
1080	0.12	303.8	1.64E-02	1.92E-02
1085	0	274.0	1.54E-02	1.73E-02
1090	0.12	227.3	1.23E-02	1.43E-02
1095	0	187.6	1.21E-02	1.18E-02
1100	0.12	153.3	9.70E-03	9.67E-03
1105	0	124.5	1.00E-02	7.85E-03
1110	0.12	107.3	8.02E-03	6.77E-03
1115	0	97.3	8.66E-03	6.14E-03
1120	0.12	91.5	6.94E-03	5.78E-03
1125	0.12	90.3	7.80E-03	5.70E-03
1130	0	91.5	8.48E-03	5.78E-03
1135	0	92.8	6.80E-03	5.85E-03
1140	0	91.5	5.45E-03	5.78E-03
1145	0.12	84.8	4.37E-03	5.35E-03
1150	0	74.0	5.73E-03	4.67E-03
1155	0	64.0	4.60E-03	4.04E-03
1160	0.12	55.8	3.68E-03	3.52E-03
1165	0.12	51.3	5.19E-03	3.23E-03
1170	0.24	55.3	6.39E-03	3.49E-03
1175	0.24	79.6	9.59E-03	5.02E-03
1180	0.12	132.1	1.22E-02	8.34E-03
1185	0.12	197.4	1.20E-02	1.25E-02
1190	0.24	254.0	1.18E-02	1.60E-02
1195	0.12	298.7	1.40E-02	1.88E-02
1200	0.24	315.5	1.34E-02	1.99E-02
1205	0.12	306.4	1.52E-02	1.93E-02
1210	0.24	291.2	1.44E-02	1.84E-02
1215	0.12	293.7	1.60E-02	1.85E-02
1220	0.24	307.7	1.51E-02	1.94E-02
1225	0.12	315.5	1.66E-02	1.99E-02
1230	0.12	307.7	1.55E-02	1.94E-02
1235	0.24	296.2	1.47E-02	1.87E-02
1240	0.12	296.2	1.62E-02	1.87E-02
1245	0.24	302.5	1.52E-02	1.91E-02
1250	0.36	327.4	1.67E-02	2.07E-02
1255	0.24	389.6	2.01E-02	2.46E-02
1260	0.24	461.6	2.06E-02	2.91E-02
1265	0.12	474.9	2.09E-02	3.00E-02
1270	0.12	426.3	1.90E-02	2.69E-02
1275	0.12	353.5	1.75E-02	2.23E-02
1280	0	291.2	1.62E-02	1.84E-02
1285	0	232.7	1.30E-02	1.47E-02
1290	0	185.7	1.04E-02	1.17E-02
1295	0	145.7	8.36E-03	9.19E-03
1300	0	112.1	6.70E-03	7.07E-03
1305	0	86.0	5.37E-03	5.43E-03

1310	0	66.5	4.30E-03	4.20E-03
1315	0.12	52.1	3.45E-03	3.29E-03
1320	0	40.9	5.00E-03	2.58E-03
1325	0	32.7	4.00E-03	2.06E-03
1330	0	25.5	3.21E-03	1.61E-03
1335	0	20.8	2.57E-03	1.31E-03
1340	0	17.2	2.06E-03	1.08E-03
1345	0	14.2	1.65E-03	8.94E-04
1350	0	12.0	1.32E-03	7.59E-04
1355	0	10.1	1.06E-03	6.38E-04
1360	0	8.7	8.50E-04	5.47E-04
1365	0	7.5	6.81E-04	4.74E-04
1370	0	6.6	5.46E-04	4.15E-04
1375	0	5.7	4.37E-04	3.61E-04
1380	0	5.0	3.51E-04	3.17E-04
1385	0	4.5	2.81E-04	2.84E-04
1390	0	4.0	2.25E-04	2.53E-04
1395	0	3.6	1.80E-04	2.29E-04
1400	0	3.2	1.45E-04	2.02E-04
1405	0	3.0	1.16E-04	1.87E-04
1410	0	2.7	9.28E-05	1.67E-04
1415	0	2.5	7.44E-05	1.58E-04
1420	0	2.2	5.96E-05	1.40E-04
1425	0	2.0	4.78E-05	1.28E-04
1430	0	1.8	3.83E-05	1.16E-04
1435	0	1.7	3.07E-05	1.05E-04
1440	0	1.6	2.46E-05	9.85E-05
1445	0	1.5	1.97E-05	9.18E-05
1450	0	1.3	1.58E-05	8.23E-05
1455	0	1.2	1.27E-05	7.62E-05
1460	0	1.1	1.01E-05	7.05E-05
1465	0	1.0	8.13E-06	6.51E-05
1470	0	1.0	6.51E-06	6.24E-05

APPENDIX D

LOADOGRAPH

1) Input/Output for Loadograph on 9/18/04

For Storm on 9/16/04 5:30 a.m.

Begin of Storm	End of Storm : Date	Q Total (gal)	Date of Storm:	End of Storm : Date	Precip. Meas. (in.)	Precip. Meas. (m.)	A Eff. (m^2)	A Eff. (%)
9/28/04 3:45 PM	9/30/04 3:20 PM	252618	9/28/04 11:35 AM	9/29/04 12:35 PM	2.55	0.064770	14764.0	63.43%

Input:

ωS min (kg/m^2-s)	1.0E-08
ωS max (kg/m^2-s)	1.0E-01
nn	478
Ω min	1.00E-06
Ω max	0.1

Cl Factor (kg-cm/m^3-μS) 0.193

Hydrograph:

M opt	1
Ω opt (s^{-1})	7.39E-04

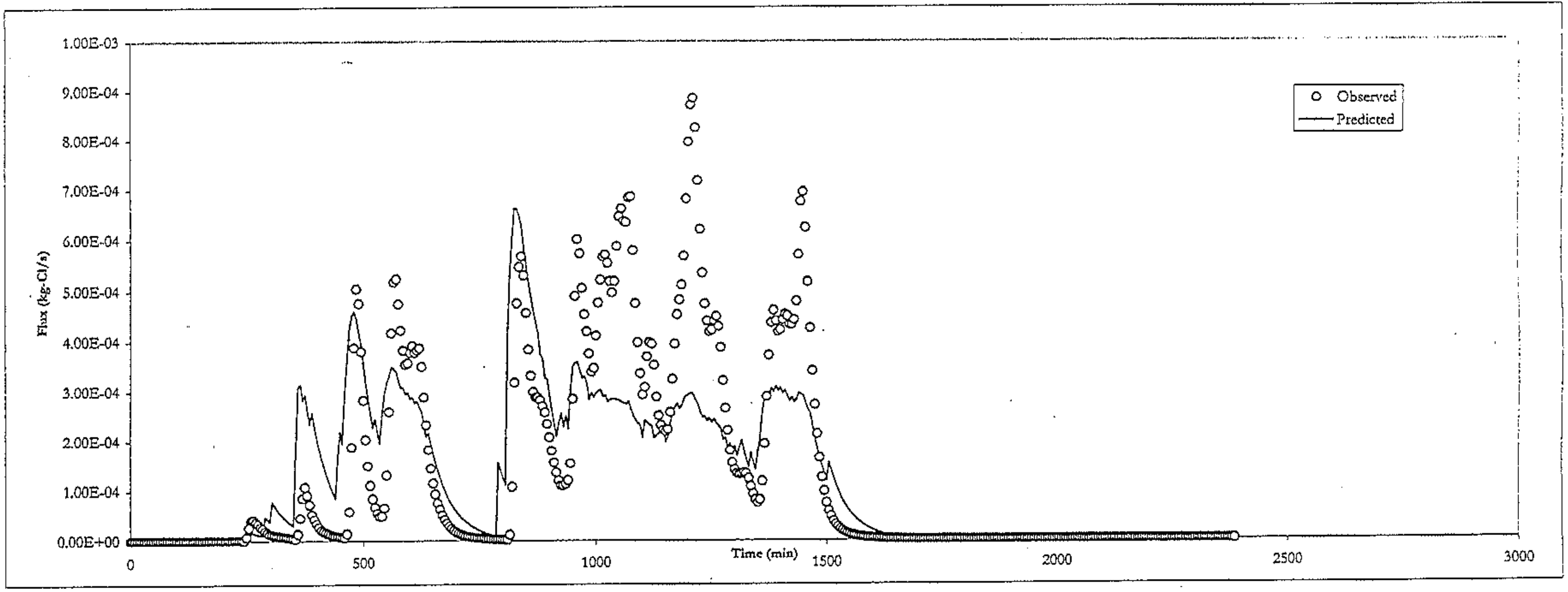
A Eff. (m^2)	14885
δ	0
t_S (min)	143100
Dep. Storage: ζ (m)	3.30E-03
Eff. # of Pts.	429

Σ P (m)	6.15E-02
Σ Q (m^3)	915.0

Note: δ is Mean Error

Loadograph:

δ Flux (kg/m^2-s)	8.261E-05
ωS (kg/m^2-s)	1.56E-08
Ω opt (s^{-1})	3.66E-04



Time (min)	Precipitation$_{Meas}$ (in/hr)	Flow$_{Meas}$ (gpm)	Flow$_{Meas}$ (m^3/s)	Spec. Cond. (uS/cm)	Flux measured (kg Cl / sec)	Flux predicted (mg Cl / sec)
0	0.1	0.0	0.00E+00	256	0.00E+00	
5	0.0	0.0	0.00E+00	256	0.00E+00	
10	0.0	0.0	0.00E+00	256	0.00E+00	
15	0.1	0.0	0.00E+00	256	0.00E+00	
20	0.0	0.0	0.00E+00	256	0.00E+00	
25	0.0	0.0	0.00E+00	256	0.00E+00	
30	0.0	0.0	0.00E+00	258	0.00E+00	
35	0.0	0.0	0.00E+00	210	0.00E+00	
40	0.0	0.0	0.00E+00	200	0.00E+00	
45	0.0	0.0	0.00E+00	162	0.00E+00	
50	0.0	0.0	0.00E+00	122	0.00E+00	
55	0.0	0.0	0.00E+00	102	0.00E+00	
60	0.0	0.0	0.00E+00	96	0.00E+00	
65	0.0	0.0	0.00E+00	94	0.00E+00	
70	0.0	0.0	0.00E+00	94	0.00E+00	
75	0.0	0.0	0.00E+00	94	0.00E+00	
80	0.0	0.0	0.00E+00	94	0.00E+00	
85	0.1	0.0	0.00E+00	96	0.00E+00	
90	0.0	0.0	0.00E+00	98	0.00E+00	
95	0.0	0.0	0.00E+00	102	0.00E+00	
100	0.0	0.0	0.00E+00	108	0.00E+00	
105	0.0	0.0	0.00E+00	118	0.00E+00	
110	0.0	0.0	0.00E+00	132	0.00E+00	
115	0.0	0.0	0.00E+00	144	0.00E+00	
120	0.0	0.0	0.00E+00	154	0.00E+00	
125	0.0	0.0	0.00E+00	162	0.00E+00	
130	0.0	0.0	0.00E+00	168	0.00E+00	
135	0.0	0.0	0.00E+00	170	0.00E+00	
140	0.0	0.0	0.00E+00	174	0.00E+00	
145	0.0	0.0	0.00E+00	174	0.00E+00	
150	0.0	0.0	0.00E+00	176	0.00E+00	
155	0.0	0.0	0.00E+00	176	0.00E+00	
160	0.0	0.0	0.00E+00	176	0.00E+00	
165	0.0	0.0	0.00E+00	178	0.00E+00	
170	0.0	0.0	0.00E+00	180	0.00E+00	
175	0.0	0.0	0.00E+00	166	0.00E+00	
180	0.0	0.0	0.00E+00	134	0.00E+00	
185	0.1	0.0	0.00E+00	108	0.00E+00	
190	0.0	0.0	0.00E+00	86	0.00E+00	
195	0.1	0.0	0.00E+00	76	0.00E+00	
200	0.0	0.0	0.00E+00	68	0.00E+00	
205	0.0	0.0	0.00E+00	64	0.00E+00	
210	0.1	0.0	0.00E+00	64	0.00E+00	
215	0.1	0.0	0.00E+00	58	0.00E+00	
220	0.1	0.0	0.00E+00	52	0.00E+00	
225	0.1	0.0	0.00E+00	44	0.00E+00	
230	0.1	0.0	0.00E+00	38	0.00E+00	
235	0.1	0.0	0.00E+00	36	0.00E+00	
240	0.2	0.0	0.00E+00	38	0.00E+00	
245	0.0	0.0	5.44E-07	38	3.99E-09	0.00E+00
250	0.0	15.0	9.46E-04	38	6.94E-06	0.00E+00
255	0.1	51.7	3.26E-03	40	2.52E-05	0.00E+00
260	0.0	71.8	4.53E-03	46	4.02E-05	1.67E-05
265	0.0	72.9	4.60E-03	46	4.08E-05	1.50E-05
270	0.0	64.5	4.07E-03	46	3.61E-05	1.34E-05
275	0.0	54.8	3.46E-03	48	3.21E-05	1.20E-05
280	0.0	45.7	2.88E-03	48	2.67E-05	1.08E-05
285	0.1	36.8	2.32E-03	52	2.33E-05	9.65E-06
290	0.0	30.4	1.92E-03	50	1.85E-05	4.72E-05
295	0.0	25.2	1.59E-03	50	1.53E-05	4.23E-05
300	0.1	21.6	1.36E-03	48	1.26E-05	3.79E-05
305	0.0	19.3	1.22E-03	48	1.13E-05	7.86E-05
310	0.0	17.9	1.13E-03	46	1.00E-05	7.05E-05
315	0.0	17.2	1.08E-03	44	9.21E-06	6.31E-05
320	0.0	16.5	1.04E-03	42	8.45E-06	5.66E-05
325	0.0	15.9	1.00E-03	38	7.34E-06	5.07E-05
330	0.0	14.8	9.33E-04	38	6.84E-06	4.54E-05
335	0.0	13.2	8.31E-04	38	6.10E-06	4.07E-05
340	0.0	11.7	7.36E-04	40	5.68E-06	3.65E-05
345	0.0	10.1	6.38E-04	36	4.43E-06	3.27E-05

350	0.2	8.8	5.57E-04	36	3.87E-06	2.93E-05
355	0.5	7.8	4.92E-04	34	3.23E-06	1.61E-04
360	0.1	31.7	2.00E-03	34	1.31E-05	3.08E-04
365	0.0	107.9	6.81E-03	34	4.47E-05	3.15E-04
370	0.1	194.4	1.23E-02	36	8.52E-05	2.82E-04
375	0.0	209.4	1.32E-02	42	1.07E-04	2.93E-04
380	0.0	186.7	1.18E-02	40	9.09E-05	2.63E-04
385	0.1	156.7	9.89E-03	38	7.25E-05	2.35E-04
390	0.0	126.7	8.00E-03	34	5.25E-05	2.57E-04
395	0.0	101.9	6.43E-03	34	4.22E-05	2.30E-04
400	0.0	80.7	5.09E-03	34	3.34E-05	2.06E-04
405	0.0	63.0	3.97E-03	34	2.61E-05	1.85E-04
410	0.0	49.5	3.12E-03	34	2.05E-05	1.66E-04
415	0.0	39.4	2.49E-03	36	1.73E-05	1.49E-04
420	0.0	31.0	1.96E-03	40	1.51E-05	1.33E-04
425	0.0	24.6	1.55E-03	44	1.32E-05	1.19E-04
430	0.0	19.8	1.25E-03	46	1.11E-05	1.07E-04
435	0.0	15.9	1.00E-03	50	9.65E-06	9.58E-05
440	0.1	13.2	8.31E-04	54	8.66E-06	8.59E-05
445	0.1	10.8	6.80E-04	60	7.88E-06	1.61E-04
450	0.0	9.0	5.67E-04	62	6.78E-06	2.18E-04
455	0.2	7.7	4.83E-04	66	6.15E-06	1.96E-04
460	0.2	7.2	4.57E-04	68	5.99E-06	2.97E-04
465	0.4	15.2	9.60E-04	72	1.33E-05	3.61E-04
470	0.4	64.5	4.07E-03	74	5.81E-05	4.23E-04
475	0.4	197.4	1.25E-02	78	1.87E-04	4.51E-04
480	0.2	388.1	2.45E-02	82	3.87E-04	4.60E-04
485	0.1	481.6	3.04E-02	86	5.04E-04	4.46E-04
490	0.1	443.7	2.80E-02	88	4.75E-04	4.17E-04
495	0.0	346.5	2.19E-02	90	3.80E-04	3.93E-04
500	0.0	251.7	1.59E-02	92	2.82E-04	3.53E-04
505	0.0	177.2	1.12E-02	94	2.03E-04	3.16E-04
510	0.0	126.7	8.00E-03	96	1.48E-04	2.83E-04
515	0.0	94.1	5.93E-03	96	1.10E-04	2.54E-04
520	0.1	71.8	4.53E-03	96	8.39E-05	2.27E-04
525	0.0	56.2	3.55E-03	98	6.71E-05	2.45E-04
530	0.0	46.1	2.91E-03	98	5.50E-05	2.19E-04
535	0.2	40.2	2.53E-03	98	4.79E-05	1.96E-04
540	0.2	39.8	2.51E-03	100	4.85E-05	2.56E-04
545	0.2	53.9	3.40E-03	100	6.57E-05	2.94E-04
550	0.2	106.6	6.72E-03	100	1.30E-04	3.18E-04
555	0.4	212.5	1.34E-02	100	2.59E-04	3.31E-04
560	0.2	335.5	2.12E-02	102	4.17E-04	3.49E-04
565	0.2	416.9	2.63E-02	102	5.18E-04	3.46E-04
570	0.1	421.6	2.66E-02	102	5.24E-04	3.40E-04
575	0.1	382.2	2.41E-02	102	4.75E-04	3.22E-04
580	0.2	339.6	2.14E-02	102	4.22E-04	3.07E-04
585	0.1	307.7	1.94E-02	102	3.82E-04	3.08E-04
590	0.2	285.0	1.80E-02	102	3.54E-04	2.95E-04
595	0.1	287.5	1.81E-02	102	3.57E-04	2.97E-04
600	0.2	303.8	1.92E-02	102	3.77E-04	2.84E-04
605	0.1	309.0	1.95E-02	104	3.91E-04	2.88E-04
610	0.2	303.8	1.92E-02	102	3.77E-04	2.76E-04
615	0.1	307.7	1.94E-02	102	3.82E-04	2.80E-04
620	0.1	305.1	1.92E-02	104	3.86E-04	2.69E-04
625	0.0	276.4	1.74E-02	104	3.50E-04	2.60E-04
630	0.0	227.3	1.43E-02	104	2.88E-04	2.33E-04
635	0.1	180.0	1.14E-02	106	2.32E-04	2.09E-04
640	0.0	140.8	8.89E-03	106	1.82E-04	2.16E-04
645	0.0	110.7	6.99E-03	106	1.43E-04	1.93E-04
650	0.0	88.5	5.58E-03	106	1.14E-04	1.73E-04
655	0.0	71.8	4.53E-03	106	9.27E-05	1.55E-04
660	0.0	58.1	3.67E-03	106	7.50E-05	1.39E-04
665	0.0	47.8	3.02E-03	108	6.29E-05	1.25E-04
670	0.0	38.7	2.44E-03	108	5.09E-05	1.12E-04
675	0.0	31.7	2.00E-03	108	4.16E-05	1.00E-04
680	0.0	25.8	1.63E-03	108	3.39E-05	8.97E-05
685	0.0	20.8	1.31E-03	110	2.79E-05	8.04E-05
690	0.0	17.2	1.08E-03	110	2.30E-05	7.20E-05
695	0.0	14.4	9.07E-04	110	1.93E-05	6.46E-05
700	0.0	11.9	7.48E-04	110	1.59E-05	5.79E-05
705	0.0	9.9	6.27E-04	110	1.33E-05	5.18E-05
710	0.0	8.5	5.38E-04	110	1.14E-05	4.65E-05

715	0.0	7.2	4.57E-04	110	9.69E-06	4.16E-05
720	0.0	6.2	3.91E-04	110	8.30E-06	3.73E-05
725	0.0	5.5	3.46E-04	110	7.34E-06	3.34E-05
730	0.0	4.8	3.04E-04	110	6.45E-06	3.00E-05
735	0.0	4.3	2.71E-04	110	5.76E-06	2.69E-05
740	0.0	3.9	2.47E-04	110	5.24E-06	2.41E-05
745	0.0	3.5	2.24E-04	110	4.75E-06	2.16E-05
750	0.0	3.2	2.02E-04	110	4.29E-06	1.93E-05
755	0.0	2.9	1.82E-04	110	3.86E-06	1.73E-05
760	0.0	2.5	1.58E-04	110	3.36E-06	1.55E-05
765	0.0	2.2	1.40E-04	110	2.98E-06	1.39E-05
770	0.0	2.0	1.28E-04	110	2.72E-06	1.25E-05
775	0.0	1.8	1.16E-04	110	2.47E-06	1.12E-05
780	0.0	1.7	1.05E-04	110	2.24E-06	1.00E-05
785	0.1	1.6	9.85E-05	110	2.09E-06	8.97E-06
790	0.0	1.4	8.85E-05	110	1.88E-06	1.55E-04
795	0.0	1.3	7.92E-05	110	1.68E-06	1.39E-04
800	0.0	1.2	7.34E-05	110	1.56E-06	1.24E-04
805	0.4	1.0	6.51E-05	110	1.38E-06	1.11E-04
810	0.2	1.0	6.24E-05	110	1.33E-06	4.16E-04
815	0.2	8.4	5.28E-04	110	1.12E-05	5.32E-04
820	0.4	79.6	5.02E-03	110	1.07E-04	5.99E-04
825	0.2	237.1	1.50E-02	110	3.18E-04	6.62E-04
830	0.2	354.9	2.24E-02	110	4.75E-04	6.61E-04
835	0.2	407.7	2.57E-02	110	5.46E-04	6.48E-04
840	0.1	423.1	2.67E-02	110	5.67E-04	6.28E-04
845	0.1	395.6	2.50E-02	110	5.30E-04	5.87E-04
850	0.1	341.0	2.15E-02	110	4.57E-04	5.50E-04
855	0.1	286.2	1.81E-02	110	3.83E-04	5.17E-04
860	0.1	247.2	1.56E-02	110	3.31E-04	4.88E-04
865	0.1	223.0	1.41E-02	110	2.99E-04	4.62E-04
870	0.1	214.6	1.35E-02	110	2.87E-04	4.39E-04
875	0.0	214.6	1.35E-02	110	2.87E-04	4.18E-04
880	0.1	210.5	1.33E-02	110	2.82E-04	3.75E-04
885	0.0	201.3	1.27E-02	110	2.70E-04	3.65E-04
890	0.1	188.6	1.19E-02	112	2.57E-04	3.27E-04
895	0.0	171.7	1.08E-02	112	2.34E-04	3.26E-04
900	0.0	151.6	9.56E-03	112	2.07E-04	2.92E-04
905	0.0	131.3	8.29E-03	112	1.79E-04	2.61E-04
910	0.0	113.5	7.16E-03	112	1.55E-04	2.34E-04
915	0.1	98.6	6.22E-03	112	1.34E-04	2.10E-04
920	0.1	86.6	5.47E-03	112	1.18E-04	2.36E-04
925	0.0	80.2	5.06E-03	112	1.09E-04	2.56E-04
930	0.1	80.2	5.06E-03	112	1.09E-04	2.29E-04
935	0.0	81.9	5.17E-03	112	1.12E-04	2.51E-04
940	0.4	87.2	5.50E-03	112	1.19E-04	2.24E-04
945	0.4	112.1	7.07E-03	112	1.53E-04	3.06E-04
950	0.2	208.4	1.31E-02	112	2.84E-04	3.50E-04
955	0.2	359.1	2.27E-02	112	4.90E-04	3.57E-04
960	0.1	440.5	2.78E-02	112	6.01E-04	3.58E-04
965	0.1	420.0	2.65E-02	112	5.73E-04	3.41E-04
970	0.2	370.5	2.34E-02	112	5.05E-04	3.27E-04
975	0.1	332.8	2.10E-02	112	4.54E-04	3.30E-04
980	0.0	307.7	1.94E-02	112	4.20E-04	3.16E-04
985	0.2	275.2	1.74E-02	112	3.75E-04	2.83E-04
990	0.1	248.3	1.57E-02	112	3.39E-04	2.96E-04
995	0.2	254.0	1.60E-02	112	3.46E-04	2.88E-04
1000	0.2	301.3	1.90E-02	112	4.11E-04	2.97E-04
1005	0.2	349.3	2.20E-02	112	4.76E-04	3.01E-04
1010	0.1	382.2	2.41E-02	112	5.21E-04	3.02E-04
1015	0.2	407.7	2.57E-02	114	5.66E-04	2.88E-04
1020	0.1	410.7	2.59E-02	114	5.70E-04	2.91E-04
1025	0.2	398.6	2.51E-02	114	5.53E-04	2.79E-04
1030	0.2	373.4	2.36E-02	114	5.18E-04	2.82E-04
1035	0.2	357.7	2.26E-02	114	4.97E-04	2.84E-04
1040	0.2	373.4	2.36E-02	114	5.18E-04	2.83E-04
1045	0.2	423.1	2.67E-02	114	5.87E-04	2.82E-04
1050	0.2	464.9	2.93E-02	114	6.45E-04	2.80E-04
1055	0.2	476.6	3.01E-02	114	6.62E-04	2.78E-04
1060	0.2	458.3	2.89E-02	114	6.36E-04	2.76E-04
1065	0.4	456.7	2.88E-02	114	6.34E-04	2.73E-04
1070	0.1	491.8	3.10E-02	114	6.83E-04	2.79E-04
1075	0.1	485.0	3.06E-02	116	6.85E-04	2.64E-04

1080	0.1	416.9	2.63E-02	114	5.79E-04	2.52E-04
1085	0.1	342.3	2.16E-02	114	4.75E-04	2.43E-04
1090	0.1	286.2	1.81E-02	114	3.97E-04	2.36E-04
1095	0.0	241.5	1.52E-02	114	3.35E-04	2.31E-04
1100	0.4	210.5	1.33E-02	114	2.92E-04	2.07E-04
1105	0.1	221.9	1.40E-02	114	3.08E-04	2.41E-04
1110	0.1	265.7	1.68E-02	114	3.69E-04	2.36E-04
1115	0.1	286.2	1.81E-02	114	3.97E-04	2.32E-04
1120	0.0	278.9	1.76E-02	116	3.94E-04	2.29E-04
1125	0.1	249.4	1.57E-02	116	3.52E-04	2.06E-04
1130	0.1	207.4	1.31E-02	114	2.88E-04	2.10E-04
1135	0.1	177.2	1.12E-02	116	2.50E-04	2.15E-04
1140	0.1	163.7	1.03E-02	116	2.31E-04	2.18E-04
1145	0.0	156.7	9.89E-03	116	2.21E-04	2.21E-04
1150	0.1	155.0	9.78E-03	116	2.19E-04	1.98E-04
1155	0.2	157.5	9.94E-03	116	2.23E-04	2.08E-04
1160	0.2	181.9	1.15E-02	116	2.57E-04	2.36E-04
1165	0.2	229.4	1.45E-02	116	3.24E-04	2.55E-04
1170	0.2	278.9	1.76E-02	116	3.94E-04	2.67E-04
1175	0.1	320.8	2.02E-02	116	4.53E-04	2.74E-04
1180	0.2	341.0	2.15E-02	116	4.82E-04	2.64E-04
1185	0.4	361.9	2.28E-02	116	5.11E-04	2.71E-04
1190	0.4	401.6	2.53E-02	116	5.67E-04	2.84E-04
1195	0.4	481.6	3.04E-02	116	6.80E-04	2.90E-04
1200	0.5	563.1	3.55E-02	116	7.95E-04	2.92E-04
1205	0.4	616.5	3.89E-02	116	8.71E-04	2.97E-04
1210	0.2	626.3	3.95E-02	116	8.85E-04	2.92E-04
1215	0.2	583.7	3.68E-02	116	8.25E-04	2.81E-04
1220	0.1	507.4	3.20E-02	116	7.17E-04	2.73E-04
1225	0.1	438.9	2.77E-02	116	6.20E-04	2.58E-04
1230	0.2	377.8	2.38E-02	116	5.34E-04	2.46E-04
1235	0.1	335.5	2.12E-02	116	4.74E-04	2.49E-04
1240	0.2	311.6	1.97E-02	116	4.40E-04	2.39E-04
1245	0.1	296.2	1.87E-02	116	4.18E-04	2.45E-04
1250	0.2	298.7	1.88E-02	116	4.22E-04	2.36E-04
1255	0.1	311.6	1.97E-02	116	4.40E-04	2.43E-04
1260	0.1	318.1	2.01E-02	116	4.49E-04	2.35E-04
1265	0.1	303.8	1.92E-02	116	4.29E-04	2.29E-04
1270	0.0	274.0	1.73E-02	116	3.87E-04	2.25E-04
1275	0.1	227.3	1.43E-02	116	3.21E-04	2.02E-04
1280	0.0	187.6	1.18E-02	116	2.65E-04	2.05E-04
1285	0.1	153.3	9.67E-03	118	2.20E-04	1.84E-04
1290	0.0	124.5	7.85E-03	118	1.79E-04	1.94E-04
1295	0.1	107.3	6.77E-03	118	1.54E-04	1.74E-04
1300	0.0	97.3	6.14E-03	118	1.40E-04	1.88E-04
1305	0.1	91.5	5.78E-03	118	1.32E-04	1.69E-04
1310	0.1	90.3	5.70E-03	118	1.30E-04	1.86E-04
1315	0.0	91.5	5.78E-03	118	1.32E-04	2.01E-04
1320	0.0	92.8	5.85E-03	118	1.33E-04	1.80E-04
1325	0.0	91.5	5.78E-03	118	1.32E-04	1.61E-04
1330	0.1	84.8	5.35E-03	118	1.22E-04	1.45E-04
1335	0.0	74.0	4.67E-03	118	1.06E-04	1.74E-04
1340	0.0	64.0	4.04E-03	118	9.19E-05	1.56E-04
1345	0.1	55.8	3.52E-03	120	8.15E-05	1.40E-04
1350	0.1	51.3	3.23E-03	120	7.49E-05	1.75E-04
1355	0.2	55.3	3.49E-03	120	8.08E-05	2.03E-04
1360	0.2	79.6	5.02E-03	120	1.16E-04	2.55E-04
1365	0.1	132.1	8.34E-03	120	1.93E-04	2.89E-04
1370	0.1	197.4	1.25E-02	120	2.88E-04	2.88E-04
1375	0.2	254.0	1.60E-02	120	3.71E-04	2.87E-04
1380	0.1	298.7	1.88E-02	120	4.36E-04	3.05E-04
1385	0.2	315.5	1.99E-02	120	4.61E-04	2.98E-04
1390	0.1	306.4	1.93E-02	118	4.40E-04	3.09E-04
1395	0.2	291.2	1.84E-02	118	4.18E-04	2.99E-04
1400	0.1	293.7	1.85E-02	118	4.22E-04	3.07E-04
1405	0.2	307.7	1.94E-02	118	4.42E-04	2.95E-04
1410	0.1	315.5	1.99E-02	118	4.53E-04	3.01E-04
1415	0.1	307.7	1.94E-02	120	4.50E-04	2.89E-04
1420	0.2	296.2	1.87E-02	120	4.33E-04	2.79E-04
1425	0.1	296.2	1.87E-02	120	4.33E-04	2.86E-04
1430	0.2	302.5	1.91E-02	120	4.42E-04	2.76E-04
1435	0.4	327.4	2.07E-02	120	4.78E-04	2.82E-04
1440	0.2	389.6	2.46E-02	120	5.69E-04	2.96E-04

1445	0.2	461.6	2.91E-02	120	6.75E-04	2.93E-04
1450	0.1	474.9	3.00E-02	120	6.94E-04	2.89E-04
1455	0.1	426.3	2.69E-02	120	6.23E-04	2.75E-04
1460	0.1	353.5	2.23E-02	120	5.16E-04	2.63E-04
1465	0.0	291.2	1.84E-02	120	4.25E-04	2.54E-04
1470	0.0	232.7	1.47E-02	120	3.40E-04	2.28E-04
1475	0.0	185.7	1.17E-02	120	2.71E-04	2.04E-04
1480	0.0	145.7	9.19E-03	120	2.13E-04	1.83E-04
1485	0.0	112.1	7.07E-03	120	1.64E-04	1.64E-04
1490	0.0	86.0	5.43E-03	118	1.24E-04	1.47E-04
1495	0.0	66.5	4.20E-03	120	9.72E-05	1.32E-04
1500	0.1	52.1	3.29E-03	118	7.49E-05	1.18E-04
1505	0.0	40.9	2.58E-03	118	5.88E-05	1.54E-04
1510	0.0	32.7	2.06E-03	120	4.77E-05	1.38E-04
1515	0.0	25.5	1.61E-03	120	3.72E-05	1.24E-04
1520	0.0	20.8	1.31E-03	120	3.04E-05	1.11E-04
1525	0.0	17.2	1.08E-03	122	2.55E-05	9.92E-05
1530	0.0	14.2	8.94E-04	122	2.10E-05	8.89E-05
1535	0.0	12.0	7.59E-04	122	1.79E-05	7.97E-05
1540	0.0	10.1	6.38E-04	122	1.50E-05	7.14E-05
1545	0.0	8.7	5.47E-04	122	1.29E-05	6.40E-05
1550	0.0	7.5	4.74E-04	122	1.12E-05	5.73E-05
1555	0.0	6.6	4.15E-04	122	9.77E-06	5.14E-05
1560	0.0	5.7	3.61E-04	122	8.49E-06	4.60E-05
1565	0.0	5.0	3.17E-04	120	7.35E-06	4.13E-05
1570	0.0	4.5	2.84E-04	120	6.58E-06	3.70E-05
1575	0.0	4.0	2.53E-04	120	5.86E-06	3.31E-05
1580	0.0	3.6	2.29E-04	122	5.40E-06	2.97E-05
1585	0.0	3.2	2.02E-04	122	4.76E-06	2.66E-05
1590	0.0	3.0	1.87E-04	120	4.32E-06	2.38E-05
1595	0.0	2.7	1.67E-04	122	3.94E-06	2.14E-05
1600	0.0	2.5	1.58E-04	122	3.72E-06	1.91E-05
1605	0.0	2.2	1.40E-04	122	3.31E-06	1.72E-05
1610	0.0	2.0	1.28E-04	122	3.02E-06	1.54E-05
1615	0.0	1.8	1.16E-04	122	2.74E-06	1.38E-05
1620	0.0	1.7	1.05E-04	122	2.48E-06	1.23E-05
1625	0.0	1.6	9.85E-05	122	2.32E-06	1.11E-05
1630	0.0	1.5	9.18E-05	94	1.66E-06	9.91E-06
1635	0.0	1.3	8.23E-05	126	2.00E-06	8.88E-06
1640	0.0	1.2	7.62E-05	130	1.91E-06	7.96E-06
1645	0.0	1.1	7.05E-05	130	1.77E-06	7.13E-06
1650	0.0	1.0	6.51E-05	130	1.63E-06	6.39E-06
1655	0.0	1.0	6.24E-05	130	1.57E-06	5.73E-06
1660	0.0	0.9	5.49E-05	130	1.38E-06	5.13E-06
1665	0.0	0.8	5.02E-05	130	1.26E-06	4.60E-06
1670	0.0	0.8	4.80E-05	130	1.20E-06	4.12E-06
1675	0.0	0.8	4.80E-05	130	1.20E-06	3.69E-06
1680	0.0	0.7	4.36E-05	130	1.10E-06	3.31E-06
1685	0.0	0.6	3.96E-05	130	9.93E-07	2.97E-06
1690	0.0	0.6	3.96E-05	130	9.93E-07	2.66E-06
1695	0.0	0.6	3.76E-05	130	9.44E-07	2.38E-06
1700	0.0	0.5	3.39E-05	130	8.51E-07	2.14E-06
1705	0.0	0.5	3.04E-05	130	7.63E-07	1.91E-06
1710	0.0	0.5	2.87E-05	128	7.10E-07	1.71E-06
1715	0.0	0.5	2.87E-05	128	7.10E-07	1.54E-06
1720	0.0	0.5	2.87E-05	128	7.10E-07	1.38E-06
1725	0.0	0.4	2.71E-05	130	6.81E-07	1.23E-06
1730	0.0	0.4	2.71E-05	128	6.70E-07	1.11E-06
1735	0.0	0.4	2.41E-05	128	5.95E-07	9.91E-07
1740	0.0	0.4	2.41E-05	128	5.95E-07	8.88E-07
1745	0.0	0.4	2.41E-05	128	5.95E-07	7.96E-07
1750	0.0	0.4	2.27E-05	128	5.60E-07	7.13E-07
1755	0.0	0.3	2.13E-05	128	5.25E-07	6.39E-07
1760	0.0	0.3	2.13E-05	128	5.25E-07	5.73E-07
1765	0.0	0.3	2.13E-05	128	5.25E-07	5.13E-07
1770	0.0	0.3	2.13E-05	128	5.25E-07	4.60E-07
1775	0.0	0.3	1.99E-05	128	4.92E-07	4.12E-07
1780	0.0	0.3	1.99E-05	128	4.92E-07	3.69E-07
1785	0.0	0.3	1.86E-05	126	4.53E-07	3.31E-07
1790	0.0	0.3	1.86E-05	126	4.53E-07	2.97E-07
1795	0.0	0.3	1.74E-05	126	4.23E-07	2.66E-07
1800	0.0	0.3	1.74E-05	126	4.23E-07	2.38E-07
1805	0.0	0.3	1.74E-05	126	4.23E-07	2.13E-07

1810	0.0	0.3	1.74E-05	126	4.23E-07	1.91E-07
1815	0.0	0.3	1.62E-05	126	3.95E-07	1.71E-07
1820	0.0	0.275898354	1.74E-05	126	4.23E-07	1.54E-07
1825	0.0	0.275898354	1.74E-05	126	4.23E-07	1.38E-07
1830	0.0	0.275898354	1.74E-05	126	4.23E-07	1.23E-07
1835	0.0	0.25713605	1.62E-05	126	3.95E-07	1.11E-07
1840	0.0	0.25713605	1.62E-05	126	3.95E-07	9.90E-08
1845	0.0	0.25713605	1.62E-05	126	3.95E-07	8.87E-08
1850	0.0	0.239160884	1.51E-05	126	3.67E-07	7.95E-08
1855	0.0	0.25713605	1.62E-05	126	3.95E-07	7.13E-08
1860	0.0	0.239160884	1.51E-05	128	3.73E-07	6.39E-08
1865	0.0	0.239160884	1.51E-05	128	3.73E-07	5.72E-08
1870	0.0	0.239160884	1.51E-05	128	3.73E-07	5.13E-08
1875	0.0	0.221961528	1.40E-05	128	3.46E-07	4.60E-08
1880	0.0	0.221961528	1.40E-05	128	3.46E-07	4.12E-08
1885	0.0	0.221961528	1.40E-05	128	3.46E-07	3.69E-08
1890	0.0	0.221961528	1.40E-05	128	3.46E-07	3.31E-08
1895	0.0	0.221961528	1.40E-05	128	3.46E-07	2.96E-08
1900	0.0	0.221961528	1.40E-05	128	3.46E-07	2.66E-08
1905	0.0	0.221961528	1.40E-05	128	3.46E-07	2.38E-08
1910	0.0	0.221961528	1.40E-05	128	3.46E-07	2.13E-08
1915	0.0	0.221961528	1.40E-05	128	3.46E-07	1.91E-08
1920	0.0	0.205526489	1.30E-05	128	3.20E-07	1.71E-08
1925	0.0	0.189844094	1.20E-05	128	2.96E-07	1.53E-08
1930	0.0	0.205526489	1.30E-05	128	3.20E-07	1.38E-08
1935	0.0	0.205526489	1.30E-05	128	3.20E-07	1.23E-08
1940	0.0	0.205526489	1.30E-05	128	3.20E-07	1.10E-08
1945	0.0	0.205526489	1.30E-05	128	3.20E-07	9.90E-09
1950	0.0	0.205526489	1.30E-05	128	3.20E-07	8.87E-09
1955	0.0	0.189844094	1.20E-05	128	2.96E-07	7.95E-09
1960	0.0	0.189844094	1.20E-05	130	3.01E-07	7.12E-09
1965	0.0	0.205526489	1.30E-05	130	3.25E-07	6.38E-09
1970	0.0	0.189844094	1.20E-05	130	3.01E-07	5.72E-09
1975	0.0	0.189844094	1.20E-05	130	3.01E-07	5.13E-09
1980	0.0	0.189844094	1.20E-05	130	3.01E-07	4.59E-09
1985	0.0	0.189844094	1.20E-05	130	3.01E-07	4.12E-09
1990	0.0	0.189844094	1.20E-05	130	3.01E-07	3.69E-09
1995	0.0	0.189844094	1.20E-05	130	3.01E-07	3.31E-09
2000	0.0	0.189844094	1.20E-05	130	3.01E-07	2.96E-09
2005	0.0	0.189844094	1.20E-05	130	3.01E-07	2.65E-09
2010	0.0	0.189844094	1.20E-05	130	3.01E-07	2.38E-09
2015	0.0	0.189844094	1.20E-05	130	3.01E-07	2.13E-09
2020	0.0	0.174902491	1.10E-05	130	2.77E-07	1.91E-09

2025	0.0	0.174902491	1.10E-05	130	2.77E-07	1.71E-09
2030	0.0	0.174902491	1.10E-05	130	2.77E-07	1.53E-09
2035	0.0	0.174902491	1.10E-05	130	2.77E-07	1.37E-09
2040	0.0	0.174902491	1.10E-05	130	2.77E-07	1.23E-09
2045	0.0	0.174902491	1.10E-05	130	2.77E-07	1.10E-09
2050	0.0	0.174902491	1.10E-05	130	2.77E-07	9.89E-10
2055	0.0	0.174902491	1.10E-05	130	2.77E-07	8.86E-10
2060	0.0	0.174902491	1.10E-05	130	2.77E-07	7.94E-10
2065	0.0	0.174902491	1.10E-05	130	2.77E-07	7.12E-10
2070	0.0	0.174902491	1.10E-05	130	2.77E-07	6.38E-10
2075	0.0	0.174902491	1.10E-05	130	2.77E-07	5.72E-10
2080	0.0	0.174902491	1.10E-05	130	2.77E-07	5.12E-10
2085	0.0	0.174902491	1.10E-05	132	2.81E-07	4.59E-10
2090	0.0	0.174902491	1.10E-05	132	2.81E-07	4.11E-10
2095	0.0	0.174902491	1.10E-05	132	2.81E-07	3.69E-10
2100	0.0	0.174902491	1.10E-05	132	2.81E-07	3.30E-10
2105	0.0	0.174902491	1.10E-05	132	2.81E-07	2.96E-10
2110	0.0	0.174902491	1.10E-05	132	2.81E-07	2.65E-10
2115	0.0	0.174902491	1.10E-05	132	2.81E-07	2.38E-10
2120	0.0	0.174902491	1.10E-05	132	2.81E-07	2.13E-10
2125	0.0	0.174902491	1.10E-05	132	2.81E-07	1.91E-10
2130	0.0	0.174902491	1.10E-05	132	2.81E-07	1.71E-10
2135	0.0	0.16068963	1.01E-05	132	2.58E-07	1.53E-10
2140	0.0	0.147193264	9.29E-06	132	2.37E-07	1.37E-10
2145	0.0	0.147193264	9.29E-06	132	2.37E-07	1.23E-10
2150	0.0	0.147193264	9.29E-06	132	2.37E-07	1.10E-10
2155	0.0	0.147193264	9.29E-06	132	2.37E-07	9.89E-11
2160	0.0	0.147193264	9.29E-06	132	2.37E-07	8.86E-11
2165	0.0	0.147193264	9.29E-06	132	2.37E-07	7.94E-11
2170	0.0	0.147193264	9.29E-06	132	2.37E-07	7.11E-11
2175	0.0	0.147193264	9.29E-06	132	2.37E-07	6.38E-11
2180	0.0	0.147193264	9.29E-06	132	2.37E-07	5.71E-11
2185	0.0	0.147193264	9.29E-06	132	2.37E-07	5.12E-11
2190	0.0	0.147193264	9.29E-06	132	2.37E-07	4.59E-11
2195	0.0	0.147193264	9.29E-06	132	2.37E-07	4.11E-11
2200	0.0	0.147193264	9.29E-06	132	2.37E-07	3.68E-11
2205	0.0	0.147193264	9.29E-06	132	2.37E-07	3.30E-11
2210	0.0	0.122299935	7.72E-06	132	1.97E-07	2.96E-11
2215	0.0	0.122299935	7.72E-06	132	1.97E-07	2.65E-11
2220	0.0	0.134400928	8.48E-06	132	2.16E-07	2.38E-11
2225	0.0	0.122299935	7.72E-06	134	2.00E-07	2.13E-11
2230	0.0	0.122299935	7.72E-06	134	2.00E-07	1.91E-11
2235	0.0	0.122299935	7.72E-06	134	2.00E-07	1.71E-11
2240	0.0	0.122299935	7.72E-06	134	2.00E-07	1.53E-11
2245	0.0	0.122299935	7.72E-06	134	2.00E-07	1.37E-11
2250	0.0	0.122299935	7.72E-06	134	2.00E-07	1.23E-11
2255	0.0	0.11087736	7.00E-06	134	1.81E-07	1.10E-11
2260	0.0	0.11087736	7.00E-06	134	1.81E-07	9.88E-12
2265	0.0	0.122299935	7.72E-06	134	2.00E-07	8.86E-12
2270	0.0	0.11087736	7.00E-06	134	1.81E-07	7.94E-12
2275	0.0	0.100120028	6.32E-06	134	1.63E-07	7.11E-12
2280	0.0	0.100120028	6.32E-06	134	1.63E-07	6.37E-12
2285	0.0	0.100120028	6.32E-06	134	1.63E-07	5.71E-12
2290	0.0	0.11087736	7.00E-06	134	1.81E-07	5.12E-12
2295	0.0	0.100120028	6.32E-06	134	1.63E-07	4.59E-12
2300	0.0	0.100120028	6.32E-06	134	1.63E-07	4.11E-12
2305	0.0	0.11087736	7.00E-06	134	1.81E-07	3.68E-12
2310	0.0	0.100120028	6.32E-06	134	1.63E-07	3.30E-12
2315	0.0	0.100120028	6.32E-06	134	1.63E-07	2.96E-12
2320	0.0	0.11087736	7.00E-06	134	1.81E-07	2.65E-12
2325	0.0	0.11087736	7.00E-06	134	1.81E-07	2.37E-12
2330	0.0	0.100120028	6.32E-06	134	1.63E-07	2.13E-12
2335	0.0	0.100120028	6.32E-06	134	1.63E-07	1.91E-12
2340	0.0	0.100120028	6.32E-06	134	1.63E-07	1.71E-12
2345	0.0	0.100120028	6.32E-06	134	1.63E-07	1.53E-12
2350	0.0	0.100120028	6.32E-06	134	1.63E-07	1.37E-12
2355	0.0	0.100120028	6.32E-06	134	1.63E-07	1.23E-12
2360	0.0	0.100120028	6.32E-06	134	1.63E-07	1.10E-12
2365	0.0	0.100120028	6.32E-06	134	1.63E-07	9.88E-13
2370	0.0	0.100120028	6.32E-06	134	1.63E-07	8.85E-13
2375	0.0	0.100120028	6.32E-06	134	1.63E-07	7.93E-13
2380	0.0	0.100120028	6.32E-06	134	1.63E-07	7.11E-13
2385	0.0	0.100120028	6.32E-06	134	1.63E-07	6.37E-13

APPENDIX E

WATER SAMPLES AND ION TRENDS

1) Trends in Na^+, Cl^-, Ca^{+2}, Mg^{+2} from Automated Sampling
2) Storm event on 2/6/04 sampled by Automated Sampler and by Manual Collection

Year	Collection Type		Na	Cl	Ca	Mg
2003		5-Dec	0.189	0.272	0.014	0.013
2004	Manual	7-Feb	0.324	0.431	0.023	0.020
		7-Feb	0.200	0.289	0.015	0.014
	Manual	3-Feb	0.348	0.476	0.013	0.008
		3-Feb	0.255	0.384	0.013	0.007
		16-Mar	0.217	0.295	0.007	0.007
		2-Apr	0.193	0.254	0.010	0.006
		4-Apr	0.174	0.277	0.008	0.008
		19-May	0.265	0.336	0.016	0.011
		6-Jun	0.185	0.262	0.012	0.005
		7-Jul	0.184	0.258	0.019	0.008
		13-Jul	0.173	0.232	0.014	0.005
		29-Jul	0.203	0.234	0.016	0.005
		5-Aug	0.221	0.243	0.018	0.005
		13-Aug	0.193	0.214	0.015	0.004
		21-Aug	0.165	0.167	0.017	0.004
		28-Sep	0.164	0.193	0.023	0.005
		26-Oct	0.164	0.189	0.016	0.005
		12-Nov	0.162	0.218	0.024	0.006
		24-Nov	0.168	0.235	0.011	0.003
		20-Dec	0.151	0.169	0.020	0.003
2005		7-Jan	0.187	0.283	0.003	0.002
	Manual	3-Feb	0.200	0.303	0.008	0.007
		9-Feb	0.163	0.227	0.006	0.004
		14-Feb	0.173	0.240	0.011	0.015
		5-Mar	0.173	0.228	0.013	0.017
		12-Mar	0.193	0.265	0.005	0.007
		24-Mar	0.247	0.316	0.002	0.002
		28-Mar	0.200	0.266	0.002	0.002

All numbers presented are in units of (kg-cm/m^3-μS)

Manual = Manual Collection of Storm Events.

These are values for the trends collected both by manual collection and autosampling with the values compared to the measured specific conductivity in (uS/cm) to the concentration of the ions in mg/L

6712 Sampler - Plymouth West Weir
February 6 '04

pCO₂ = 10^-3.5 atm

Time ID	Sample ID	Date & Time	Time from Beginning	Normalized Time	Q	Σ	Q Norm	pH	Measured Conductivity (mS/cm)	Calculated Conductivity (mS/cm)	Measured Cond. Field Instr.	Net Charge	HCO₃⁻ Conc. (mg/L)	HCO₃⁻ C / Cmax	HCO₃⁻ Σ	HCO₃⁻ Normalized	Expected Amt. in Equil. @ pH w/ Atm	HCO₃⁻ Adjusted	Acetate Conc. (mg/L)	Acetate C / Cmax	Acetate Σ	Acetate Normalized	Cl⁻ Conc. (mg/L)	Cl⁻ C / Cmax	Cl⁻ Σ	Cl⁻ Normalized
Precipitation Collected During the week of 2/3/04 and 2/10/04								4.75	12.1		12.5						0.0000						0.69			
Manual Collection																										
1:30	1	2/6/04 13:30	0	0.0000	0.9487	4.7434	0.0000	5.0	2570	2982	4614	4.7%	3.7	0.0339	3.7	0.0023	0.06	3.68	95.8404	0.0341	95.8	0.0027	1083.0	0.1839	1083.0	0.0133
1:40	2	2/6/04 13:40	10	0.0175	1.9682	24.4250	0.0000	5.7	2440	2896	4652	5.5%	17.4	0.1579	20.8	0.0131	0.31	17.14	94.2283	0.0336	190.1	0.0053	1033.5	0.1755	2116.4	0.0259
1:50	3	2/6/04 13:50	20	0.0351	13.9672	164.0966	0.0002	6.2	2370	2909	4668	5.4%	39.5	0.3548	59.3	0.0374	0.97	38.51	93.3946	0.0333	283.5	0.0079	1030.7	0.1750	3147.1	0.0385
1:55	4	2/6/04 13:55	25	0.0439	40.1793	364.9933	0.0004	6.3	2755	3166	12272	6.1%	44.1	0.3947	102.2	0.0645	1.22	42.84	102.0445	0.0364	385.5	0.0107	1130.4	0.1920	4277.5	0.0524
2:00	5	2/6/04 14:00	30	0.0526	70.1904	715.9453	0.0007	6.5	3370	3967	20478	5.7%	64.8	0.5792	165.0	0.1041	1.93	62.87	195.7368	0.0697	581.2	0.0162	1446.7	0.2457	5724.2	0.0701
2:05	6	2/6/04 14:05	35	0.0614	92.8023	1179.9568	0.0012	6.7	4800	5318	23124	5.7%	83.5	0.7412	245.5	0.1549	3.06	80.45	471.3501	0.1679	1052.6	0.0293	1962.6	0.3333	7686.8	0.0941
2:10	7	2/6/04 14:10	40	0.0702	112.1245	1740.5793	0.0018	6.8	8280	8999	23380	6.1%	81.3	0.7138	323.0	0.2037	3.85	77.47	1416.2512	0.5045	2468.8	0.0688	3419.3	0.5807	11106.1	0.1360
2:15	8	2/6/04 14:15	45	0.0789	130.5701	2393.4299	0.0024	7.6	12600	14595	22420	5.0%	101.6	0.7120	400.2	0.2525	24.29	77.28	2778.8001	0.9899	5247.6	0.1462	5854.0	0.9942	16960.0	0.2077
2:20	9	2/6/04 14:20	50	0.0877	143.2696	3109.7781	0.0031	7.6	12810	14497	21768	6.7%	102.0	0.7160	478.0	0.3015	24.29	77.71	2714.1935	0.9669	7961.8	0.2219	5724.1	0.9721	22684.2	0.2778
2:25	11	2/6/04 14:25	55	0.0965	153.2619	3876.0876	0.0039	7.7	12500	14530	21610	3.4%	139.1	1.0000	586.5	0.3700	30.58	108.54	2807.1658	1.0000	10769.0	0.3001	5888.4	1.0000	28572.6	0.3500
2:30	12	2/6/04 14:30	60	0.1053	165.4342	4703.2585	0.0047	7.9	12500	13777	20892	7.0%	92.8	0.4083	630.8	0.3979	48.47	44.32	2631.1967	0.9373	13400.2	0.3734	5372.2	0.9123	33944.8	0.4158
2:35	13	2/6/04 14:35	65	0.1140	173.3922	5580.2194	0.0056	7.9	11850	13049	19710	5.5%	91.7	0.3983	674.0	0.4252	48.47	43.23	2489.5839	0.8869	15889.8	0.4428	5132.6	0.8716	39077.4	0.4786
2:40	14	2/6/04 14:40	70	0.1228	183.8007	6499.2230	0.0066	7.9	11130	12206	18606	5.3%	105.1	0.5220	730.7	0.4609	48.47	56.66	2389.2122	0.8508	18278.0	0.5093	4733.0	0.8038	43810.4	0.5366
2:45	15	2/6/04 14:45	75	0.1316	192.4466	7461.4560	0.0075	7.9	10450	11710	17560	7.6%	123.8	0.7121	808.0	0.5097	48.47	77.29	2242.7234	0.7989	20520.7	0.5718	4409.7	0.7489	48220.1	0.5906
2:50	16	2/6/04 14:50	80	0.1404	203.3393	8478.1524	0.0086	7.9	9900	10646	16430	4.4%	91.4	0.3956	850.9	0.5368	48.47	42.94	2094.0283	0.7460	22614.7	0.6302	4068.5	0.6909	52288.6	0.6404
2:55	17	2/6/04 14:55	85	0.1491	210.4591	9530.4480	0.0096	7.9	9100	10164	15284	3.0%	93.7	0.4165	896.1	0.5653	48.47	45.21	1982.4333	0.7062	24597.2	0.6854	3915.8	0.6650	56204.4	0.6884
3:00	18	2/6/04 15:00	90	0.1579	213.5556	10598.2259	0.0107	7.9	8520	9247	14280	5.9%	112.9	0.5938	960.6	0.6060	48.47	64.45	1754.1558	0.6249	26351.3	0.7343	3404.7	0.5782	59609.2	0.7301
3:05	19	2/6/04 15:05	95	0.1667	214.5938	11671.1948	0.0118	7.9	7850	8979	13168	1.6%	111.5	0.5806	1023.6	0.6457	48.47	63.02	1733.8677	0.6177	28085.2	0.7826	3427.5	0.5821	63036.7	0.7721
3:10	20	2/6/04 15:10	100	0.1754	219.8301	12770.3453	0.0129	8.0	7220	7995	12310	3.4%	87.3	0.2423	1049.9	0.6623	61.02	26.29	1488.6782	0.5303	29573.9	0.8241	2953.3	0.5015	65990.0	0.8083
3:15	22	2/6/04 15:15	105	0.1842	230.5309	13922.9999	0.0140	8.0	6610	7621	11432	5.0%	81.1	0.1847	1069.9	0.6749	61.02	20.05	1352.8837	0.4819	30926.8	0.8618	2770.0	0.4704	68760.0	0.8422
3:30	25	2/6/04 15:30	120	0.2105	257.4692	17785.0381	0.0179	7.9	6270	6255	9178	5.7%	81.7	0.3065	1103.2	0.6959	48.47	33.26	902.5279	0.3215	31829.3	0.8869	2248.9	0.3819	71008.9	0.8697
3:40	26	2/6/04 15:40	130	0.2281	263.3073	20418.1113	0.0206	7.8	5800	5635	8084	5.8%	83.5	0.4145	1148.2	0.7243	38.50	44.99	788.4894	0.2809	32617.8	0.9089	1987.4	0.3375	72996.3	0.8941
3:50	27	2/6/04 15:50	140	0.2456	274.0145	23158.2561	0.0234	7.8	5360	5004	7072	5.4%	68.1	0.2725	1177.8	0.7430	38.50	29.58	675.6994	0.2407	33293.5	0.9277	1742.3	0.2959	74738.6	0.9154
4:00	28	2/6/04 16:00	150	0.2632	265.6646	25814.9019	0.0260	7.8	5040	4600	6426	5.7%	68.8	0.2793	1208.1	0.7621	38.50	30.31	617.9506	0.2201	33911.4	0.9449	1569.0	0.2665	76307.6	0.9346
4:30	29	2/6/04 16:30	180	0.3158	326.0750	35597.1506	0.0359	7.9	4485	3878	5272	5.3%	74.2	0.2369	1233.8	0.7783	48.47	25.71	508.2538	0.1811	34419.7	0.9591	1282.3	0.2178	77589.9	0.9503
5:00	31	2/6/04 17:00	210	0.3684	539.3118	51776.5047	0.0522	7.8	3580	2908	3806	4.2%	68.1	0.2725	1263.4	0.7970	38.50	29.58	400.3230	0.1426	34820.0	0.9702	906.4	0.1539	78496.3	0.9614
5:30	32	2/6/04 17:30	240	0.4211	1755.1765	104431.8010	0.1054	7.7	2962	1603	1962	2.7%	61.5	0.2848	1294.3	0.8165	30.58	30.91	205.4646	0.0732	35025.5	0.9760	453.8	0.0771	78950.1	0.9670
6:00	33	2/6/04 18:00	270	0.4737	948.4663	132885.7886	0.1341	7.6	2160	1370	1636	3.2%	53.9	0.2730	1323.9	0.8352	24.29	29.63	170.7591	0.0608	35196.2	0.9807	377.6	0.0641	79327.7	0.9716
8:00	35	2/6/04 20:00	390	0.6842	1751.5100	343066.9881	0.3461	5.6	2160	1469	1776	5.7%	10.2	0.0922	1333.9	0.8415	0.24	10.01	146.1217	0.0521	35342.4	0.9848	434.2	0.0737	79761.9	0.9769
8:30	36	2/6/04 20:30	420	0.7368	2345.2162	413423.4746	0.4171	7.2	1143	1225	1476	2.9%	54.5	0.4130	1378.8	0.8698	9.67	44.83	107.8279	0.0384	35450.2	0.9878	349.6	0.0594	80111.5	0.9812
9:00	37	2/6/04 21:00	450	0.7895	2855.3338	499083.4899	0.5035	7.6	975	1094	1342	1.4%	64.1	0.3664	1418.5	0.8948	24.29	39.77	93.2852	0.0332	35543.5	0.9904	307.0	0.0521	80418.5	0.9850
9:30	38	2/6/04 21:30	480	0.8421	3548.6733	605543.6899	0.6109	7.5	47	1078	1364	1.9%	61.9	0.3923	1461.1	0.9217	19.30	42.58	88.9788	0.0317	35632.5	0.9929	302.3	0.0513	80720.8	0.9887
10:00	39	2/6/04 22:00	510	0.8947	3953.5556	724150.3583	0.7306	7.5	1123	1001	1622	2.8%	56.5	0.3426	1498.3	0.9452	19.30	37.19	81.1978	0.0289	35713.6	0.9951	276.4	0.0469	80997.2	0.9921
10:30	40	2/6/04 22:30	540	0.9474	4309.0969	853423.2665	0.8610	7.4	875	1118	1770	2.2%	59.3	0.4048	1542.2	0.9729	15.33	43.94	87.2908	0.0311	35800.9	0.9976	318.3	0.0540	81315.5	0.9960
11:00	42	2/6/04 23:00	570	1.0000	4591.1582	991158.0134	1.0000	6.7	758	1141	1840	3.3%	44.1	0.3962	1585.2	1.0000	3.06	43.00	86.8532	0.0309	35887.8	1.0000	329.2	0.0559	81644.6	1.0000
Sampler Collection																										
Bottle 1	43	2/6/04 14:00	0	0.0000	70.1904	350.9520	0.0074	6.3	4276	3378	20478	2.0%	58.5	0.4524	57.3	0.0343	1.22	57.27	66.1	0.0214	66.1	0.0027	1276.4	0.1835	1276.4	0.0212
Bottle 2	44	2/6/04 14:10	10	0.0556	112.1245	1472.1970	0.0312	6.8	18810	13336	23380	1.7%	120.8	0.9235	174.2	0.1042	3.85	116.90	2051.7	0.6634	2117.9	0.0872	5664.8	0.8146	6941.2	0.1150
Bottle 3	45	2/6/04 14:20	20	0.1111	143.2696	2904.8934	0.0616	7.0	23080	16862	21768	4.3%	132.7	1.0000	300.8	0.1799	6.10	126.59	3092.6	1.0000	5210.5	0.2144	6954.2	1.0000	13895.4	0.2303
Bottle 4	46	2/6/04 14:30	30	0.1667	165.4342	4559.2352	0.0966	7.1	21290	15104	20892	5.8%	128.3	0.9525	421.3	0.2520	7.68	120.58	2585.6	0.8360	7796.1	0.3208	6142.4	0.8833	20037.8	0.3321
Bottle 5	47	2/6/04 14:40	40	0.2222	183.8007	6397.2424	0.1355	7.1	20680	15069	18606	2.6%	120.8	0.8933	534.4	0.3196	7.68	113.08	2683.3	0.8676	10479.3	0.4312	6294.0	0.9051	26331.8	0.4364
Bottle 6	48	2/6/04 14:50	50	0.2778	203.3393	8430.6353	0.1786	7.2	18390	13387	16430	3.1%	120.3	0.8741	645.1	0.3858	9.67	110.65	2407.8	0.7786	12887.1	0.5303	5471.2	0.7867	31802.9	0.5271
Bottle 7	49	2/6/04 15:00	60	0.3333	213.5556	10566.1911	0.2239	7.2	16200	11744	14280	4.6%	109.5	0.7890	744.9	0.4456	9.67	99.87	2103.5	0.6802	14990.7	0.6169	4641.3	0.6674	36444.2	0.6040
Bottle 8	50	2/6/04 15:10	70	0.3889	219.8301	12764.4921	0.2705	7.2	14120	10289	12310	-0.5%	110.2	0.7940	845.4	0.5057	9.67	100.50	1883.3	0.6090	16874.0	0.6944	4161.0	0.5983	40605.2	0.6729
Bottle 9	51	2/6/04 15:20	80	0.4444	243.7768	15202.2605	0.3221	7.1	12030	8849	10570	1.5%	100.0	0.7292	937.7	0.5609	7.68	92.31	1547.4	0.5003	18421.4	0.7581	3442.1	0.4950	44047.3	0.7300
Bottle 10	52	2/6/04 15:30	90	0.5000	257.4692	17776.9526	0.3767	7.2	10430	7868	9178	-0.4%	99.2	0.7074	1027.3	0.6144	9.67	89.35	1322.1	0.4275	19743.5	0.8125	3065.2	0.4408	47112.6	0.7808
Bottle 12	54	2/6/04 15:50	110	0.6111	274.0145	23257.2424	0.4928	7.3	7920	6067	7072	1.6%	87.0	0.5908	1102.1	0.6592	12.18	74.78	795.7	0.2573	20539.2	0.8452	2287.5	0.3289	49400.1	0.8187
Bottle 13	55	2/6/04 16:00	120	0.6667	265.6646	25913.8881	0.5491	7.1	6980	5382	6426	2.0%	89.4	0.6458	1183.8	0.7081	7.68	81.75	677.5	0.2191	21216.7	0.8731	1981.0	0.2849	51381.1	0.8515
Bottle 14	56	2/6/04 16:10	130	0.7222	256.3110	28476.9982	0.6034	7.1	6310	4932	5976	1.9%	90.8	0.6565	1266.9	0.7578	7.68	83.11	607.8	0.1965	21824.6	0.8981	1788.0	0.2571	53169.1	0.8811
Bottle 15	57	2/6/04 16:20	140	0.7778	278.8556	31265.5545	0.6625	7.1	5890	4595	5642	1.4%	93.8	0.6801	1353.0	0.8093	7.68	86.09	566.9	0.1833	22391.5	0.9214	1646.0	0.2367	54815.0	0.9084
Bottle 16	58	2/6/04 16:30	150	0.8333	326.0750	34526.3041	0.7316	7.1	5570	4368	5272	1.5%	83.8	0.6015	1429.2	0.8548	7.68	76.14	529.8	0.1713	22921.2	0.9432	1555.5	0.2234	56368.5	0.9342
Bottle 17	59	2/6/04 16:40	160	0.8889	340.9745	37936.0487	0.8038	7.2	5140	4102	4848	1.4%	88.3	0.6212	1507.8	0.9018	9.67	78.64	486.3	0.1572	23407.5	0.9632	1442.9	0.2075	57811.4	0.9581
Bottle 18	60	2/6/04 16:50	170	0.9444	386.6124	41802.1730	0.8857	7.1	4724	3802	4480	1.4%	90.3	0.6527	1590.4	0.9513	7.68	82.63	450.8	0.1458	23858.3	0.9818	1313.7	0.1889	59125.1	0.9799
Bottle 19	61	2/6/04 17:00	180	1.0000	539.3118	47195.2910	1.0000	7.1	4450	3592	3806	1.8%	89.2	0.6437	1671.9	1.0000	7.68	81.49	442.4	0.1430	24300.6	1.0000	1215.6	0.1748	60340.7	1.0000

6712 Sampler - Plymouth West V
February 6 '04

Time ID	Sample ID	SO_4^{-2} Conc. (mg/L)	C / Cmax	Σ	Normalized	Na^+ Conc. (mg/L)	C / Cmax	Σ	Normalized	K^+ Conc. (mg/L)	C / Cmax	Σ	Normalized	Ca^{+1} Conc. (mg/L)	C / Cmax	Σ	Normalized	Mg^{+2} Conc. (mg/L)	C / Cmax	Σ	Normalized	Ionic Strength	Y
Precipitation Collected During		0.79				0.41				0.02				0.04				0.03					
Manual Collection																							
1:30	1	10.2836	0.2530	10.3	0.0168	736.4316	0.1647	736.4	0.0119	9.2	1.0000	9.2	0.0574	32.4	0.0947	32.4	0.0070	21.6	0.0626	21.6	0.0051	0.036	0.840
1:40	2	9.9888	0.2458	20.3	0.0331	720.1186	0.1611	1456.6	0.0235	8.3	0.8954	17.5	0.1087	31.9	0.0933	64.3	0.0138	21.4	0.0621	43.0	0.0101	0.035	0.841
1:50	3	9.9040	0.2437	30.2	0.0492	724.8720	0.1621	2181.4	0.0351	8.1	0.8801	25.7	0.1592	32.4	0.0948	96.7	0.0208	21.7	0.0629	64.7	0.0152	0.035	0.841
1:55	4	10.3074	0.2536	40.5	0.0660	810.7761	0.1814	2992.2	0.0482	7.9	0.8500	33.5	0.2080	34.6	0.1013	131.4	0.0283	22.6	0.0656	87.3	0.0205	0.039	0.836
2:00	5	11.8975	0.2928	52.4	0.0855	1045.8684	0.2339	4038.1	0.0651	8.1	0.8741	41.6	0.2582	48.6	0.1420	179.9	0.0388	33.8	0.0982	121.2	0.0284	0.051	0.820
2:05	6	15.2181	0.3745	67.6	0.1103	1442.5305	0.3227	5480.6	0.0883	8.5	0.9153	50.1	0.3107	84.6	0.2474	264.5	0.0570	69.6	0.2020	190.8	0.0448	0.074	0.798
2:10	7	26.3105	0.6474	93.9	0.1532	2639.0353	0.5903	8119.6	0.1308	8.4	0.9064	58.4	0.3627	185.5	0.5424	450.1	0.0969	171.1	0.4962	361.9	0.0849	0.142	0.762
2:15	8	39.6147	0.9748	133.5	0.2178	4414.4442	0.9875	12534.1	0.2019	6.8	0.7334	65.2	0.4047	340.5	0.9955	790.6	0.1703	342.4	0.9930	704.3	0.1652	0.249	0.738
2:20	9	38.6218	0.9503	172.1	0.2808	4470.5320	1.0000	17004.6	0.2739	6.5	0.7001	71.7	0.4449	342.1	1.0000	1132.6	0.2440	344.8	1.0000	1049.2	0.2461	0.248	0.738
2:25	11	40.6398	1.0000	212.8	0.3471	4316.4309	0.9655	21321.0	0.3435	6.4	0.6893	78.0	0.4844	332.2	0.9711	1464.8	0.3155	337.4	0.9783	1386.5	0.3252	0.247	0.738
2:30	12	36.2693	0.8925	249.1	0.4063	4230.8564	0.9464	25331.9	0.4116	6.0	0.6465	84.0	0.5213	327.8	0.9582	1792.6	0.3861	333.9	0.9684	1720.4	0.4035	0.233	0.740
2:35	13	35.5103	0.8738	284.6	0.4642	3920.6330	0.8770	29472.5	0.4748	5.6	0.6111	89.7	0.5566	303.4	0.8870	2096.0	0.4515	307.8	0.8927	2028.3	0.4757	0.221	0.742
2:40	14	33.6391	0.8277	318.2	0.5191	3622.5543	0.8103	33095.1	0.5332	5.3	0.5693	94.9	0.5892	286.4	0.8373	2382.4	0.5131	292.4	0.8480	2320.7	0.5443	0.206	0.745
2:45	15	30.5948	0.7528	348.8	0.5690	3551.8316	0.7945	36646.9	0.5904	5.6	0.6082	100.6	0.6241	280.6	0.8205	2663.1	0.5736	285.9	0.8290	2606.6	0.6114	0.198	0.747
2:50	16	29.4456	0.7246	378.2	0.6171	3145.4104	0.7036	39792.3	0.6410	5.1	0.5542	105.7	0.6559	250.7	0.7328	2913.7	0.6276	206.4	0.5987	2813.0	0.6598	0.174	0.752
2:55	17	27.3125	0.6721	405.6	0.6616	2935.9836	0.6567	42728.3	0.6883	4.8	0.5160	110.4	0.6853	234.5	0.6855	3148.2	0.6781	191.1	0.5543	3004.1	0.7046	0.165	0.755
3:00	18	25.3205	0.6230	430.9	0.7029	2724.5616	0.6094	45452.9	0.7322	4.5	0.4888	115.0	0.7136	217.8	0.6368	3366.1	0.7250	177.9	0.5158	3182.0	0.7463	0.149	0.759
3:05	19	25.9692	0.6390	456.8	0.7453	2500.5240	0.5593	47953.4	0.7725	4.2	0.4533	119.2	0.7396	201.3	0.5885	3567.3	0.7684	165.1	0.4787	3347.1	0.7850	0.142	0.762
3:10	20	22.9365	0.5644	479.8	0.7827	2235.8708	0.5001	50189.3	0.8085	3.9	0.4218	123.1	0.7638	177.8	0.5198	3745.1	0.8067	146.8	0.4258	3493.9	0.8195	0.125	0.769
3:15	22	22.4538	0.5525	502.2	0.8193	2146.6758	0.4802	52335.9	0.8431	3.7	0.4052	126.8	0.7870	172.2	0.5035	3917.4	0.8438	141.5	0.4105	3635.4	0.8527	0.119	0.771
3:30	25	16.8259	0.4140	519.1	0.8468	1707.4736	0.3819	54043.4	0.8706	3.2	0.3455	130.0	0.8068	133.1	0.3891	4050.4	0.8724	111.0	0.3218	3746.4	0.8787	0.093	0.785
3:40	26	15.1495	0.3728	534.2	0.8715	1512.6778	0.3384	55556.1	0.8950	2.9	0.3102	132.9	0.8246	117.1	0.3424	4167.6	0.8976	99.0	0.2871	3845.4	0.9019	0.083	0.792
3:50	27	13.7447	0.3382	548.0	0.8939	1308.5137	0.2927	56864.6	0.9161	2.7	0.2890	135.5	0.8412	100.7	0.2945	4268.3	0.9193	86.3	0.2503	3931.7	0.9222	0.072	0.800
4:00	28	12.9349	0.3183	560.9	0.9150	1186.4496	0.2654	58051.1	0.9352	2.7	0.2876	138.2	0.8577	92.3	0.2698	4360.6	0.9392	80.1	0.2324	4011.9	0.9410	0.065	0.805
4:30	29	11.2573	0.2770	572.2	0.9334	966.3872	0.2162	59017.4	0.9508	2.9	0.3183	141.1	0.8760	75.4	0.2204	4436.0	0.9555	66.8	0.1937	4078.7	0.9566	0.054	0.817
5:00	31	8.7598	0.2155	580.9	0.9477	674.2238	0.1508	59691.7	0.9616	3.7	0.4051	144.9	0.8992	57.5	0.1681	4493.5	0.9678	52.7	0.1527	4131.3	0.9690	0.039	0.835
5:30	32	4.8550	0.1195	585.8	0.9556	340.8988	0.0763	60032.6	0.9671	2.6	0.2830	147.5	0.9154	27.3	0.0797	4520.8	0.9737	25.3	0.0735	4156.7	0.9749	0.020	0.871
6:00	33	4.0057	0.0986	589.8	0.9621	290.7296	0.0650	60323.3	0.9718	2.1	0.2278	149.6	0.9285	21.9	0.0639	4542.6	0.9784	20.5	0.0596	4177.2	0.9797	0.016	0.880
8:00	35	4.2440	0.1044	594.0	0.9691	326.4328	0.0730	60649.7	0.9771	1.9	0.2028	151.5	0.9402	20.9	0.0611	4563.5	0.9829	18.3	0.0532	4195.6	0.9840	0.017	0.878
8:30	36	3.4550	0.0850	597.5	0.9747	263.1595	0.0589	60912.9	0.9813	1.7	0.1798	153.1	0.9505	15.9	0.0464	4579.4	0.9863	13.7	0.0399	4209.3	0.9873	0.014	0.887
9:00	37	3.1047	0.0764	600.6	0.9798	230.9312	0.0517	61143.8	0.9850	1.6	0.1680	154.7	0.9601	13.1	0.0382	4592.5	0.9892	11.5	0.0334	4220.8	0.9900	0.012	0.893
9:30	38	3.0698	0.0755	603.6	0.9848	229.6299	0.0514	61373.4	0.9887	1.5	0.1626	156.2	0.9694	12.6	0.0367	4605.0	0.9919	10.9	0.0317	4231.8	0.9925	0.012	0.894
10:00	39	2.8467	0.0700	606.5	0.9894	213.9755	0.0479	61587.4	0.9922	1.6	0.1707	157.8	0.9792	11.6	0.0340	4616.7	0.9944	9.9	0.0287	4241.7	0.9949	0.011	0.897
10:30	40	3.2163	0.0791	609.7	0.9947	239.5964	0.0536	61827.0	0.9960	1.6	0.1781	159.4	0.9894	12.9	0.0377	4629.6	0.9972	10.9	0.0317	4252.6	0.9974	0.013	0.892
11:00	42	3.2784	0.0807	613.0	1.0000	247.2219	0.0553	62074.2	1.0000	1.7	0.1840	161.1	1.0000	13.2	0.0387	4642.8	1.0000	11.0	0.0319	4263.6	1.0000	0.013	0.891
Sampler Collection																							
Bottle 1	43	11.2733	0.2546	11.3	0.0261	828.0608	0.1640	828.1	0.0195	7.7889	1.0000	7.8	0.0967	35.3444	0.0865	35.3	0.0107	22.7085	0.0546	22.7	0.0073	0.041	0.832
Bottle 2	44	37.8247	0.8543	49.1	0.1135	3887.0941	0.7699	4715.2	0.1111	6.1930	0.7951	14.0	0.1736	275.4881	0.6742	310.8	0.0938	258.6638	0.6218	281.4	0.0907	0.219	0.743
Bottle 3	45	44.2772	1.0000	93.4	0.2158	5048.7311	1.0000	9763.9	0.2301	7.3596	0.9449	21.3	0.2649	408.6049	1.0000	719.4	0.2171	416.0096	1.0000	697.4	0.2248	0.291	0.734
Bottle 4	46	39.3404	0.8885	132.7	0.3067	4596.4390	0.9104	14360.3	0.3384	6.8647	0.8813	28.2	0.3501	355.6341	0.8704	1075.1	0.3245	357.4378	0.8592	1054.8	0.3400	0.257	0.737
Bottle 5	47	41.3165	0.9331	174.0	0.4022	4413.0257	0.8741	18773.4	0.4424	6.1204	0.7858	34.3	0.4261	342.6522	0.8386	1417.7	0.4279	348.6469	0.8381	1403.5	0.4524	0.255	0.737
Bottle 6	48	35.8903	0.8106	209.9	0.4852	3892.5286	0.7710	22665.9	0.5342	5.5844	0.7170	39.9	0.4954	306.2699	0.7496	1724.0	0.5203	311.8817	0.7497	1715.3	0.5529	0.225	0.741
Bottle 7	49	32.6471	0.7373	242.6	0.5606	3414.5412	0.6763	26080.4	0.6147	4.8625	0.6243	44.8	0.5558	272.5668	0.6671	1996.6	0.6026	278.3940	0.6692	1993.7	0.6426	0.196	0.747
Bottle 8	50	30.0600	0.6789	272.6	0.6301	2832.8026	0.5611	28913.2	0.6814	4.6043	0.5911	49.4	0.6129	232.6156	0.5693	2229.2	0.6728	184.8715	0.4444	2178.6	0.7022	0.165	0.755
Bottle 9	51	26.4612	0.5976	299.1	0.6912	2430.4002	0.4814	31343.6	0.7387	4.0549	0.5206	53.4	0.6633	201.3240	0.4927	2430.5	0.7336	162.0387	0.3895	2340.7	0.7544	0.139	0.763
Bottle 10	52	23.6780	0.5348	322.8	0.7460	2076.3434	0.4113	33420.0	0.7876	3.6222	0.4650	57.1	0.7082	168.0902	0.4114	2598.6	0.7843	137.4547	0.3304	2478.1	0.7987	0.121	0.771
Bottle 12	54	17.3944	0.3929	340.2	0.7862	1558.3119	0.3087	34978.3	0.8244	2.9238	0.3754	60.0	0.7445	122.0241	0.2986	2720.6	0.8211	102.6729	0.2468	2580.8	0.8318	0.088	0.788
Bottle 13	55	15.3881	0.3475	355.6	0.8217	1359.4433	0.2693	36337.7	0.8564	2.6884	0.3452	62.7	0.7779	105.7926	0.2589	2826.4	0.8531	90.5475	0.2177	2671.3	0.8610	0.077	0.796
Bottle 14	56	14.4042	0.3253	370.0	0.8550	1223.2798	0.2423	37561.0	0.8852	2.7049	0.3473	65.4	0.8115	95.7209	0.2343	2922.1	0.8820	82.9571	0.1994	2754.3	0.8878	0.070	0.802
Bottle 15	57	13.8532	0.3129	383.8	0.8870	1116.5676	0.2212	38677.6	0.9115	2.6050	0.3345	68.0	0.8438	89.1001	0.2181	3011.2	0.9088	77.6024	0.1865	2831.9	0.9128	0.064	0.806
Bottle 16	58	13.3811	0.3022	397.2	0.9180	1052.2844	0.2084	39729.9	0.9363	2.5970	0.3334	70.6	0.8761	83.3462	0.2040	3094.6	0.9340	73.5679	0.1768	2905.5	0.9365	0.060	0.810
Bottle 17	59	12.6480	0.2857	409.8	0.9472	977.2390	0.1936	40707.1	0.9594	2.7615	0.3545	73.3	0.9103	77.0313	0.1885	3171.6	0.9573	68.7146	0.1652	2974.2	0.9586	0.056	0.814
Bottle 18	60	11.7842	0.2661	421.6	0.9744	892.3596	0.1767	41599.5	0.9804	3.2883	0.4222	76.6	0.9512	71.4428	0.1748	3243.0	0.9788	64.2481	0.1544	3038.4	0.9793	0.052	0.819
Bottle 19	61	11.0615	0.2498	432.7	1.0000	831.3403	0.1647	42430.8	1.0000	3.9341	0.5051	80.6	1.0000	70.1828	0.1718	3313.2	1.0000	64.1092	0.1541	3102.5	1.0000	0.049	0.822

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February 6 '04

Time ID	Sample ID	Amount of CMA (mmol / L) Magnesium	Amount of CMA Calcium	Amount of CMA Acetate	Sum of Mass	Amount of NaCl (mmol / L) Sodium	Amount of Premix (mmol / L)		Amount of NaCl (mmol / L)	Mass		Cl - Calculated (mg / L) Sodium	Cl - Calculated (mg / L)	% Error No premix	% Error	M Total (mmol / L)	M CMA (mmol / L)	M Premix (mmol / L)	M Salt (mmol / L)
Precipitation Collected During																			
Manual Collection																			
1:30	1	1.27	2.69	0.81	22.78	32.03	3.56	63.95	28.90	518.91		1135.66	1165.95	4.6%	7.1%	33.73	3.8%	10.6%	85.7%
1:40	2	1.26	2.65	0.80	93.76	31.32	3.49	260.08	28.25	2104.83		1110.50	1140.19	6.9%	9.4%	33.00	3.8%	10.6%	85.6%
1:50	3	1.27	2.70	0.79	673.79	31.53	3.56	1879.63	28.40	15016.48		1117.83	1148.07	7.8%	10.2%	33.23	3.8%	10.7%	85.5%
1:55	4	1.33	2.88	0.86	1011.24	35.27	3.88	2950.22	31.85	24223.52		1250.30	1283.30	9.6%	11.9%	37.06	3.6%	10.5%	85.9%
2:00	5	1.99	4.04	1.66	2641.94	45.49	5.13	6810.89	40.98	54443.76		1612.84	1656.45	10.3%	12.7%	48.10	4.1%	10.7%	85.2%
2:05	6	4.09	7.04	3.99	7187.48	62.75	7.37	12940.07	56.26	98826.14		2224.53	2287.20	11.8%	14.2%	67.72	6.0%	10.9%	83.1%
2:10	7	10.05	15.43	11.99	21332.77	114.79	13.45	28543.02	102.96	218492.89		4069.67	4184.07	16.0%	18.3%	126.46	7.9%	10.6%	81.4%
2:15	8	20.12	28.32	23.53	49717.62	192.02	20.52	50703.30	173.96	429918.37		6807.54	6982.06	14.0%	16.2%	214.60	9.4%	9.6%	81.1%
2:20	9	20.26	28.45	22.99	54939.19	194.46	20.48	55546.21	176.43	478426.72		6894.03	7068.27	17.0%	19.0%	217.18	9.3%	9.4%	81.2%
2:25	11	19.82	27.63	23.77	57497.25	187.75	19.52	56632.52	170.37	494803.30		6656.39	6822.46	11.5%	13.7%	209.92	9.4%	9.3%	81.3%
2:30	12	19.62	27.27	22.28	61431.09	184.03	19.13	59901.51	167.20	523527.46		6524.43	6687.10	17.7%	19.7%	205.95	9.5%	9.3%	81.2%
2:35	13	18.09	25.23	21.08	60040.86	170.54	17.88	59350.59	154.81	513902.45		6046.03	6198.11	15.1%	17.2%	190.77	9.5%	9.4%	81.1%
2:40	14	17.18	23.82	20.23	59768.69	157.57	16.61	57771.50	142.96	497327.72		5586.36	5727.62	15.3%	17.4%	176.75	9.7%	9.4%	80.9%
2:45	15	16.80	23.34	18.99	61181.09	154.49	16.37	59634.56	140.09	510268.48		5477.30	5610.56	19.5%	21.5%	173.26	9.7%	9.4%	80.9%
2:50	16	12.13	20.85	17.73	46681.20	136.82	21.80	83912.52	117.63	452719.72		4850.55	5035.99	16.1%	19.2%	151.56	8.0%	14.4%	77.6%
2:55	17	11.23	19.50	16.79	44730.89	127.71	20.69	82410.49	109.50	436191.90		4527.60	4703.55	13.5%	16.7%	141.42	7.9%	14.6%	77.4%
3:00	18	10.45	18.12	14.86	42238.21	118.51	19.17	77503.55	101.64	410822.92		4201.56	4364.64	19.0%	22.0%	131.26	8.0%	14.6%	77.4%
3:05	19	9.70	16.74	14.68	39393.92	108.77	17.61	71531.65	93.27	378825.68		3856.07	4005.86	11.1%	14.4%	120.58	8.0%	14.6%	77.4%
3:10	20	8.63	14.79	12.61	35896.30	97.25	15.40	64086.01	83.70	348259.73		3447.95	3578.95	14.3%	17.5%	107.73	8.0%	14.3%	77.7%
3:15	22	8.32	14.32	11.46	36284.78	93.37	15.02	65553.03	80.15	349737.85		3310.40	3438.18	16.3%	19.4%	103.49	8.0%	14.5%	77.4%
3:30	25	6.52	11.07	7.64	95323.47	74.27	11.37	166293.01	64.26	939467.47		2633.10	2729.85	14.6%	17.6%	82.16	7.9%	13.8%	78.2%
3:40	26	5.82	9.74	6.68	57977.76	65.80	9.81	97799.06	57.16	569765.91		2332.71	2416.16	14.8%	17.7%	72.79	8.0%	13.5%	78.5%
3:50	27	5.07	8.38	5.72	52608.87	56.92	8.27	85765.05	49.64	514908.65		2017.87	2088.19	13.7%	16.6%	62.98	8.1%	13.1%	78.8%
4:00	28	4.71	7.68	5.23	47356.30	51.61	7.42	74631.99	45.08	453320.03		1829.63	1892.75	14.2%	17.1%	57.21	8.2%	13.0%	78.8%
4:30	29	3.92	6.27	4.30	145313.05	42.04	5.87	217189.58	36.87	1365451.54		1490.27	1540.16	14.0%	16.7%	46.66	8.4%	12.6%	79.0%
5:00	31	3.09	4.78	3.39	189537.22	29.33	4.22	258696.75	25.61	1568512.76		1039.72	1075.65	12.8%	15.7%	32.93	9.4%	12.8%	77.8%
5:30	32	1.49	2.27	1.74	296642.03	14.83	1.95	388715.71	13.11	2613550.03		525.70	542.39	13.7%	16.3%	16.55	9.0%	11.8%	79.2%
6:00	33	1.21	1.82	1.45	130044.40	12.65	1.53	164762.48	11.30	1217122.26		448.34	461.35	15.8%	18.2%	14.04	8.6%	10.9%	80.5%
8:00	35	1.08	1.74	1.24	857333.68	14.20	1.65	1314110.75	12.75	10140719.41		503.39	517.44	13.7%	16.1%	15.47	7.0%	10.7%	82.4%
8:30	36	0.81	1.32	0.91	215109.99	11.45	1.28	341103.78	10.32	2748452.04		405.82	416.71	13.8%	16.1%	12.41	6.5%	10.3%	83.2%
9:00	37	0.68	1.09	0.79	219571.08	10.04	1.02	331915.42	9.14	2965090.08		356.12	364.83	13.8%	15.9%	10.84	6.2%	9.4%	84.3%
9:30	38	0.64	1.05	0.75	258764.65	9.99	1.01	406175.79	9.10	3667845.66		354.11	362.69	14.6%	16.7%	10.75	6.0%	9.4%	84.7%
10:00	39	0.58	0.97	0.69	260939.19	9.31	0.97	433705.11	8.46	3797159.89		329.97	338.19	16.2%	18.3%	10.00	5.8%	9.7%	84.5%
10:30	40	0.64	1.07	0.74	314579.95	10.42	1.07	525959.80	9.48	4637133.58		369.48	378.63	13.9%	15.9%	11.19	5.7%	9.6%	84.7%
11:00	42	0.65	1.10	0.74	336609.92	10.75	1.14	592480.27	9.75	5085364.41		381.24	390.91	13.7%	15.8%	11.54	5.6%	9.9%	84.6%
				mmol	4160476.44	12.93		6297289.85	mmol		48522222.57	458.50					7.4%	11.4%	81.3%
			Vol * Conc.	Mass (kg)	611.74		991158.0134	362.87	Mass (kg)	2835.77							524430.9966	4408187.456	59296401.2
				Mass (lbs)	1348.66			799.98	Mass (lbs)		6251.81						0.82%	6.86%	92.32%
Sampler Collection																			
Bottle 1	43	1.33	2.94	0.56	1772.51	36.02	4.01	5332.52	32.49	43158.33									
Bottle 2	44	15.20	22.91	17.38	64504.47	169.08	19.30	81898.32	152.10	645568.84									
Bottle 3	45	24.44	33.98	26.19	132559.57	219.61	23.87	129446.96	198.60	1077100.91									
Bottle 4	46	21.00	29.38	21.90	131516.21	199.93	21.46	134362.89	181.05	1133826.79									
Bottle 5	47	20.48	28.50	22.72	142523.53	191.95	20.05	139482.11	174.32	1212817.98									
Bottle 6	48	18.32	25.47	20.39	141047.28	169.31	17.88	137638.48	153.58	1182145.77									
Bottle 7	49	16.36	22.67	17.81	132228.28	148.52	15.79	127658.00	134.63	1088331.34									
Bottle 8	50	10.86	19.35	15.95	90388.00	123.22	21.22	176557.43	104.55	870010.35									
Bottle 9	51	9.52	16.74	13.10	87854.64	105.72	18.06	166693.64	89.82	828865.04									
Bottle 10	52	8.08	13.98	11.20	78711.55	90.32	14.76	143895.95	77.32	753621.66									
Bottle 12	54	6.03	10.15	6.74	125144.77	67.78	10.29	213548.64	58.72	1218251.89									
Bottle 13	55	5.32	8.80	5.74	33501.19	59.13	8.70	87488.28	51.48	517680.30									
Bottle 14	56	4.87	7.96	5.15	47290.56	53.21	7.72	74904.90	46.42	450350.64									
Bottle 15	57	4.56	7.41	4.80	48129.18	48.57	7.13	75262.67	42.29	446448.07									
Bottle 16	58	4.32	6.93	4.49	53353.03	45.77	6.53	80553.46	40.03	494091.27									
Bottle 17	59	4.04	6.41	4.12	52110.37	42.51	5.93	76486.18	37.29	481352.77									
Bottle 18	60	3.77	5.94	3.82	55244.61	38.82	5.42	79317.40	34.05	498264.13									
Bottle 19	61	3.77	5.84	3.75	76897.80	36.16	5.18	105713.66	31.60	645216.06									

6712 Sampler - Plymouth West Y
February 6 '04

Time ID	Sample) ID	Assuming Conservative M Acetate (mmol / L) Predicted	M Acetate (mmol / L) Predicted	M Acetate (mmol / L) Observed	% Error	% Error Percent	Error mmol / L Absolute	Error mmol / L	Error mg/L	Observed Bicarbonate Acetate	Mass of Acetate with degradation to bicarbonate Acetate (Predicted - Obse mmol / L	Acetate dicted - Obse mmol / L	O_3^- from Ace Predicted mmol / L	O_3^- from Ace Predicted mmol / L	Acetate HCO_3^- Observed mmol / L	cetate Degra mmol / L	HCO_3^- cetate Degra	cetate YHCO / HCO_3^- Observed	Cl % Error	harge Balance
Precipitation Collected During t																				
Manual Collection																				
1:30	1	2.5	5.4	1.6	69.9%	36.0%	0.91	3.76	53.96	0.03716913	0.9	3.76	0.9	3.8	0.1	-0.9	-3.7	-1414.7%	7.1%	4.7%
1:40	2	2.5	5.3	1.6	69.9%	36.6%	0.92	3.71	54.37	0.17600466	0.9	3.71	0.9	3.7	0.3	-0.6	-3.4	-227.9%	9.4%	5.5%
1:50	3	2.5	5.4	1.6	70.7%	37.9%	0.97	3.81	57.09	0.39900288	1.0	3.81	1.0	3.8	0.6	-0.3	-3.2	-53.2%	10.2%	5.4%
1:55	4	2.7	5.8	1.7	70.0%	35.0%	0.93	4.03	54.97	0.40620849	0.9	4.03	0.9	4.0	0.7	-0.2	-3.3	-32.6%	11.9%	6.1%
2:00	5	4.0	8.1	3.3	59.0%	16.6%	0.66	4.76	39.08	0.31077559	0.7	4.76	0.7	4.8	1.0	0.4	-3.7	35.7%	12.7%	5.7%
2:05	6	8.2	14.1	8.0	43.3%	2.4%	0.20	6.09	11.83	0.16513293	0.2	6.09	0.2	6.1	1.3	1.1	-4.8	84.8%	14.2%	5.7%
2:10	7	20.1	30.9	24.0	22.3%	-19.3%	3.88	6.87	229.28	0.05292889	-3.9	6.87	-3.9	6.9	1.3	5.2	-5.6	405.9%	18.3%	6.1%
2:15	8	40.2	56.6	47.1	16.9%	-17.0%	6.83	9.57	403.27	0.02690764	-6.8	9.57	-6.8	9.6	1.3	8.1	-8.3	639.3%	16.2%	5.0%
2:20	9	40.5	56.9	46.0	19.2%	-13.5%	5.45	10.93	321.86	0.02770301	-5.5	10.93	-5.5	10.9	1.3	6.7	-9.7	528.1%	19.0%	6.7%
2:25	11	39.6	55.3	47.5	13.9%	-19.9%	7.90	7.70	466.68	0.03741	-7.9	7.70	-7.9	7.7	1.8	9.7	-5.9	544.4%	13.7%	3.4%
2:30	12	39.2	54.5	44.6	18.3%	-13.6%	5.33	9.97	314.57	0.01629641	-5.3	9.97	-5.3	10.0	0.7	6.1	-9.2	833.6%	19.7%	7.0%
2:35	13	36.2	50.5	42.2	16.4%	-16.6%	5.99	8.30	353.94	0.0168014	-6.0	8.30	-6.0	8.3	0.7	6.7	-7.6	946.2%	17.2%	5.5%
2:40	14	34.4	47.6	40.3	15.1%	-17.7%	6.09	7.19	359.30	0.02295332	-6.1	7.19	-6.1	7.2	0.9	7.0	-6.3	735.8%	17.4%	5.3%
2:45	15	33.6	46.7	38.0	18.6%	-13.1%	4.39	8.70	259.37	0.03334262	-4.4	8.70	-4.4	8.7	1.3	5.7	-7.4	446.9%	21.5%	7.6%
2:50	16	24.3	41.7	35.5	14.9%	-46.2%	11.21	6.23	661.79	0.01983831	-11.2	6.23	-11.2	6.2	0.7	11.9	-5.5	1693.1%	19.2%	4.4%
2:55	17	22.5	39.0	33.6	13.9%	-49.5%	11.12	5.43	656.47	0.0220631	-11.1	5.43	-11.1	5.4	0.7	11.9	-4.7	1600.9%	16.7%	3.0%
3:00	18	20.9	36.2	29.7	18.0%	-42.2%	8.81	6.52	520.23	0.03555124	-8.8	6.52	-8.8	6.5	1.1	9.9	-5.5	934.2%	22.0%	5.9%
3:05	19	19.4	33.5	29.4	12.3%	-51.4%	9.97	4.12	588.60	0.03516853	-10.0	4.12	-10.0	4.1	1.0	11.0	-3.1	1065.3%	14.4%	1.6%
3:10	20	17.3	29.6	25.2	14.7%	-46.1%	7.96	4.36	469.96	0.01708953	-8.0	4.36	-8.0	4.4	0.4	8.4	-3.9	1947.3%	17.5%	3.4%
3:15	22	16.6	28.6	22.9	20.0%	-37.8%	6.28	5.73	370.94	0.01433945	-6.3	5.73	-6.3	5.7	0.3	6.6	-5.4	2012.1%	19.4%	5.0%
3:30	25	13.0	22.1	~15.3	30.9%	-17.2%	2.25	6.85	132.61	0.03565799	-2.2	6.85	-2.2	6.9	0.5	2.8	-6.3	512.0%	17.6%	5.7%
3:40	26	11.6	19.5	13.4	31.4%	-14.8%	1.72	6.13	101.64	0.05520731	-1.7	6.13	-1.7	6.1	0.7	2.5	-5.4	333.5%	17.7%	5.8%
3:50	27	10.1	16.8	11.4	31.7%	-12.8%	1.30	5.31	76.81	0.04235348	-1.3	5.31	-1.3	5.3	0.5	1.8	-4.8	368.4%	16.6%	5.4%
4:00	28	9.4	15.4	10.5	31.8%	-11.1%	1.05	4.89	61.91	0.04746429	-1.0	4.89	-1.0	4.9	0.3	1.5	-4.4	311.1%	17.1%	5.7%
4:30	29	7.8	12.5	8.6	31.3%	-9.7%	0.76	3.93	44.88	0.0489442	-0.8	3.93	-0.8	3.9	0.4	1.2	-3.5	280.4%	16.7%	5.3%
5:00	31	6.2	9.6	6.8	29.1%	-9.6%	0.59	2.79	34.90	0.07148782	-0.6	2.79	-0.6	2.8	0.5	1.1	-2.3	221.9%	15.7%	4.2%
5:30	32	3.0	4.5	3.5	23.3%	-16.9%	0.50	1.06	29.73	0.14557285	-0.5	1.06	-0.5	1.1	0.5	1.0	-0.5	199.4%	16.3%	2.7%
6:00	33	2.4	3.6	2.9	20.5%	-19.8%	0.48	0.75	28.19	0.16789394	-0.5	0.75	-0.5	0.7	0.5	1.0	-0.3	198.3%	18.2%	3.2%
8:00	35	2.2	3.5	2.5	28.8%	-14.8%	0.32	1.00	18.88	0.06624866	-0.3	1.00	-0.3	1.0	0.2	0.5	-0.8	295.1%	16.1%	5.7%
8:30	36	1.6	2.6	1.8	30.8%	-13.1%	0.21	0.81	12.46	0.40227046	-0.2	0.81	-0.2	0.8	0.7	0.9	-0.1	128.7%	16.1%	2.9%
9:00	37	1.4	2.2	1.6	27.3%	-16.7%	0.23	0.59	13.33	0.41247986	-0.2	0.59	-0.2	0.6	0.7	0.9	0.1	134.6%	15.9%	1.4%
9:30	38	1.3	2.1	1.5	27.9%	-17.4%	0.22	0.58	13.16	0.46298786	-0.2	0.58	-0.2	0.6	0.7	0.9	0.1	131.9%	16.7%	1.9%
10:00	39	1.2	1.9	1.4	28.9%	-18.3%	0.21	0.56	12.57	0.44311913	-0.2	0.56	-0.2	0.6	0.6	0.8	0.0	134.9%	18.3%	2.8%
10:30	40	1.3	2.1	1.5	31.1%	-15.0%	0.19	0.67	11.38	0.48701572	-0.2	0.67	-0.2	0.7	0.7	0.9	0.1	126.8%	15.9%	2.2%
11:00	42	1.3	2.2	1.5	33.1%	-13.9%	0.18	0.73	10.62	0.47900018	-0.2	0.73	-0.2	0.7	0.7	0.9	0.0	125.5%	15.8%	3.3%
Sampler Collection																				
Bottle 1	43																			
Bottle 2	44																			
Bottle 3	45																			
Bottle 4	46																			
Bottle 5	47																			
Bottle 6	48																			
Bottle 7	49																			
Bottle 8	50																			
Bottle 9	51																			
Bottle 10	52																			
Bottle 12	54																			
Bottle 13	55																			
Bottle 14	56																			
Bottle 15	57																			
Bottle 16	58																			
Bottle 17	59																			
Bottle 18	60																			
Bottle 19	61																			

APPENDIX F

MATERIALS APPLICATION DATA

1) 2003-2004 and 2004-2005 Deicing Agent Application

Wareham CMA Use Summary on Rt. 25 in Plymouth - 2004-2005 salt season

	Tons												Gallons		
	Salt			Sand			Premix			CMA			Liquid Calcium		
Date	Applied	Delivered	On Hand	Applied	Delivered	On Hand	Applied	Delivered	On Hand	Applied	Delivered	On Hand	Applied	Delivered	On Hand
			1385			904			0			57			2500
11/13/2004	44		1341			904			0			57			2500
			1385			904			0			57			2500
12/7/2004			1341			904			0		48.23	105			2500
12/16/2004	28		1313			904			0			105			2500
12/17/2004	6		1307			904			0			105			2500
12/19/2004	6		1301	30		874			0			105			2500
12/20/2004	350		951			874			0	21		84			2500
12/26/2004	120		831			874			0	6		78			2500
12/27/2004	600		231	40		834			0	16		62			2500
12/29/2004	46		185			834			0	6		56			2500
12/30/2004		593	778			834			0			56			2500
			778			834			0			56			2500
1/5/2005	200		578	20		814			0	8		48			2500
1/6/2005	300		278	30		784			0	12		36			2500
1/7/2005	20		258	10		774			0	6		30			2500
1/8/2005	62		196			774			0			30			2500
1/10/2005			196			774			0	2		28			2500
1/11/2005		407.96	604			774			0			28			2500
1/12/2005	288		316	25		749			0	10		18			2500
1/14/2005	40		276			749			0	2		16			2500
1/15/2005		712.21	988			749			0			16			2500
1/16/2005	263		725	75		674			0	4		12			2500
1/17/2005	287		438	75		599			0	2		10			2500
1/19/2005	145		293			599			0			10			2500
1/20/2005	145		148	18		581			0	6		4			2500
1/21/2005		460	608			581			0			4			2500
1/22/2005	50		558	20		561			0	3		1			2500
adj*						561			0		19	20			2500
1/23/2005			558			561			0	2		18			2500
1/24/2005	387		171	57		504			0	2		16			2500
1/25/2005		205.55	377			504			0			16			2500
1/26/2005	100		277	10		494			0			16			2500
1/27/2005	200		77	25		469			0	4		12			2500
			77			469			0			12			2500
2/1/2005		578.61	655			469			0			12			2500
2/3/2005	30		625			469			0			12			2500
2/5/2005	90		535			469			0			12			2500
2/9/2005		554	1089			469			0			12			2500
2/10/2005	100		989			469			0	4		8			2500
2/11/2005	136		853			469			0	4		4			2500
2/17/2005	30		823			469			0			4			2500
2/21/2005	350		473	100		369			0	2		2			2500
2/22/2005	120		353	40		329			0	2		0			2500
2/23/2005	110		243	35		294			0			0			2500
2/24/2005	160		83	50		244			0			0			2500
2/25/2005	160	277	200	50		194			0			0			2500
2/28/2005	100		100	125		69			0			0			2500
			100			69			0			0			2500
3/1/2005	10		90	20		49			0			0			2500
3/2/2005	100		[redacted]	40		9			0			0			2500
3/3/2005		489	479			9			0			0			2500
adj*			479		491	500			0			0			2500
3/8/2005	200		279	10		490			0			0			2500
3/9/2005	200		79	10		480			0			0			2500
3/10/2005		130	209			480			0			0			2500
3/11/2005	100	162	271	5		475			0			0			2500
3/12/2005	300		[redacted]	15		460			0			0			2500
3/15/2005		450	421			460			0			0			2500
adj*		29	450			460			0			0			2500
3/22/2005	100	840	1190	5		455			0			0			2500
3/23/2005	200		990	10		445			0			0			2500
3/24/2005			990			445			0			0			2500
			990			445			0			0			2500
4/5/2005		150	1140			445			0			0			2500
			1140			445			0			0			2500
	6283	6038		950	491		0	0		124	67		0	0	

Wareham CMA Use Summary on Rt. 25 in Plymouth - 2003-2004 salt season

	Tons												Gallons		
	Salt			Sand			Premix			CMA			Liquid Calcium		
Date	Applied	Delivered	On Hand	Applied	Delivered	On Hand	Applied	Delivered	On Hand	Applied	Delivered	On Hand	Applied	Delivered	On Hand
11/22/2003			647			70			0			115			2351
11/23/2003		413	1060			70			0			115			2351
12/5/2003	90		970	10		60			0			115			2351
12/6/2003	350		620	30		30			0	14		101			2351
adj*		40	660			30			0			101			2351
12/7/2003	400		260	13		17			0	4		97			2351
12/8/2003	60		200	5	497	509			0			97			2351
12/12/2003	20		180	5		504			0			97			2351
adj*			180	1		503			0			97			2351
12/14/2003	30		150	10		-493			0	2		95			2351
12/15/2003	10	405	545			493			0			95			2351
adj*			545			493			0			95			2351
12/29/2003	30	734	1249	10		483			0			95			2351
12/30/2003	30		1219	10		473			0			95			2351
1/2/2004	90		1129	20		453			0	3		92			2351
adj*			1129			453			0			92			2351
1/5/2004	60		1069	10		443			0	1.5		91			2351
1/6/2004	60		1009	15		428			0	1.5		89			2351
adj*	10		999	8		420			0			89			2351
1/11/2004	140		859	30		390			0	5		84			2351
1/12/2004	60		799	10		380			0	1		83			2351
1/13/2004	50		749			380			0	1		82			2351
1/15/2004	140		609	40		340			0			82			2351
1/16/2004	20		589			340		34.39	34			82			2351
adj*			589			340			34	5		77			2351
1/18/2004	250		339	50		290		245.48	280	6		71			2351
1/20/2004			339			290			280			71			2351
1/22/2004	40		299	5		285			280	1		70			2351
1/26/2004		527.64	827			285			280			70			2351
1/28/2004	360		467	70		215	90		190	9		61			2351
1/29/2004	20		447			215			190			61			2351
adj*			447	10		205			190			61			2351
2/3/2004		351.97	799			205			190			61			2351
2/4/2004	40		759	5		200			190	1		60			2351
2/6/2004	220		539	30		170			190	3		57			2351
adj*			539			170			190		33	90			2351
2/18/2004	350	286	475	50		120	40		150	6		84			2351
2/21/2004			475		488	608			150			84			2351
2/22/2004	60		415	15		593			150			84			2351
2/27/2004		600	1015			593			150			84			2351
adj*			1015			593			150	1		83			2351
3/8/2004	170		845	30		563			150	2		81			2351
3/9/2004	60		785	10		553			150	1		80			2351
3/11/2004	120		665	20		533			150	2		78			2351
			665			533			150			78			2351
3/16/2004	150		515	40		493	80		70	6		72			2351
3/17/2004	150	210.3	575	30		463	60		10	6		66			2351
3/18/2004	50		525	10		453			10	4		62			2351
3/19/2004	140		385	35		418	10		0	5		57			2351
3/30/2004		416	801		472	890			0			57			2351
adj*		33	834			890			0			57			2351
TOTALS	3820	3592		618	1457		280	280		85	0		0	0	