STREAMWATER DYNAMICS AND CARBON AND NUTRIENT LOSSES IN TROPICAL HEADWATER CATCHMENTS AT A SOIL DEGRADATION GRADIENT

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STREAMWATER DYNAMICS AND CARBON AND NUTRIENT LOSSES IN TROPICAL HEADWATER CATCHMENTS AT A SOIL DEGRADATION GRADIENT

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Tropical Africa is affected by intense land use change, particularly forest conversion to agricultural land. Four small headwater catchments that cover a degradation gradient ranging from intact forest to agricultural land under maize cultivation for 5, 10 and 50 years were examined. With increasing duration of cultivation, soil bulk density (ρ_b) at a depth of 0-0.1 m increased by 46%, while soil organic carbon (SOC) concentrations and total porosity decreased by 75% and 20%, respectively. The annual catchment discharge expressed as a percentage of rainfall increased from an average of 16.0% in the forest to 32.4% in the 50-year-old agricultural catchment. The average runoff ratio was 0.033 in the forest and increased gradually to 0.095 with increasing duration of cultivation. Flow-weighted stream water concentrations of different organic C fractions, all N species, total P, K and Na significantly ($P<0.05$) increased in streams after forest conversion and long-term cultivation. Solute concentrations increased despite the fact that soil contents decreased and total water flow increased indicating mobilization of C and N, P and K from soil with progressing cultivation. Total C and nutrient exports increased with longer cultivation ($P<0.05$) due to greater

water discharge. Fluvial organic C and total N losses were 2% and 21% of total SOC and total N decline, respectively, in the top 0.1m over 50 years. During storm events, concentrations of DOC and K increased with larger discharge in all studied watersheds. This suggests a quick transfer of these solutes to the stream through overland flow and preferential flow through soil macropores. The Ca, Mg, Na, TDN and NO_3^--N concentrations did not change in the forested watershed, while their concentrations decreased with increasing discharge in the agricultural watersheds. Baseflow that is rich in Ca, Mg, and Na was diluted by the storm event runoff. Based on end-member mixing analysis (EMMA) modeling, groundwater was shown to be the dominant flowpath which was higher ($P<0.05$) in the forest compared to the 10- and 50-year conversion watersheds. The contribution of overland flowpath compared to streamwater was significantly lower ($P<0.05$) in the forest and 5-year watershed than the 50-year watershed.

BIOGRAPHICAL SKETCH

John's childhood was spent on a peasant farm in Mumias, Kakamega County of western Kenya. He is the son of an elementary school teacher. His mother worked entirely on the farm. The childhood life spurred John to develop interest in acquiring agricultural skills, in order to help his people get enough food and income. After graduating from high school in Musingu, Kakamega County, he completed a Bachelor of Science degree in Agriculture at the University of Nairobi in Kenya.

John went on to start a secondary school in his home village in 1996, where he worked for nine months before moving on to teach in an established secondary school after getting government employment. He pursued a school based Post Graduate Diploma in Education at Kenyatta University between 1997 and 1998. He received a scholarship for his Master of Science degree in Soil Science and Land Management at Sokoine University of Agriculture in the United Republic of Tanzania, which was completed in 2000. He married Beatrice Augustine Madeghe in Morogoro, Tanzania.

Returning to Kenya in 2001, he continued to teach in high school for two years. In 2003, he joined a non-governmental organization and worked on management of environmental resources. In 2004, he began a career in research working as a technician with the World Agroforestry Centre (ICRAF) in western Kenya. He began working towards a PhD in Soil Science at Cornell University with Dr. Johannes Lehmann in 2007. John and Beatrice have 4 children, Joycatherine, Shammah, Josiah and Ethan.

To my wife Beatrice, our daughter Joycatherine, our sons Shammah, Josiah and Ethan,

my parents, brothers, sisters, and friends

For all your support and patience, you merit

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I would like to sincerely recognize the financial support, advice, valuable feedback and assistance of my main advisor Dr. Johannes Lehmann. I am equally grateful to my other advisors Dr. Alice N. Pell, and Dr. Michael Todd Walter. Each of the above named professors contributed in significant ways towards the work summarized in this dissertation. Dr. Lehmann's unique intellectual discernment, patience and gentle instruction are reflected in this document. Dr. Walter's expertise provided a background for stimulating discussions on hydrological processes in the complex landscape. In addition to facilitating funding for part of the program, Dr. Pell emphasized the solute dynamics and challenged me to look at the big picture of agriculture and rural development.

I had the opportunity of getting support from other professors in the Department of Crop and Soil Sciences. Dr. Stephen DeGloria assisted me with the GIS outputs. Dr. Janice Thies provided additional soil microbiology skills, and financial support in the transition from the program towards postdoctoral work. I am grateful to ICRAF scientists, Dr. Louis Verchot (now with CIFOR), and Dr. Laura Dutaur for intellectual input and fieldwork support. Dr. David Mbugua provided guidance into the program. Dr. Mark Johnson not only guided us during installation of the weirs and instrumentation, but also gave feedback on the results. Brett Gleitsmann did the initial field instrumentation and sample collection, while Henry Biwott religiously helped with all the fieldwork. Hellen Ochieng of the ICRAF training unit facilitated logistics in Nairobi.

I would like to give thanks to Dr. Dawit Solomon, David Guerena, David Bluhm, Kelly Hanley, and Akio Enders for their research help and kind support at various stages. The rest of Dr. Lehmann’s lab group made academic life bearable for me; like Dr. Bente Foereid, Dr. Steven Vanek, Dorisel Torres, Thea Whitman, Karen Heyman, Lydiah Gatere and Susan Blum. Last but not least, I thank all the Christian friends in the Winston Court Fellowship, Asbury Church, in Kenya, in Tanzania, and elsewhere who constantly encouraged, supported and prayed for me all the time. All the glory goes back to God for the ability to accomplish this work.

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CHAPTER 1

STREAM DISCHARGE IN TROPICAL HEADWATER CATCHMENTS AS A RESULT OF FOREST CLEARING AND SOIL DEGRADATION

Abstract

Tropical Africa is affected by intense land use change, particularly forest conversion to agricultural land. In this study, the hydrology of four small headwater catchments located within an area of 6 km^2 in western Kenya was examined for two years (2007, 2008). The catchments cover a degradation gradient ranging from intact forest to agricultural land under maize cultivation for 5, 10 and 50 years. With increasing duration of cultivation, soil bulk density (ρ_b) at a depth of 0-0.1 m increased by 46%, while soil organic carbon (SOC) concentrations and total porosity decreased by 75% and 20%, respectively. The annual catchment discharge expressed as a percentage of rainfall increased from an average of 16.0% in the forest to 32.4% in the 50-year-old agricultural catchment. Similarly, the average runoff ratio was 0.033 in the forest and increased gradually to 0.095 with increasing duration of cultivation. The conversion from forest to agricultural land in the first 5 years caused about half of the total observed increases in runoff ratio (46.3%) and discharge in relation to rainfall (50.6%). The other half of the changes in discharge occurred later during soil degradation after forest clearing. The changes in hydrological responses that only started after forest clearing may suggest a significant potential for improved land management in alleviating runoff and enhanced storm flow and moisture retention in agricultural watersheds.

INTRODUCTION

Land use is one of the key parameters controlling fluxes in the hydrologic cycle. Removal of forest cover typically results in a considerable increase in water yield (Bosch and Hewlett, 1982, Farley *et al*., 2005) with significant effects on stream water quality, soil erosion and losses of nutrients (Grip *et al*., 2004). The impact of land use change on hydrologic processes in the tropics is particularly severe since soil degradation is more rapid than in temperate zones due to more rapid mineralization of tropical soil organic matter (SOM) and often high erosion (Spaans *et al*., 1989; Malmer and Grip, 1990; Hartemink *et al*., 2008; Solomon *et al*., 2009). Changes in watershed dynamics in response to deforestation in the humid tropics were widely investigated during the 1980s (Bruijnzeel, 1990; Bonell and Balek, 1993) but less work has been done recently. Most of these studies focused on catchments in tropical Asia or Central and South America. Limited results from West Africa are available showing that forest clearing and subsequent land use significantly affect the magnitude of runoff and erosion using plot studies (Lal, 1981). Yet there are limited studies on stream water discharge, runoff partitioning and their relation to land use change, particularly for East Africa where forest pressures continue to be acute due to the rural population density which is among the highest in the world (Kenya Forest Service, 2007).

Forest removal is a major factor increasing total stream water discharge and the proportion of discharge occurring as storm runoff (Mumeka, 1986). In humid regions, the forest vegetation transpires water throughout the entire year (Calder, 1998), whereas in agricultural landscapes annual crops consume water only during the growing season. In addition, the larger plant litter input and root turnover in forests compared to cropped fields maintain greater soil organic carbon (SOC) concentrations, which in turn preserves soil structure and promotes higher infiltration capacities, lower Hortonian overland flow and greater water storage capacity (Fritsch, 1993). With continued cultivation, particularly in low-input and subsistence systems, soils begin to lose SOC and become compacted, which has profound effects on soil hydrology (Giertz and Diekkruger, 2003; Awiti *et al*., 2008). Particularly in the tropics, SOC losses can be rapid (Solomon *et al*., 2007). It is, therefore, especially likely that for tropical agricultural landscapes, soil degradation, in addition to the loss of forest cover, has important impacts on stream water discharge.

The aim of this study was to quantify the effects of forest conversion to continuous cultivation on the stream discharge of headwater catchments in tropical Africa. The effects of cultivation on water yield were investigated for a chronosequence of catchments in Western Kenya comprised of a forested headwater catchment and three headwater catchments under continuous maize production for 5, 10, and 50 years following forest conversion.

METHODS

The study site

The field measurements were done in Kapchorwa, located in the Nandi district in western Kenya (Figure 1). The site is located 60 km northeast of Lake Victoria at longitude 35°0'0" E and latitude 0°10'0"N. The region belongs to the sub-humid ecological zone characterized by a bimodal rainy season with a mean annual precipitation of 2000 mm (Haupt, 2000). The “long rain season” is from April to June (~1200 mm) and the “short rain season” from August to

October (~800 mm). The site has an elevation of 1750-1900 m above sea level, an average maximum daily temperature of 26°C and a minimum of 11°C (Glenday, 2006).

The Kakamega-Nandi forest in Western Kenya is the country's only remaining tropical rain forest. Total forest cover in Kenya decreased by 0.3% year^{-1} on average between 1990 and 2005, to 35,220 km^2, which represents 6% of the country's territory according to the Global Forest Resources Assessment (FAO [Food and Agriculture Organization of the United Nations], 2006). The forest forms the easternmost relic of the Guinean-Congolian rainforest belt, which once spanned from East to West Africa. The area around this forest is among the most densely populated rural areas in the world. It had a population density of 778 persons per km^2 in 2009 compared to 73 persons per km^2 for the entire country (Kenya National Bureau of Statistics, 2010). Consequently, the forest is under high anthropogenic pressure, which is mirrored by the decreasing natural forest cover and intensive cultivation (deGraffenried and Shepherd, 2009; Swallow *et al*., 2009). Past deforestation rates in the Kakamega-Nandi forest indicated a decrease of forest area and an increase in the fragmentation of natural, old-growth forest (Mitchell, 2004; Lung and Schaab, 2006).

Soils in the Kapchorwa catchment are kaolinitic Acrisols (FAO-UNESCO-ISRIC, 1988), which are classified as Ultisols in the US soil taxonomy (Soil Survey Staff, 1998). The parent material of these soils is principally granitic, with some inclusions of Precambrian gneisses, which supports Luvisols (Werner *et al*., 2008) and other undifferentiated basement system rocks at higher elevations (Jätzold and Schmidt, 1983). Soils in the study area have 45-49% clay, 15-25% silt, and 26-40% sand (Kimetu *et al*., 2008).

The forest section of the Kapchorwa catchment is part of the Kakamega-Nandi forest composed of tropical rainforest species. It is largely an indigenous forest with a 30 m closed canopy dominated by evergreen hardwood species. The most common species are *Funtumia africana*, *Ficus* species, *Croton* species, and *Celtis* species (Glenday, 2006). Other species include *Aningeria altissima* (A. Chev.), *Milicia excelsa* (Welw.) C.C. Berg, *Antiaris toxicaria* (Lesch) and *Chrysophyllum albidum* (G. Don), *Olea capensis* (L.) and *Croton megalocarpus* (Hutch) (Kinyangi, 2008). The above and below ground net primary production of trees in a tropical forest was estimated at 15.2 Mg ha^{-1} $year^{-1}$ (Hertel *et al*., 2009). The agricultural catchments have maize as the sole crop, and have been under maize cultivation since conversion from forest. The maize grain yield without fertilizer input in the 5, 10 and 50 year old agricultural catchments are 6.5, 5.5 and 2.5 Mg ha^{-1} $year^{-1}$, respectively (Ngoze *et al*., 2008).

Hydrologic instrumentation and field data collection

The headwater catchments were identified in August 2006. The specific age classes designating when native forests were converted to agriculture were determined from historical community settlement patterns over the last century (Bleher *et al*., 2005). Specific years of conversion were verified from data available from records of the Kenyan government from the Department of Forests, the Ministry of Agriculture, as well as from interviews with officials of local institutions and from county council records. Within each site, there were distinct population settlement patterns where newly acquired fields were excised from sections of the native forest for agriculture. All four headwater catchments are located within an area of 6 km^2 and represent a soil degradation gradient that corresponds to years under maize cultivation that has been used and its validity verified by several other studies (Solomon *et al*., 2007; Kimetu *et al*., 2008, 2009; Ngoze *et al*., 2008). Such chronosequences substitute time for space and have to be carefully selected to assure similar properties before the change (Huggett, 1998). Also hydrological differences between catchments unrelated to land cover have to be considered (Elsenbeer, 2001; Johnson *et al*., 2006). Therefore, the relationship between hydrological responses and physical watershed attributes such as size and slope as well as location characteristics such as rainfall were investigated as a source of random variation.

Hydrologic instrumentation was installed in mid-December 2006 and catchments monitored for 2 years. The boundaries of each catchment were surveyed and delineated using a Global Positioning System (GPS). The GPS data were then used to generate Geographical Information System (GIS) output and a map of the area (Figure 1.1). The sizes of the catchments were 12.8 ha for the forest, 14.4 ha for the 5 year old conversion, 9.1 ha for the 10 year conversion and 10.0 ha for the 50 year conversion. A standard V-notch weir was constructed at each catchment outlet for determining stream discharge. Stream stage was recorded using water capacitance probes (Odyssey Dataflow Systems Pty Ltd, New Zealand) installed at the weir. The probes were programmed to give a reading of the average stream stage between 2-4 minutes. Data from these probes were downloaded biweekly. The weir ratings were determined at low and intermediate flows using a stage downstream and discharge at the weir. The correlation coefficients of the weir ratings were $r^2 = 0.944$ ($y=0.5483x-12.079$), $r^2 = 0.915$ ($y=0.5495x-18.286$), $r^2 = 0.926$ ($y=0.5329x-16.382$), and $r^2 = 0.931$ ($y=0.8608x-48.769$) for the forest, 5 year, 10 year and 50 year

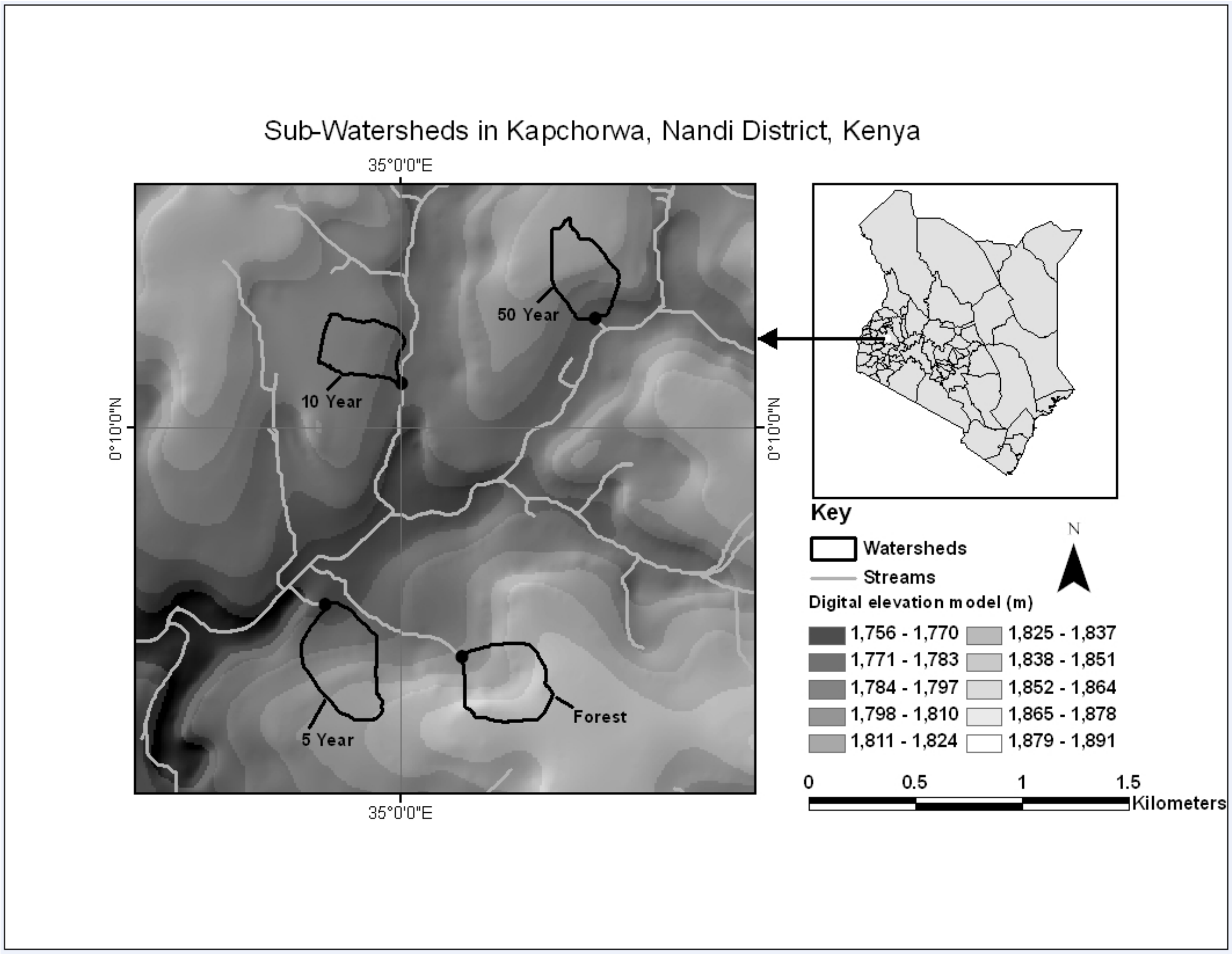

Figure 1.1: Map of the study area of the Kapchorwa headwater catchments. The weir positions are shown by dots in each catchment.

conversions, respectively. The stream hydrographs were normalized by corresponding catchment sizes to allow comparison among responses for the 4 catchments. These data were subjected to online hydrograph separation implemented in WHAT (Web GIS based Hydrograph Analysis Tool) using the Recursive Digital Filter method for baseflow separation (Lim *et al*., 2005, 2010). This approach to hydrograph separation has been used in hydrological studies of forested and agricultural watersheds in tropical and temperate regions (Longobardi and Villani, 2008; Schwartz, 2007). Two other separation techniques, specifically the WHAT Local Minimum

Method and the WHAT One Parameter Digital Filter Method (Lim *et al*., 2005) were used for comparison. The trends in the amount of baseflow and runoff were similar for all the methods, with a variation of up to 12.8% in the final results. The WHAT Web GIS system can be used in the calibration and validation processes of hydrologic and water quality models (Lim *et al*., 2010).

Precipitation for each catchment was determined from a tipping bucket rain gauge connected to a data logger installed 1 m above the ground surface, representing throughfall for the forested catchment, and above-canopy rainfall for the agricultural catchments. For all calculations, an average of above-canopy precipitation was used (CV of less than 1% between watersheds). The below-canopy throughfall in the forest was on average 5% lower than above-canopy rainfall over both years.

Five soil samples from 0-0.1 m depth were collected randomly by stratifying for location within slope and plateau of each catchment, after removing the litter layer (capturing the mineral A horizon). In addition, four sites were randomly selected in each catchment and soil sampled at depths of 0.1-0.3m, 0.3-0.9m, 0.9-1.5m, 1.5-2.4m. The average slopes for the headwater catchments were measured using clinometers. The final average slope figure is a mean of five readings taken from the position of the weir up the slope. The resulting mean slope for the catchments were 7.5% for the forest, 6.4% for the 5 year conversion, 4.4% for the 10 year conversion and 5.8 % for the 50 year conversion. Bulk density was determined from undisturbed soil cores; we used five soil samples from a depth of 0-0.1 m in each catchment (Campbell and

Henshall, 1991). The soil porosity (ø) was computed from bulk density (ρ_b) and particle density (ρ_p) using the formula $ø=1- (\rho_b / \rho_p)$.

Laboratory measurements of soil properties

Total C was determined by dry combustion after fine grinding soil using a Mixer Mill (MM301, Retsch, Germany). The five replicate samples were analyzed for C content with a Europa ANCA-GSL CN analyzer (PDZ Europa Ltd., Sandbach, UK). SOM was determined by loss on ignition (Storer, 1984). The soil moisture retention curve was determined by applying soil suction to undisturbed soil cores (Klute, 1986).

Statistical analyses

Statistical analyses were done using JMP Version 8 (SAS Institute Inc, Cary, NC, USA) for soil properties, runoff ratio, baseflow index, and streamflow discharge as a percentage of rainfall against the physical properties of the four catchments. The runoff ratio is the ratio of the total runoff to total rainfall (e.g., Berger and Entekhabi, 2001) and the baseflow index is the ratio of total baseflow to total rainfall, which is somewhat different than the traditional baseflow index that is the ratio of baseflow to total discharge (e.g., Bloomfield *et al.*, 2009). The comparisons were made at $P<0.05$ unless otherwise stated. A linear function was fitted for all the correlations.

RESULTS

Soil properties

Within the top 0.1 m, the SOM levels decreased by 59% and SOC by 75% from the forest to the 50 year old agricultural catchment (Table 1.1). SOM and SOC degradation was very rapid in the first 10 years of conversion linearly decreasing by 50% and 66%, respectively ($r^2 = 0.99$; $P<0.05$). At a depth of below 0.5 m, the SOC values are not significantly different between the watersheds (Figure 1.2). The soil ρ_b increased rapidly by 28.8% in the first 10 years from 0.80 to 1.03 g cm^{-3} ($r^2 = 0.98$; $P<0.1$). Overall, the soil ρ_b increased by 46.3% from 0.8 to 1.17 within 50 years of cultivation. The rapid increase in ρ_b in the first 10 years following conversion leads to a 12.9% drop in the total porosity from 0.70 to 0.61 in the same period ($r^2 = 0.99$; $P<0.1$).

The porosity decreased by 20% following 50 years of continuous cultivation. The topsoil moisture content at field capacity followed a similar trend to the total porosity. It dropped by 28.3% in the first 10 years of cultivation, with an overall reduction of 33.8% in the 50 years of cultivation. More than half the changes in hydrologically important topsoil properties occurred between 5 and 50 years of cultivation. Changes during the conversion process, as indicated by differences between the forest and the 5-year conversion, caused comparatively lower changes in the important hydrological properties of the topsoil, with the exception of SOC.

Table 1.1: Catchment soil properties in the top 0.1 m.

	Forest	5 year conversion	10 year conversion	50 year conversion
Soil organic matter (mg g^{-1})	170.8a	136.7b	85.3c	70.0d
Soil organic carbon (mg g^{-1})	108.3a	68.8b	36.4c	27.5c
Soil bulk density (g/ cm^3)	0.80c	0.91b	1.03ab	1.17a
Total porosity	0.70a	0.66b	0.61bc	0.56c
Moisture at 0.1 bar (%)	48.09a	43.71a	38.97b	31.72c
Moisture at 0.33 bar (field capacity) (%)	34.70a	34.05a	24.88b	22.97b
Moisture at 1 bar (%)	33.44a	32.95a	23.33b	21.89b
Moisture at 3 bar (%)	31.89a	29.56a	20.07b	18.71c
Moisture at 15 bar (permanent wilting point) (%)	30.27a	27.78b	17.18c	15.54c

Means within a row followed by the same letters are not significantly different from each other at $P < 0.05$ (n=5).

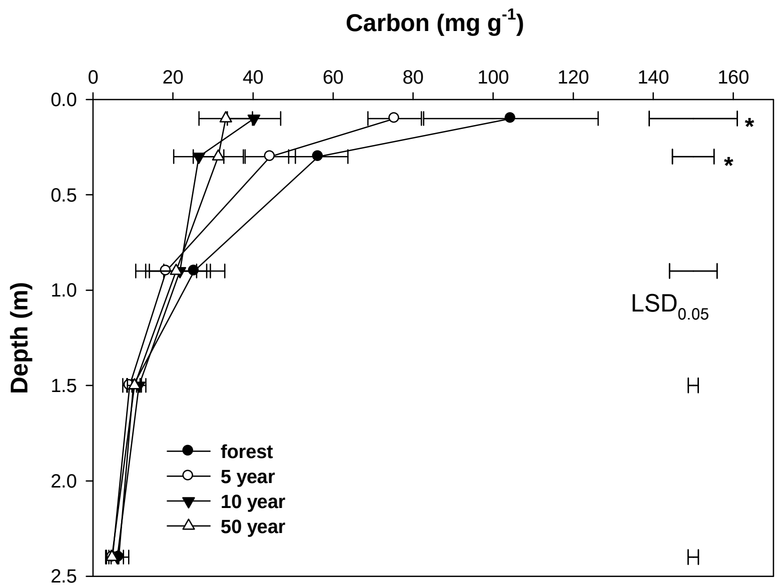

Figure 1.2: Soil carbon (mg g^{-1}) at various depths in the watersheds. Bars are ±1 standard deviation of the mean for each soil depth. Error bars at the right indicate the LSD at each depth. LSD error bars followed by * indicate the presence of significant differences at $P < 0.05$ (n=4).

Hydrologic fluxes

There was no clear separation between the long rainy (April - June) and short rainy (August – October) seasons in the Kapchorwa catchment area during the study period (Figure 1.3). Truly dry seasons occurred between November and March. The streamflow response to precipitation events varied with land use history (Figure 1.3). Unlike the rapid streamflow responses for catchments under cultivation, the discharge in the forest did not respond immediately to the rainfall. There was minimal storm runoff for the forest and a gradual increase in the streamflow discharge in the forest during the rainy season that reached its peak in October. The initial rainfall in April 2007 following the usual dry season did not lead to sudden increased discharge in agricultural catchments. After about one month of rainfall, the streamflow exhibited periods of slowly increased discharge in the agricultural catchments associated with rainfall and longer periods of slowly decreasing discharge of water stored in the catchment.

The annual water yield of the catchments (Table 1.2) indicates a pronounced increase between forest and 5 years cultivation catchment, followed by a gradual increase in the streamwater discharge with longer periods of cultivation. The total streamwater yield for the year 2007 in relation to the precipitation was 17.9% in the forest, 26.6% in the 5 year, 30.3% in the 10 year and 34.0% in the 50 year conversion to agriculture. The annual streamwater yield for the year 2008 in relation to the precipitation was 14.1% in the forest, 22.0% in the 5 year, 27.4% in the 10 year and 30.7% in the 50 year conversions. About half of the change (50.6%) in discharge as a fraction of rainfall occurred over the first 5 years of cultivation after forest clearing, with the remaining increase over the chronosequence (49.4%) observed for 5 to 50 years of cultivation. A

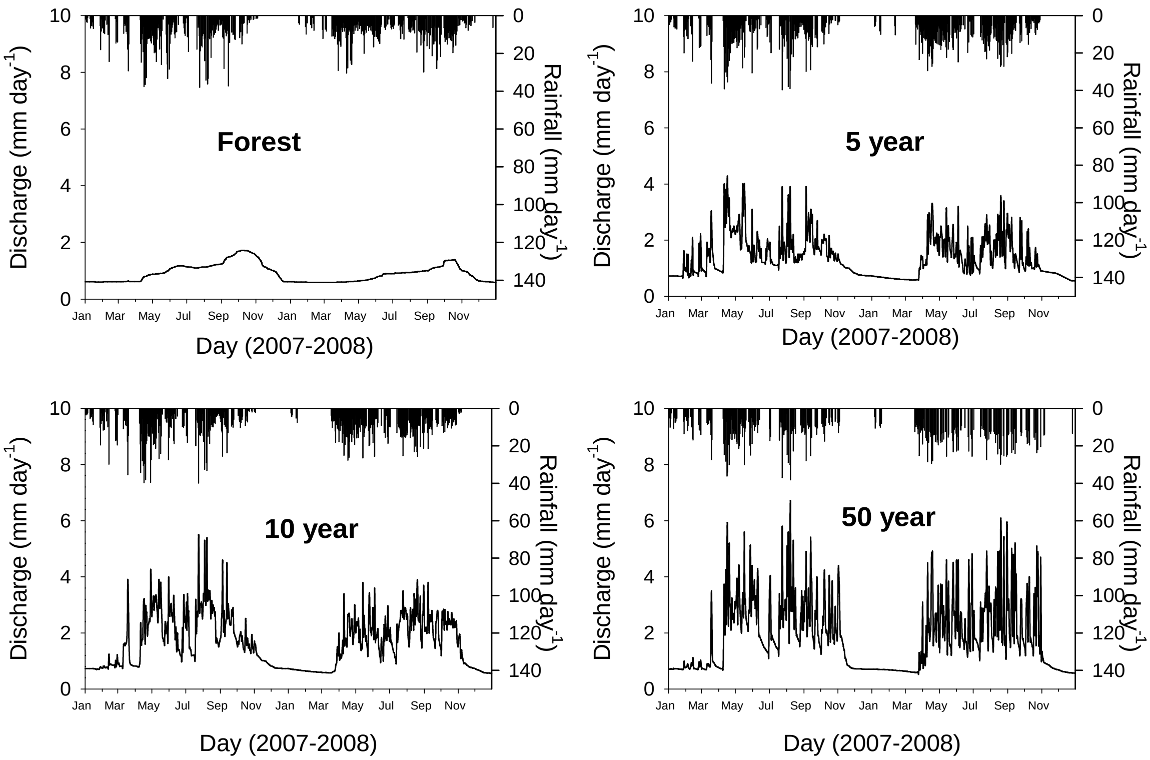

Figure 1.3: Daily discharge and rainfall of the Kapchorwa catchments in 2007 and 2008.

similar observation was made for the runoff ratio, discharge and baseflow index (Table 1.2). The runoff ratio for the forested catchment increased from 0.033 and 0.029 (2007 and 2008 data, respectively) to 0.092 and 0.097 after 50 years of cultivation (2007 and 2008). Slightly less than half of the change (46.3%) was observed within the first 5 years of cultivation (0.064 and 0.059 for 2007 and 2008, respectively). On average for both years, the baseflow index decreased by

Table 1.2: The hydrological attributes of the Kapchorwa catchments in 2007 and 2008.

	Forest		5 year conversion		10 year conversion		50 year conversion	
	2007	2008	2007	2008	2007	2008	2007	2008
Precipitation (mm)	2064.7	2099.7	2064.7	2099.7	2064.7	2099.7	2064.7	2099.7
Discharge (mm)	369.87	296.43	548.58	462.23	636.66	574.35	702.40	645.25
Discharge/precipitation	0.179	0.141	0.266	0.220	0.303	0.274	0.340	0.307
Direct runoff (mm)	76.91	61.26	131.17	123.04	162.95	150.48	189.47	202.83
Runoff ratio[a]	0.037	0.029	0.064	0.059	0.079	0.072	0.092	0.097
Base flow (mm)	292.96	235.17	417.41	339.19	473.71	423.87	512.93	442.42
Base flow index[b]	0.792	0.793	0.761	0.734	0.744	0.738	0.730	0.686

[a]Storm runoff/precipitation

[b]Base flow/total discharge

11% over 50 years of continuous agriculture following forest clearing. Less than half (45%) of that decrease occurred after forest clearing and within the first 5 years of cultivation.

Streamwater discharge as a percentage of rainfall and the runoff ratio were inversely related to SOC ($P<0.01$) and total porosity ($P<0.05$) and positively correlated to ρ_b ($P<0.05$; Table 1.3). Conversely, the baseflow index had a significant inverse relationship with ρ_b ($P<0.05$), positive correlation with total porosity ($P<0.05$), but was not significantly correlated with SOC. There were no significant relationships between the three aforementioned hydrological properties and

Table 1.3: Correlation coefficients (r^2) and regression equations for some physical and hydrological attributes averaged for both 2007 and 2008 of the Kapchorwa headwater catchments.

	Discharge as a percentage of rainfall	Runoff ratio	Baseflow index
Soil organic carbon (%)	y = - 1.9233x+36.988 r^2 = 0.987*	y = - 0.007x+0.1086 r^2= 0.958*	y = 0.0096x + 0.693 r^2 = 0.896 ns
Bulk density (g/cm^3)	y = 43.15x-16.779x - 14.496 r^2 = 0.937*	y = 0.1613x-0.0911 r^2 = 0.965*	y = - 0.212x + 0.954 r^2 = 0.925*
Total porosity	y = - 112.96x+96.845 r^2 = 0.937*	y = - 0.4212x+0.3329 r^2 = 0.961*	y = 0.5503x + 0.3994 r^2 = 0.913*
Soil moisture content at field capacity (%)	y = - 1.0407x+55.736 r^2 = 0.799 ns	y = - 0.0038x+1778 r^2 = 0.793 ns	y = 0.0047x + 0.609 r^2 = 0.679ns
Average slope (%)	y = - 4.3015x+51.317 r^2 = 0.614 ns	y = - 0.0146x+0.1545 r^2 = 0.520 ns	y = 0.0173x + 0.643 r^2 = 0.409 ns
Catchment size (ha)	y = - 1.8969x+47.357 r^2 = 0.431 ns	y = 0.0068x+0.1447 r^2 = 0.403 ns	y = 0.0075x + 0.661 r^2 = 0.276 ns

* indicate significant correlations at P<0.05, respectively (n=5).

ns, not significant at P<0.05

either the average slope or catchment size (P<0.05) that would indicate a bias in watershed responses due to random spatial effects.

DISCUSSION

Effects of forest removal

The conversion of forest to maize cultivation led to drastic changes of the landscape that significantly affected the stream discharge. The discharge expressed as a percentage of the rainfall increased by an average of 44.2% from forest to the adjacent catchment after 5 years of maize cultivation (Table 1.2). This translates to a yearly average increase of 34.4 mm year^{-1} (8.8%). The reduced water use of annual crops such as maize compared to a full-grown forest reflects not only the diminished capacity of short vegetation to intercept and evaporate rainfall (Van Dijk and Bruijnzeel, 2001), but also to extract water from deeper soil layers during periods of drought (Eeles, 1979). The former relates primarily to the lower aerodynamic roughness of short annual crops (and possibly to their smaller leaf area), whereas the reduced water uptake of crops reflects their more limited rooting depth (Nepstad *et al*., 1994; Calder, 1998). Interception likely reduced discharge and throughfall, and while spatially and temporally highly variable (Zimmermann *et al*., 2009) is typically about 10-25% lower than above-canopy rainfall as shown for a variety of tropical forests (Cuartas *et al*., 2007; De Villiers and Du, 1982, Tobon *et al*., 2000). A study by Ruprecht and Schofield (1989) in a catchment area of 94 ha showed that clearing native vegetation and establishment of agricultural plants on a small catchment in southwest Australia resulted in a large streamflow increase. The streamflow increased markedly in the first year after clearing (about 10% rainfall) and continued to increase linearly at a slower rate for a further five years, when a new streamflow equilibrium was reached (Ruprecht and Schofield, 1989). Low and Goh (1972), reporting on catchment research in peninsular Malaysia, showed an annual increase of 10% in water yield in a largely cleared catchment compared to yield trends in three forested catchments. Therefore, the removal of forest vegetation in our study in Kenya appeared to have increased stream discharge at a magnitude similar to the upper end of other observations.

Unlike the forested catchment, the immediacy of streamflow response to rainfall after 5 years of continuous cultivation (Figure 1.3) suggests that part of the rainfall follows a rapid route to the stream channel, producing quickflow. In the forest, the complex of permanent soil cover, litter layer and roots acts as a sponge soaking up water during rainy spells and releasing it evenly (Bruijnzeel, 2004a). The beneficial effects on soil aggregate stability and water intake capacity afforded by the high organic matter content and abundant faunal activity of forest soils may persist for one or two years after clearing (Bruijnzeel, 2004b). However, exposure of the soil to continuous cultivation generally leads to a rapid decline thereafter (Lal, 1987). Lal (1983) studied a 44-ha forested drainage basin on an Alfisol in the humid tropical area of western Nigeria from 1979 to 1981. He observed virtually no Hortonian overland flow and soil erosion and attributed it to the thick undergrowth and leaf litter layer. Deforestation significantly increased the total water yield by 140 mm per year (10%) from 1979 to 1981 (Lal, 1983). An additional aspect in agricultural catchments is that considerable areas may become permanently occupied by compacted surfaces such as houses, yards, trails and paths. This is almost inevitably followed by increases in amounts of runoff (Grip *et al*., 2004). A study in sub-humid, tropical Benin by Giertz *et al*. (2005) showed that continuous cropping for 100 years led to a streamwater discharge yield of 16.4% (190 mm) of the rainfall per year, which was only a small increase compared to a yield of 10.2% (117 mm) in the forest catchment. However, in the Benin study, both the forest and agricultural catchments were larger in size than in our experiment; about 300 ha each. Rigorous experimental designs like the 'paired catchment' technique have produced detectable changes in streamflow also including large basins (Trimble *et al*., 1987; Bruijnzeel, 1990; Malmer, 1992; Fritsch, 1993; Costa *et al*., 2003). In all cases, the removal of more than 33% of forest cover resulted in significant increases in annual streamflow during the first 3 years. Initial gains in water yield after complete forest clearance ranged between 145 mm year^{-1} (9.7%) and 820 mm year^{-1} (32.8%) (Bruijnzeel, 1990; Malmer, 1992; Fritsch, 1993). In addition, increases in water yield proved to be roughly proportional to the fraction of biomass removed. These changes in water yield mainly reflect the different evaporative characteristics of mature tropical forest and (very) young secondary or planted vegetation and, to a much lesser extent, increases in storm runoff (response to rainfall). Under mature tropical rain forest, typically 80–95% of incident rainfall infiltrates into the soil, of which over 1000 mm year^{-1} (67%) is transpired again by the trees when soil moisture is not limiting, whereas the remainder sustains streamflow (Bruijnzeel, 2004). Chevallier and Planchon (1993) found a mean annual evapotranspiration of 1600 mm in a four year study in a 136 ha humid savannah basin in Ivory Coast.

During the dry seasons, the water discharge in the agricultural watersheds gradually diminished to low levels but never dried completely. A review by Bruijnzeel (2004) suggested that the water holding capacity i.e., ‘sponge effect’ is lost after clearing, resulting in diminished dry season flows despite the logical assumption that the reduced evaporation associated with the removal of forest should have produced higher baseflow. The dry season and inter-storm streamflow consist solely of ground water.

The 42.6% increase in the runoff coefficient from the forest to the maize fields after 5 years of cultivation is consistent with the study by Giertz *et al*. (2005) in Benin. In the Benin study, runoff coefficients were 0.095 and 0.158 for the forest and agricultural catchments, respectively. In formerly forested areas in Indonesia, typical surface runoff coefficients associated with bench terraced rainfed agriculture on volcanic soils in upland West Java also ranged from 0.16 to 0.18 for terraces on moderately steep slopes to greater values of 0.27 – 0.33 on steep slopes (Purwanto and Bruijnzeel, 1998). Our data and data from various other studies therefore indicate that conversion to agriculture causes a dramatic shift in the hydrological behavior of headwater catchments.

Effects of cultivation

The similar increase in runoff ratio and storm discharge during the cultivation phase between 5 and 50 years following conversion compared to the change associated with the initial deforestation (Table 1.2) may possibly be explained by the continued and significant changes in soil properties. Despite the greater increase in runoff ratio per year between forest and 5 years of cultivation (15% $year^{-1}$) compared to the following 45 years (1% $year^{-1}$), the total change after forest clearing and during the first 5 years (43% of total increase) or between 5 and 50 years (57% of total increase) after forest conversion suggests long-term soil changes and their management to be important drivers of headwater hydrology. The increase in topsoil ρ_b from the 5 to the 50 year old agricultural catchment may be an indication of changes in the soil profile that cause reduced rainfall infiltration. Several factors may contribute to reduced infiltration including continued exposure of bare soil after forest clearance to intense, high energy rainfall (Lal, 1996), loss of SOC (Table I; Solomon *et al*., 2007), compaction of topsoil by mechanical operations (Malmer and Grip, 1990) or grazing (Gilmour *et al*., 1987), gradual disappearance of soil faunal activity (Aina, 1984), and increases in the area occupied by impervious surfaces such as paths and settlements (Ziegler and Giambelluca, 1997). Increased bulk density and reduced infiltration may lead to a more pronounced catchment response to rainfall (Giertz and Diekkruger, 2003) and increases in storm runoff during the rainy season may become so large as to seriously impair the recharging of the soil and groundwater reserves feedings springs and maintaining baseflow. It is not clear, however, whether lower infiltration at the soil surface triggered the observed greater runoff, since infiltration rates may still be greater than rainfall intensities (Zimmermann *et al*., 2006). Often, subsurface compaction may rather be responsible for overland flow through saturation excess. A perched water table was found to be responsible for a doubling in runoff events and a 17-fold increase in runoff volume by conversion of forest to pasture in western Amazonia (Germer *et al*., 2010). We are not able to distinguish between subsurface and soil surface processes that led to the observed increases in runoff in our study. It is unlikely, however, that a subsurface layer with low permeability is present in all watersheds which caused the greater proportion of runoff through a perched water table, as we would not expect greater runoff with longer duration of maize cultivation without other changes in management or plant cover. However, compaction of not only the topsoil but also the subsoil through cultivation may be a possible explanation for the observed greater runoff. If existing, any subsoil compaction seem unrelated to SOC contents, however, as SOC contents did not change below a depth of 0.5 m.

In the Benin study, Giertz *et al*. (2005) showed that 100 or more years of cultivation led to soil loss and biological degradation. These authors attributed the reduction of permeability to lower abundance and activity of soil organisms due to the mechanical destruction of the soil structure as well as a decrease in litterfall (Edwards and Bohlen, 1996). Lower microbial activity (Kimetu *et al*., 2009) was also found at our sites but an explicit connection between microbial activity and soil hydrological properties has not been examined. Pedobiological investigations by Giertz *et al*. (2005) also demonstrated that a reduction of macrofauna activity on agricultural fields compared with natural vegetation may cause an extreme reduction of macropores at the soil surface. Reduced macroporosity is an important contributor to lower permeability of the surface in agricultural catchments. An explicit connection between macrofauna and soil permeability was not examined in our study, but could well have played a role in increasing the runoff ratio.

Following 50 years of cultivation in the Kapchorwa catchments, the ability of the topsoil (0-0.1 m) to hold moisture at field capacity was reduced by about 34% (Table 1.1). This may be attributed to losses in SOC, erosion of finer soil particles, or mechanical compaction. Soil organic C losses have been found to be significant with 67-86% over 100 years following forest conversion to permanent cultivation at our study site (Solomon *et al*., 2007). Similar results are obtained using SOC stocks with fixed sampling depth (Nguyen *et al*., 2008) or with equivalent mass (Kinyangi, 2008). Such SOC losses can only be compensated with organic matter amendments (Kimetu *et al*., 2008). Therefore, maintenance of SOC and soil biological activity, including soil macrofauna, may help reduce storm runoff and, to some extent, stream discharge in tropical headwater catchments to compensate for the loss of maintenance of a forest cover. Whether such interventions in the topsoil would actually reduce discharge cannot be proven and warrants manipulative experimentation.

CONCLUSIONS

The physical soil properties were shown to be significantly affected by forest conversion to agriculture as well as by subsequent long-term cultivation. Impacts of cultivation on soils included a decrease in SOC, total porosity, field capacity and increased bulk density, whereas moisture retention at field capacity did not change in the short term due to loss of forest cover. The increase of surface runoff as a result of the loss of forest cover was similar in magnitude as increases observed corresponding to long-term cultivation. This would suggest that preservation of forest cover is only one avenue for decreasing storm water runoff and discharge from headwaters. Equally important is the maintenance of infiltration and water retention in soil, but it is not clear to what extent subsurface changes contributed to the observed runoff responses. Further experimentation is required to evaluate whether discharge and runoff can be reduced by SOC build-up, reduced compaction or less sealing of surfaces. This would have important implications for policy interventions to promote soil conservation techniques. Questions arise whether nutrient and C losses follow the same trends as water discharge shown here. In addition, soil management that maintains water retention and decreases runoff and discharge warrant evaluation on a watershed scale.

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CHAPTER 2

HYDROCHEMICAL BEHAVIOR OF NUTRIENTS IN TROPICAL HEADWATER CATCHMENTS AT A SOIL DEGRADATION GRADIENT

Abstract

Carbon and nutrient losses were quantified from four small headwater catchments in western Kenya. They include a forested catchment and three catchments under maize continuously cultivated for 5, 10 and 50 years following forest conversion. The C isotopic composition of dissolved organic C (DOC) in stream discharge suggested that soil organic C (SOC) derived from the original forest rather than C from maize may have contributed to a large extent to watershed OC losses. Flow-weighted stream water concentrations of different organic C fractions, all N species, total P, K and Na significantly ($P<0.05$) increased in streams after forest conversion and long-term cultivation. Solute concentrations increased despite the fact that soil contents decreased and total water flow increased indicating mobilization of C and N, P and K from soil with progressing cultivation. In contrast, Ca and Mg concentrations in stream water did not systematically change after deforestation and cultivation, and may be controlled by geochemical weathering rather than by changing water flow paths or topsoil contents. All total C and nutrient exports increased with longer cultivation ($P<0.05$) as a result of greater water discharge. Fluvial organic C and total N losses were 2% and 21% of total SOC and total N decline, respectively, in the top 0.1 m over 50 years. Fluvial OC losses therefore played a minor role, and SOC losses were mainly a result of microbial mineralization. Resulting total N losses

by stream discharge, however, were large with 31 kg ha^{-1} yr^{-1} after 50 years of continuous cropping in comparison to fertilization of 40 kg N ha^{-1} yr^{-1}. Most (91%) of the N losses occurred as NO_3^-. In contrast, P losses by stream discharge were negligible in comparison to plant uptake. Water losses should be managed to reduce soil fertility declines especially through large N export from agricultural headwater catchments. However, stream concentrations of both P (0.01-0.15 mg L^{-1}) and N (0.4-4.8 mg L^{-1}) were moderate or low with respect to possible consequence for human health or eutrophication.

INTRODUCTION

Human activity affects land cover and land use (Hartemink *et al*., 2008). Historically, the driving force for most land use changes is population growth (Ramankutty *et al*., 2002) although there are several other interacting factors involved and rates of deforestation and population growth differ (Lambin *et al*., 2003). Land use is one of the key parameters controlling soil nutrient dynamics. Undisturbed forests can maintain their well developed growth by efficiently conserving nutrient capital (Yusop *et al*., 2006). Amongst the features of tropical forests that enhance nutrient conservation is a large root biomass, dense root mats in the topsoil, abundant aerial roots and the maintenance of a complex below-ground microbial community (Jordan, 1985). These sensitive structures may be severely damaged during forest harvesting and clearing, thus losing their ability to protect soil against erosion and nutrient loss (Hartono *et al*., 2003). Germer *et al*. (2010) found that deforestation for the establishment of pasture altered fundamental mechanisms of storm flow generation and increased runoff volumes in Rondonia in the southwestern Amazon Basin. Consequently, removal of forest cover typically results in significant effects on stream water quality, soil erosion and losses of nutrients (Grip *et al*., 2004).

The impact of land use change on nutrient dynamics in the tropics is particularly severe since soil degradation is more rapid than in temperate zones (Hartemink *et al*., 2008; Malmer and Grip, 1990; Solomon et al., 2009; Spaans *et al*., 1989). Continuous cultivation and land tillage cause rapid loss of C (Davidson and Ackerman, 1993; Tilman *et al*., 2002; McLauchlan, 2006; Solomon *et al*., 2007) due to the disruption of the physical, biochemical, and chemical mechanisms of soil organic matter (SOM) stabilization exposing it to microbial degradation. Soil organic matter decline leads to reduced cation exchange capacity resulting in diminished nutrient retention of the soil (Lal, 2006). However, surprisingly little information is available on how soil degradation following land use conversion affects nutrient losses from watersheds.

On a plot level, information on accelerated losses of nutrients resulting from various types of agricultural practices has been gathered in both temperate (Nair and Graetz 2004; Schipper *et al*., 2007) and tropical regions (Pandey *et al*., 2010). Studies on nutrient losses from entire catchments in tropical forests have mostly been confined to Malaysian and Amazonian forests rather than to different agricultural watersheds. The Malaysian studies examined impacts of disturbances (Zulkifli, 1990) and forest clearing (Malmer, 1996). In the central Amazon, Lesack (1993) estimated the annual export of nutrients from a terra firme rain forest by extrapolating biweekly baseflow and continuous storm event water quality. This catchment was subsequently deforested and increased losses of N were reported by Williams and Melack (1997) and Williams *et al*. (1997). In southwestern Amazonia, Thomas *et al*. (2004) found that a second order stream originating in pasture had lower concentrations of nitrate, higher concentrations of total suspended solids, particulate organic C, particulate organic N, ammonium and phosphate than a second order stream originating from forest. Zhang *et al*. (2006) reported from a chronosequence in China on solute exports from headwaters under native forest, and maize under conventional cultivation for 19 years. In contrast to the Amazonian studies, they found significantly lower SOC, total soil N, total and available soil P in the cultivated soil compared to the native forest. Even less clear is what effect continuous cultivation and accompanying soil degradation have on fluvial nutrient losses in addition to the effects of loss of forest cover.

The distribution of nutrient and C losses over the course of the year can provide insight into the mechanism and pathways of nutrient and C in watersheds (Markewitz *et al*., 2004; Johnson *et al*., 2006a). Typically, we expect a dilution of nutrient and C concentrations during the rainy season (Likens *et al*., 1995). However, under certain circumstances of highly weathered soils, concentrations may increase during the wet season as a result of greater surficial flow paths that mobilize solutes from nutrient and C-rich topsoils (Markewitz *et al*., 2004). It is not clear whether forest conversion and soil cultivation may change the relationship between water and nutrient concentrations. The fluvial organic C losses may be a significant fraction of C losses and of total solute losses in watersheds (Selva *et al*., 2007). In forest ecosystems, the majority of the fluvial organic C losses occurred as DOC (Johnson *et al*., 2006b; Selva *et al*., 2007). Despite the lower importance of particulate organic C, most of the organic C was mobilized from the topsoil litter layer (Johnson *et al*., 2006a, 2006b). Whether the same is true for agricultural soils, or whether subsoil organic C may gain in importance for soils depleted in SOC by long-term cultivation is not clear.

The purpose of this study was to quantify the fluvial nutrient losses from headwater catchments as a function of either soil degradation and soil organic matter contents or forest clearing in tropical Africa. The effects of continuous agricultural land use on nutrients were investigated by comparing three headwater catchments following forest conversion to continuous maize production for either 5, 10, or 50 years in Western Kenya with a catchment that has remained forested.

METHODS

The study site

The field measurements were done in Kapchorwa, located in the Nandi district in western Kenya. The site is located 60 km northeast of Lake Victoria at longitude 35°0'0" E and latitude 0°10'0"N. The region belongs to the sub-humid ecological zone characterized by a bimodal rainy season with a mean annual precipitation of 2000 mm (Awiti *et al*., 2004). The “long rain season” is from April to June (~1200 mm) and the “short rain season” from August to October (~800 mm). The site has a mean elevation of 1800 m above sea level, a maximum daily temperature of 26°C and a minimum of 11°C (Glenday, 2006).

The Kakamega-Nandi forest in Western Kenya is the country’s only remaining tropical rain forest. Massive deforestation has taken place to create land for settlement and farming. About 16% of forest cover was lost between 1986 and 2001 (Awiti *et al*., 2004). The forest forms the easternmost relic of the Guinean-Congolian rainforest belt, which once spanned from East to

West Africa. The area around this forest is among the most densely populated rural areas in the world. It had a population density of 778 persons per km^2 in 2009 compared to 73 persons per square kilometer for the entire country (Kenya National Bureau of Statistics, 2010). Consequently the forest is under high anthropogenic pressure, which is mirrored by the decreasing natural forest cover and intensive cultivation (deGraffenried and Shepherd, 2009; Swallow *et al*., 2009). Past deforestation rates in the Kakamega-Nandi forest indicated a decrease of forest area and an increase in the fragmentation of natural, old-growth forest (Lung and Schaab, 2006).

Soils in the Kapchorwa catchment are kaolinitic Acrisols (FAO-UNESCO-ISRIC, 1988), which are classified as Ultisols in the US soil taxonomy (Soil Survey Staff, 2003). The parent material of these soils is principally granite, with some inclusions of Precambrian gneisses, which supports Luvisols (Werner *et al*., 2007) and other undifferentiated basement system rocks at higher elevations (Jaetzold and Schmidt, 1983). Soils in the catchment have 45-49% clay, 15-25% silt, and 26-40% sand (Kimetu *et al*., 2008).

The forest section of the Kapchorwa catchment is part of the Kakamega-Nandi forest composed of tropical rainforest species. It is largely an indigenous forest with a 30 m closed canopy dominated by evergreen hardwood species. The most common species are *Funtumia africana*, *Ficus* spp, *Croton* spp, and *Celtis* spp (Glenday, 2006). Other species include *Aningeria altissima* (A. Chev.), *Milicia excelsa* (Welw.) C.C. Berg, *Antiaris toxicaria* (Lesch) and *Chrysophyllum albidum* (G. Don), *Olea capensis* (L.) and *Croton megalocarpus* (Hutch) (Kinyangi, 2008). The above and below ground net primary production of trees in a tropical forest is estimated at 15.2 Mg ha^{-1} $year^{-1}$ (Hertel *et al*., 2009). The agricultural catchments have maize as the sole crop, and have been under maize cultivation since conversion from forest cover. The maize grain yields without fertilizer input in the 5, 10 and 50 year old agricultural catchments are 6.5, 5.5 and 2.5 Mg ha^{-1} $year^{-1}$, respectively (Ngoze *et al*., 2008).

Hydrologic instrumentation and fieldwork

In order to identify the headwater catchments, the time when native forests were converted to agriculture was determined from historical community settlement patterns over the last century (Bleher *et al*., 2005). Specific years of conversion were verified from data available from records of the Kenyan government from the Department of Forests, the Ministry of Agriculture, as well as from interviews with officials of local institutions and from county council records. Within each site, population settlement patterns were distinct and newly acquired fields were excised from sections of the native forest for agriculture. All four headwater catchments are located within an area of 6 km^2 (Fig. 1) and represent a soil degradation gradient that corresponds to years under maize cultivation that has been used in several other studies (Kimetu *et al*., 2008, 2009; Ngoze et al., 2008; Kimetu and Lehmann 2010). Such chronosequences substitute time for space and have to be carefully selected to assure similar properties before the change (Huggett, 1998). Also hydrological differences between catchments have to be considered (Elsenbeer, 2001; Johnson *et al*., 2006) and only clear trends across the entire set of the four catchments are interpreted here.

Hydrologic instrumentation was installed and catchments monitored for the year 2008. The boundaries of each catchment were determined using a Global Positioning System (GPS) on the landscape around each spring up to the plateau. The GPS data were then used to generate a Geographical Information System (GIS) output and map of the area. The sizes of the catchments were 12.8 ha for the forest, 14.4 ha for the 5 year old conversion, 9.1 ha for the 10 year conversion and 10.0 ha for the 50 year conversion. There were a total of one, six, and eleven households living in the 5, 10, and 50 year conversion catchments, respectively. A standard V-notch weir was constructed at each catchment outlet for determining stream discharge. Stream stage was recorded using water capacitance probes (Odyssey Dataflow Systems Pty Ltd, New Zealand) installed at the weir. The probes were programmed to give a reading of the average stream stage at 2 minutes. Data from these probes were downloaded biweekly. The weir ratings were determined at low and intermediate flows. The weir rating correlation coefficients were $r^2= 0.944$, $r^2= 0.915$, $r^2= 0.926$, $r^2= 0.931$ for the forest, 5 year, 10 year and 50 year conversions, respectively. The stream hydrographs were normalized by corresponding catchment sizes to allow comparison between responses for the 4 catchments.

Stream water sampling was done biweekly at the weir outlet, at the beginning and mid of every month. The water samples were filtered through 0.45-µm pore-size glass-fiber filter, into two separate 50-mL centrifuge vials. We added thymol into the first 50-mL centrifuge vial that was used for determination of calcium (Ca), magnesium (Mg), sodium (Na), potassium (K), total dissolved phosphorus (TDP), nitrate nitrogen (NO_3-N), ammonium nitrogen (NH_4^+-N) and total dissolved nitrogen (TDN). We added 10% HCl into the second 50-ml centrifuge vial that was used for determination of dissolved organic carbon (DOC) and the DOC isotopic ratio of ^{13}C to ^{12}C. The 0.45-µm pore-size glass-fiber filter paper with sediment was air dried and kept for the determination of coarse particulate organic carbon (CPOC), the CPOC isotopic ratio of ^{13}C to ^{12}C, and coarse particulate nitrogen (CPON).

Five soil samples from 0-0.1 m depth were randomly collected from the slope to the plateau of each catchment for analyses of SOM, SOC, total N, available P, Ca, K, Mg and Na. Also four sites were randomly selected on each catchment and soil sampled at depths of 0.1-0.3m, 0.3-0.9m, 0.9-1.5m, 1.5-2.4m. Bulk density was determined by the soil core method; we used five soil samples from a depth of 0-0.1 m in each catchment (Campbell and Henshall, 1991). The soil porosity (ø) was computed from bulk density (ρ_b) and particle density (ρ_p) using the formula $ø=1- (\rho_b / \rho_p)$. The use of organic and inorganic fertilizers was assessed in all studied agricultural watersheds by a full survey of all households using interviews.

Laboratory measurements

Soil total C was determined by dry combustion after fine grinding soil using a Mixer Mill (MM301, Retsch, Germany). Samples were analyzed for total C contents with a Europa ANCA-GSL CN analyzer (PDZ Europa Ltd., Sandbach, UK). Soil organic matter (SOM) was determined by loss on ignition (Storer, 1984) and soil pH (in water) at the w/v ratio 1:2.5 using a glass electrode (Thermo Scientific, Beverly, MA, US). Filters containing CPOC were ground using a Mixer Mill (MM301, Retsch, Germany) and analyzed for total C, the isotopic ratio of ^{13}C to ^{12}C, and CPON using a coupled Europa 20-20 continuous isotope ratio mass spectrometry (PDZ Europa Ltd., Sandbach, UK). The Mehlich 3 extraction procedure (Mehlich, 1984) was used for the available soil P, Ca, Mg, K and Na. The Ca, Mg, K, Na and P concentrations were obtained by Inductively Coupled Plasma Atomic Emission Spectroscopy (ICP-AES, ARCOS, Germany). TDN was analyzed using Shimadzu's Total Nitrogen Module, TNM-1 that uses chemiluminescence. Dissolved organic nitrogen (DON) was computed using the formula DON=TDN- NO_3^- and NH_4^+. DOC analysis was carried out on a Shimadzu Total Organic Carbon-Visionary Series (TOC-V_{CSH}) analyzer following the procedure described by Qian and Mopper (1996). NO_3-N and NH_4^+-N were determined on a Seal AQ2-Automated Discreet Analyzer (Seal Analytical, England).

Statistical analyses

Statistical analyses were done using JMP Version 8 (SAS Institute Inc, Cary, NC, USA) for soil properties and stream water solutes of the four catchments. A one way ANOVA was used for the soil properties, and a repeated measure analysis controlling for the date was performed for the stream water solutes. Both analyses were followed with posthoc multiple comparisons using a Tukey correction for multiple comparisons when the catchment effect was significant. Comparisons were considered significant at $P<0.05$.

RESULTS

Soil properties

Within the top 0.1 m, the SOM and SOC concentrations significantly decreased by 59% and 75%, respectively, and the soil N contents by 79% from the forest to the 50 year old agricultural catchment (Table 1). The forest SOC and soil N were significantly ($P<0.05$) higher than the 5 year conversion. Soils in the 10 and 50-year conversion did not differ. The SOM, SOC and N loss was very rapid in the first 10 years of conversion decreasing by 50%, 66% and 70%

respectively. Available soil P, K and Na did not change as a result of forest clearing and soil use between the studied watersheds. In contrast, extractable Ca and Mg significantly ($P<0.05$) decreased over time (Table 2.1). Similarly, pH values significantly decreased from forest (7.39) to agriculture (5.81).

Table 2.1: Soil properties in the top 0.1 m

	Forest	5 year conversion	10 year conversion	50 year conversion
Soil organic matter (%)	17.08a	13.67b	8.53c	7.00d
Soil organic carbon (g kg^{-1})	108.3a	68.8b	36.4c	27.5c
Soil organic carbon (t ha^{-1})	86.64a	62.61b	37.49c	32.18c
Soil nitrogen (g kg^{-1})	11.2a	6.9b	3.4c	2.3c
Soil nitrogen (t ha^{-1})	8.96a	6.28b	3.50c	2.69c
Soil bulk density (g cm^{-3})	0.80c	0.91b	1.03ab	1.17a
Total porosity	0.70a	0.66b	0.61bc	0.56c
% moisture at 0.33 bar (field capacity)	34.70a	34.05a	24.88b	22.97b
pH (water, 1:2.5)	7.39a	6.48b	6.23b	5.81c
Available P (g kg^{-1})	0.011a	0.007a	0.003a	0.006a
Available K (g kg^{-1})	0.69a	0.58ab	0.23b	0.44ab
Available Ca (g kg^{-1})	6.25a	4.98a	1.77b	2.91b
Available Mg (g kg^{-1})	0.73a	0.45b	0.20c	0.33bc
Available Na (g kg^{-1})	0.026a	0.020a	0.010a	0.011a

Means within a row followed by the same letters are not significantly different from each other at $P< 0.05$ ($n=5$).

The soil ρ_b increased rapidly by 28.8% in the first 10 years of cultivation from 0.80 to 1.03 g cm^{-3} (Table 1). Overall, the soil ρ_b increased by 46.3% from 0.8 to 1.17 within 50 years of cultivation. The rapid increase in ρ_b in the first 10 years following conversion leads to a 12% drop in the total porosity from 0.69 to 0.61 in the same period.

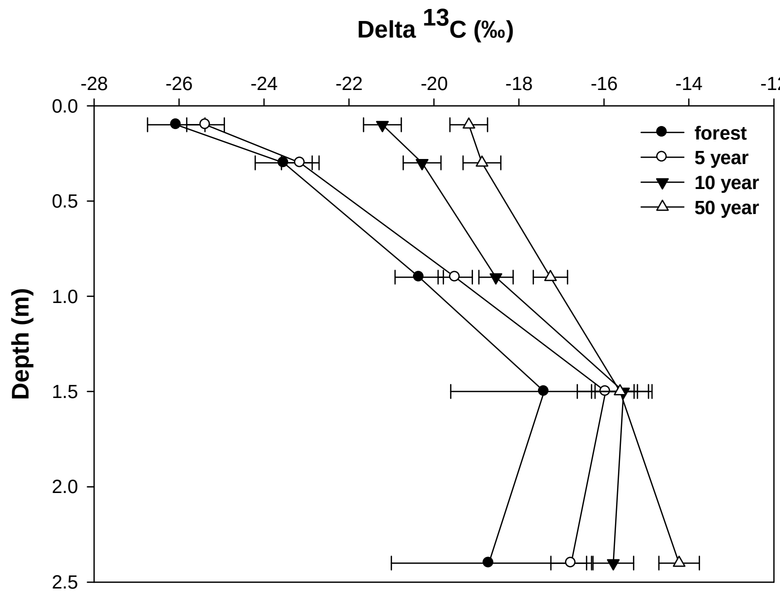

Fig. 2.1: Long term shift in the isotopic composition of $\delta^{13}C$ of the soils at various depths in the watersheds. n=4. Bars are ±1 standard deviation of the mean for each depth

In the 0-0.1 m depth, the soil $\delta^{13}C$ values were -26.07 ± 0.68 ‰, -25.37 ± 0.84 ‰, -21.21 ± 0.87 ‰ and -19.18 ± 0.44 ‰ for the forest, 5 yr, 10 year and 50 year conversion catchments, respectively (Figure 2.1). This indicates enrichment in the heavier isotope from the forest than in the catchment under cultivation for 50 years. The $\delta^{13}C$ values at the topsoil (0-0.1 m) increased linearly over time from -26.07 ‰ to -19.18 ‰ (r^2=0.95; P<0.0001), with similar trends at depth. Similarly, the $\delta^{13}C$ values became less negative deeper in the profile for all the catchments indicating a slight enrichment in the heavier isotope from the topsoil.

Table 2.2: The isotopic composition of δ ^{13}C of the CPOC and DOC, and the flow weighted nutrient concentrations of the headwater catchments.

	Forest	5 year conversion	10 year conversion	50 year conversion
		Sediment and filtered streamwater		
CPOC δ ^{13}C (‰)	-27.52b	-27.29b	-27.28b	-26.40a
DOC δ ^{13}C (‰)	-28.59c	-28.25c	-26.79b	-22.75a
		Streamflow concentrations		
DOC (mg L^{-1})	1.31a	1.48a	1.47a	1.52a
CPOC (mg L^{-1})	1.25a	1.43a	1.49a	1.65a
CPON (mg L^{-1})	0.12a	0.14a	0.15a	0.16a
TDN (mg L^{-1})	0.49b	0.67b	4.83a	4.64a
NO_3^- (mg L^{-1})	0.40b	0.58b	4.71a	4.52a
DON (mg L^{-1})	0.10a	0.09a	0.10a	0.12a
TDP (mg L^{-1})	0.03b	0.01b	0.05b	0.15a
K (mg L^{-1})	0.36c	0.80b	0.95a	1.18a
Ca (mg L^{-1})	7.23a	5.55b	5.48b	7.16a
Mg (mg L^{-1})	3.01a	2.04c	1.61d	2.54b
Na (mg L^{-1})	2.99c	3.70c	4.65b	5.61a

Means within a row followed by the same letters are not significantly different from each other at $P < 0.05$ (n=24 for CPOC δ ^{13}C, n=4 for DOC δ ^{13}C**,** and n=12 for all others).

Stream water chemistry

The $\delta^{13}C$ composition of CPOC (Table 2) did not change from the forest (-27.52‰) to the 10 year conversion (-27.28‰). The 50 year old catchment had a slightly higher $\delta^{13}C$ value compared to the other catchments. The streamwater DOC $\delta^{13}C$ composition followed the same trend as the sediment but with a significantly greater magnitude of enrichment in the heavier isotope from the forest and recent conversion to the 10 year old conversion. Discharge in the 50 year conversion had a significantly higher value than that of all other headwaters (-22.75‰). The flow-weighted average concentrations of DOC, CPOC and CPON did not change with forest conversion and duration of cultivation (Table 2). TDN concentrations in the discharge from forest and 5 year catchments did not differ, but increased with longer cultivation. NO_3^- was the dominant form of dissolved N (91%) in the Kapchorwa watershed fluvial ecosystem, followed by DON (9%), whereas NH_4^+ was below our detection limit. The 10- and 50-year conversion watersheds had nine times higher TDN concentrations compared to the forest and most recent conversion. Stream TDP concentrations were at least one order of magnitude lower compared to TDN, Ca, K, and Mg. TDP concentrations of the forest, 5 and 10 year conversions were threefold lower than that of the 50 year conversion ($P<0.05$). Stream water K and Na concentrations both increased upon forest conversion and subsequent cultivation. Overall, K concentrations increased threefold and Na concentrations twofold following 50 years of cultivation after forest conversion. In contrast to all other solutes, Ca and Mg concentrations did not show a consistent trend from forest to cultivation.

Table 2.3: Streamwater carbon and nutrient exports (kg ha^{-1} yr^{-1}) from the Kapchorwa headwater catchments

	Forest	5 year conversion	10 year conversion	50 year conversion
DOC	3.87	6.85	8.46	9.79
CPOC	3.94	6.60	8.57	10.63
CPON	0.33	0.64	0.87	1.03
TDN	1.45	3.12	27.76	29.93
NO_3^-	1.18	2.68	27.09	29.16
DON	0.27	0.44	0.67	0.77
TDP	0.09	0.03	0.29	0.98
K	1.06	3.68	5.44	7.61
Ca	21.43	25.66	31.46	46.22
Mg	8.93	9.42	9.23	16.38
Na	8.86	17.08	26.70	36.22

The total C exports increased after forest conversion and with subsequent cultivation (Table 2.3). The DOC and CPOC export doubled in the first 5 years following forest conversion. The increase continued by a further 43% and 70% from the 5 to the 50 year conversions, respectively. Amounts of CPON, TDN and NO_3^- exported were also twice the first five years after forest conversion. Upon longer cultivation between 5 and 10 years, CPON export increased 3.5 times, while the TDN and NO_3^- export increased eightfold. Between 10 and 50 years of continuous cultivation, the amount of CPON export doubled while that of TDN and NO_3^- did not increase further. The magnitude of TDP export was far less than that of C and all other nutrients. The amounts of TDP exported did not change after forest conversion (<0.03 kg ha^{-1}), but increased with subsequent cultivation up to the 0.98 kg ha^{-1}. The cations (K, Ca Mg and Na) exhibited a similar trend whereby the amounts exported increased from the forest to the 5, 10 and 50 year conversions. Among those cations, K had the lowest export while Ca had the highest.

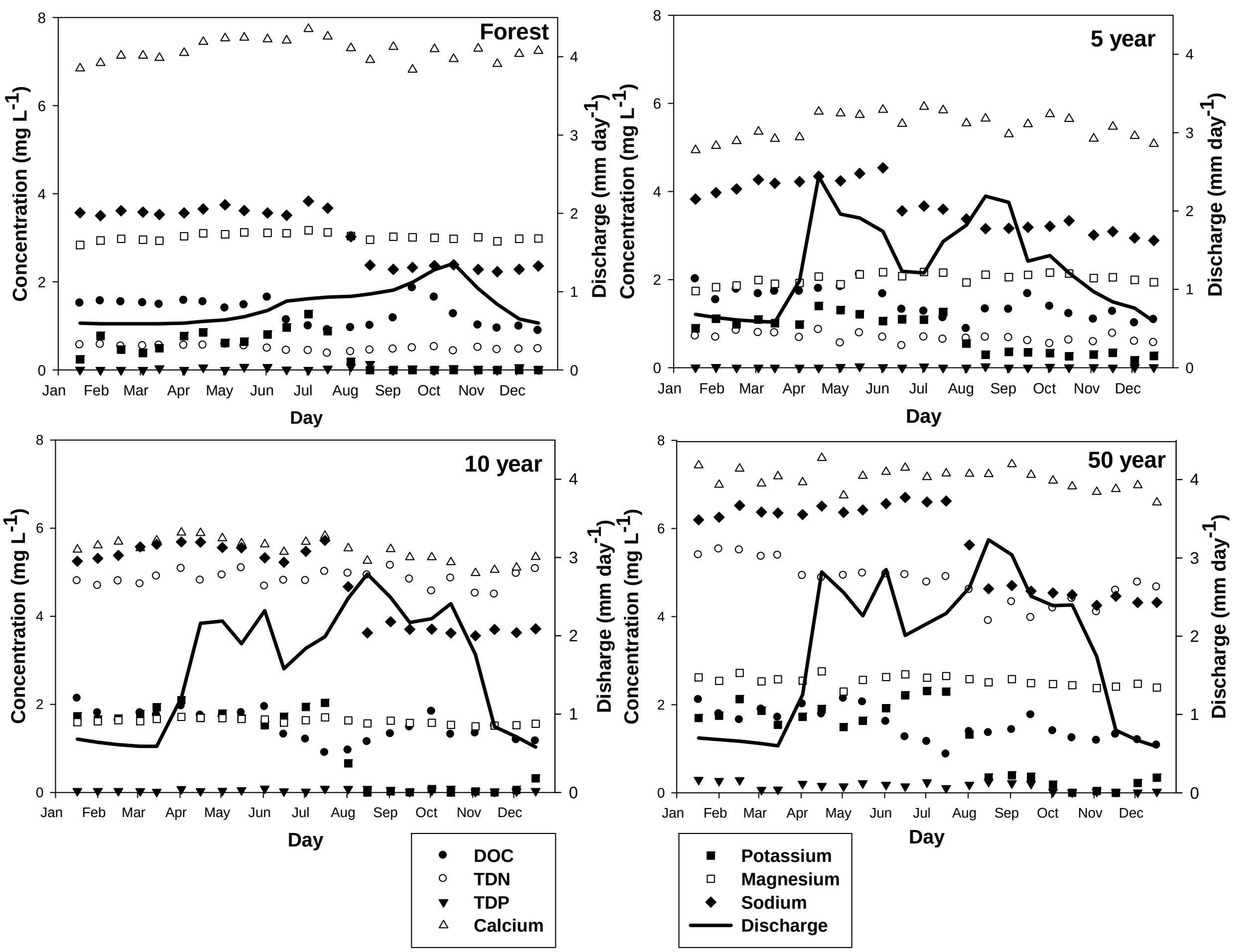

Figure 2.2: Bi-weekly discharge and concentrations of DOC, Na, Ca, K and Mg of the Kapchorwa headwater catchments

There was not a clear separation of the hydrograph between the long rainy (April-June) and short rainy (August-October) seasons in the Kapchorwa catchment in 2008. The stream flow response to precipitation events increased with longer cultivation (Figure 2.2). There were no relevant changes in the concentrations of DOC, TDN, TDP, Ca, and Mg across the whole year. The K and Na concentrations, however, decreased slightly after the long rainy season in August and remained low for the short rainy season. Overall, there was no relationship between the solute concentrations and discharge (Fig. 5).

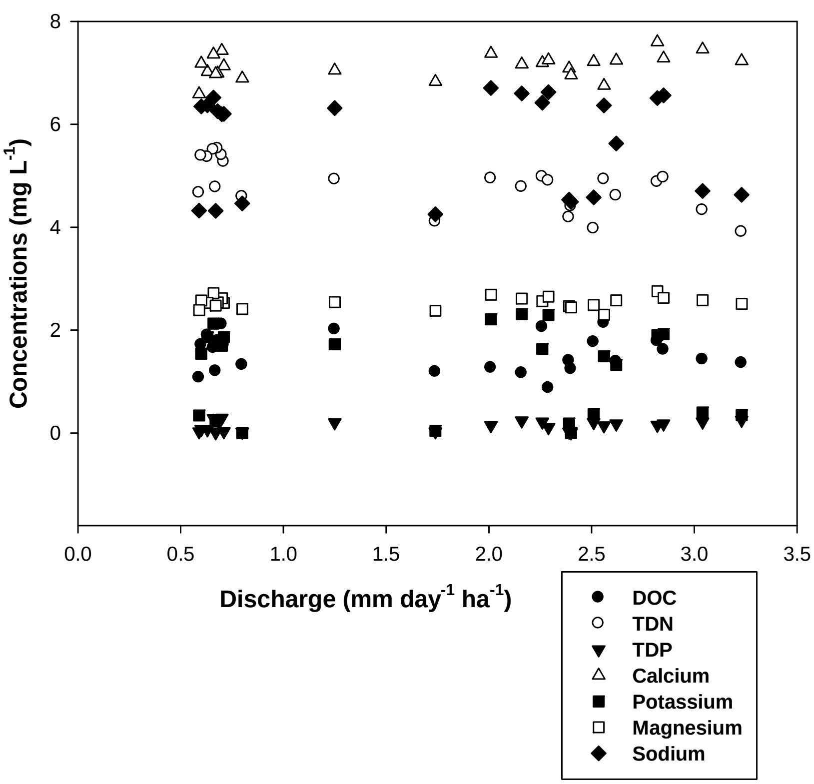

Figure 2.3: The relationship between discharge and DOC, Na and nutrient concentrations in the 50 year watershed

DISCUSSION

Sources of soil C and nutrient losses

The SOC reduction following land use conversion and cultivation is typically largely due to microbial respiration (Mann, 1986). Indeed, annual DOC and CPOC losses by stream water of 22 kg ha^{-1} from the highly degraded soils were only 2% of mineralization losses of 1,200 kg ha^{-1} determined by direct measurements from the soil surface using static vented chambers (Kimetu and Lehmann, 2010). Similarly, cumulative fluvial organic C losses were 0.9 t ha^{-1} (2%) over the first 50 years (using linear interpolation of the sum of DOC and CPOC) compared to SOC losses of 54 t ha^{-1} in the first 0.1 m (calculated from Table 1). It is possible that inorganic C and particular dissolved CO_2 may significantly contribute to total fluvial C losses from watersheds as shown in the Amazon (Johnson *et al*., 2008). However, even with a possibly larger inorganic than organic C loss, microbial mineralization from the soil still exceeds 90% of total SOC losses. The quantified fluvial C export is low compared to other studies. Moore *et al.* (2010) observed a fluvial total organic C removal of 12% by a Bornean blackwater river in a peat covered area of Indonesia. Cumulative fluvial N losses over the first 50 years (using linear interpolation of the sum of TDN and CPON) were 1.3 t ha^{-1} compared to the total soil N losses of 6.3 t ha^{-1} (representing 21%) in the first 0.1 m (calculated from Table 1). Similar to fluvial C losses, watersheds at our site showed lower export than at other locations.

Stable isotope ratios of C in topsoil increased with number of years of cultivation. Isotopic enrichment was due to establishment of the C_4 maize crop which discriminates less against ^{13}C compared to the original forest vegetation. Agren *et al*. (1996) also attributed isotopic enrichment of $\delta^{13}C$ to isotopic fractionation associated decomposition and humification processes, which explain the observed increase with depth. Increasing $\delta^{13}C$ values with soil depth were also found by Krull *et al*. (2002) at a nearby site. Both fluvial CPOC and DOC were mainly mobilized from the topsoil, as $\delta^{13}C$ values in stream discharge were lower than in the topsoil and soil values increased with depth. Similar conclusions were drawn by Frank *et al*. (2000) and Raymond and Saiers (2010) who found most of the DOC losses to be derived from the topsoil in catchments in central Switzerland and eastern United States, respectively. Alternatively, the low $\delta^{13}C$ values in our study may also indicate that organic C losses originated from older SOC fractions characterized by small size and association with minerals. This conclusion is in accordance with data from Kinyangi (2006) who showed decreasing $\delta^{13}C$ values with smaller particle size and association with the organo-mineral fraction in soils from the same chronosequence. The isotopic composition of the topsoil correlated fairly strongly with the DOC $\delta^{13}C$ (r^2=0.84; y=1.132x+7.1478) as well as with the CPOC $\delta^{13}C$ (r^2=0.83; y=18.25x-49.523), but with a low slope for CPOC.

Nutrient losses, crop production and stream pollution

Total N (TDN + CPON) losses of 31 kg ha^{-1} yr^{-1} in the highly degraded soils were relevant compared to crop N uptake of maize at the same sites with 90 kg N ha^{-1} yr^{-1} (Kimetu *et al*., 2008). There was no fertilizer application in the recent conversion, while applications in the 10 and 50 year conversions were about 40 kg N ha^{-1} (average from all farms in the studied catchments). The typical application rates to maize by most farmers in the entire region are 20 kg N ha^{-1} (Ngoze, 2008), less than the stream water losses reported here. Even more dramatic were the fluvial Ca and Mg losses of 46 and 16 kg ha^{-1} yr^{-1}, respectively, which were greater than uptake by a single maize crop of 20 and 10 kg ha^{-1}, respectively (Kimetu *et al*., 2008). In contrast, annual fluvial P losses of 1 kg ha^{-1} were low compared to plant uptake of 10 kg ha^{-1} (Kimetu *et al*., 2008) and fertilization of about 7.5 kg P ha^{-1} (sum of inorganic and organic fertilizers averaged for all farms) in the oldest conversion. Both Ca and Mg as well as P losses by stream water may not be as serious as N losses because available P, Ca, and Mg in soil decreased much less than total N (Table 1), and crops were found to respond less to P than to N additions (Ngoze *et al*., 2008). In addition, TDN concentrations and total losses by stream discharge increased the most by forest conversion and continuous cultivation compared to any other nutrient studied here.

Despite the significant N losses from stream discharge for agricultural productivity, the observed concentrations in the studied headwater catchments are not an environmental concern for aquatic environments. Average annual N concentrations at or below 3 mg L^{-1} and maximum concentrations of 6 mg L^{-1} during the dry season of December to March do not pose a risk for human health (Rubio-Arias *et al*., 2010) and are not expected to cause eutrophication (King and Balogh, 2011; Hill *et al*., 2011). Similarly, P concentrations of 0.01-0.15 mg P L^{-1} in the stream discharge are moderate but not a cause for significant environmental concern (Auer *et al*., 1986; King and Balogh, 2011; Yu *et al*., 2011). Values up to 6.7 mg PO_4-P L^{-1} have been found in the River Thames catchment in the UK (Young *et al*., 1999) and up to 10 mg PO_4-P L^{-1} in the Spree River in Germany (Lewandowski and Nutzmann, 2010). Therefore, the well documented contamination of the lower Yala River (Aloo, 2003) and Lake Victoria (Hecky *et al*., 2010) with N and P and the resulting eutrophication does not seem to be caused by agriculture in the headwater catchments, but must occur further downstream.

Carbon and nutrient losses after landuse change

Our DOC concentrations and total losses were in the same range as reported by Lesack *et al*. (1984) from the Gambia River in the West African savannah with a DOC concentration of 1.98 mg L^{-1} and DOC export of 2.67 kg ha^{-1} yr^{-1}. Similar DOC concentrations but 2-10 times greater export were found by Cairns *et al*. (2009) in the forests of the Oregon Cascades and of southern Amazonia by Johnson *et al*. (2006). A study in peatland landscapes by Stutter *et al*. (2008) in Scotland found stream flow weighted DOC concentrations between 1.42 and 9.69 mg L^{-1} while the annual export flux ranged from 10.2-49.9 kg ha^{-1} yr^{-1}. The flow weighted CPOC concentrations from the 5 to the 50 year old catchments were 1.43 mg L^{-1} and 1.65 mg L^{-1}, with an export of 6.6 and 10.63 kg ha^{-1} yr^{-1} respectively. The figures are within the range reported for a variety of watersheds elsewhere (Lesack *et al*., 1984; Stutter *et al*., 2008; Waldron *et al*., 2009; Selva *et al*., 2007). The CPOC and CPON concentrations and export were in the same order of magnitude as those of DOC and DON. This finding differs from that of Vidal-Abarca *et al*. (2001) who found DOC to be the most important fraction (98%) of organic carbon flowing in a saline and semi-arid stream in Spain. Similarly greater proportions of DOC were also reported by Johnson *et al*. (2006ab) from southern Amazonia.

The increase in streamwater concentrations of TDN, NO_3^- and DON with longer duration of cultivation can be attributed to three sources. (1) Mineralization of SOM led to accumulation of mineral N and especially nitrate (as seen from stream water concentrations) which is weakly adsorbed to soil minerals and easily leached. (2) The greater number of households on older conversions presumably led to higher inputs of farm manure from the cattle kept by the farmers. The manure was shown to consist of 22 g N kg^{-1} (Kimetu *et al*., 2008). Half of the farmers in the older conversions applied inorganic fertilizer equivalent to 40 kg N ha^{-1}. (3) As stated above, only farmers with fields that have been cultivated for 10 years or longer apply mineral fertilizers. Fields that have been recently cleared at the same sites are rarely fertilized due to their high N mineralization rates and their low response to mineral (Ngoze *et al*., 2008) and organic N applications (Kimetu *et al*., 2008).

The increase in K and Na concentrations with longer cultivation may be explained by lower SOC contents and the soil mineralogy being dominated by kaolins, both resulting in lower cation retention. Krull *et al*. (2002) reported mineralogy dominated by quartz, kaolin and mica, with minor components associated with feldspars and oxides in the adjacent Kakamega part of the forest. They observed an abundance of quartz, kaolin, muscovite and microcline with a slight increase in goethite with increasing soil depth. The observed greater proportion of surface runoff of 4% to 10% of rainfall from forest compared to long-term cultivated fields (Recha, unpubl. data) may also have led to a greater mobilization of K and Na near the surface. Extractable K concentrations did not decrease with forest conversion and cultivation (Table 1). Similar to N, a greater number of households in the older conversion watersheds may have added more kitchen waste that are rich in K and Na such as ash from firewood cookstoves and farm yard manure. Kimetu *et al.* (2008) documented contents of 23.2 g K kg^{-1} in the manure.

The lack of change or even slight decrease in Ca and Mg stream water concentrations may be a result of a dominance of weathering as the primary source of Ca and, to a certain extent, Mg. The low weathering index (Fig. 5) supports that explanation. In addition, the significant decrease in extractable Ca in the topsoil (Table 1) in combination with the rather decreasing stream water concentrations after forest conversion point at the subsoil as the primary source of Ca.

Intra-annual dynamics of stream water solutes

None of the solute concentrations (except DOC, Na and K) changed with the strong changes in discharge between January and December 2008. No significant correlations were established between any of the solutes and stream discharge which is in contrast to other studies that typically show significant changes in DOC and nutrient concentrations throughout the year (Markewitz *et al*., 2001; Johnson *et al*., 2006b; Bucker *et al*., 2011). Although variations in intra-annual stream concentrations are often observed, the solutes can either be more concentrated during high flow in the rainy season due to export of mainly surficial nutrients (Markewitz *et al*., 2001) or less concentrated due to dilution during heavy rainfall and larger volume of stream discharge (Elsenbeer *et al*., 1994; Anderson *et al*., 1997; Tsujimura *et al*., 2001; Grimalsi *et al*., 2004). The constant concentration of N, P, Mg and Ca with varying discharge in our study may be explained by a balance between changes in water delivery and chemical delivery (Salmon *et al*., 2001). Ca and Mg can be delivered from both organic-rich soil horizons and weathering of deeper soil (Yusop *et al*., 2006). During low flows, the Ca and Mg would be derived from the weathered mineral subsoil, whereas near surface storm event flow (Noguchi *et al*., 1997) could entrain these solutes from the organic-rich topsoil. As stated before, the measured low Na/(Na+ Ca) values indicate greater weathering inputs of Ca.

In contrast, the Na and K concentrations in all four catchments dropped during the month of August at the onset of the second rainy season. The sources of K as well as Na are associated with leaching and decomposition of leaves and organic matter, and thus are expected to be available at greater quantities in the upper soil profile (Proctor *et al*., 1989; Veneklass, 1991). Therefore, prolonged rain may have leached K and Na contained in the litter layer from the soil surface similar to what has been observed for DOC in southern Amazonia (Johnson *et al*., 2006b) where the litter layer disappeared towards the end of the rainy season (Selva *et al*., 2007).

CONCLUSION

Results from this study indicate that conversion of forest catchments to continuous maize cropping had a significant effect on the hydrochemistry of headwater streams. All C species and nutrient concentrations increased with forest conversion and cultivation except for Ca and Mg. The reason may be the proportional greater importance of geochemical weathering for Ca and Mg. Dilution of major solutes during the rainy season frequently observed elsewhere did not occur here, except for K and Na. Fluvial C export was low compared to mineralization of SOC and P losses were negligible, but N losses by stream water must be addressed to curtail declining crop productivity. In terms of nutrient pollution and possible contamination of water resources, the N and P levels are not of concern and agriculture in the headwaters seems to play a minor role for the observed eutrophication of the downstream Yala River system and Lake Victoria.

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CHAPTER 3

SOURCES AND SHORT-TERM NUTRIENT DYNAMICS OF STREAM DISCHARGE FROM FORESTED AND AGRICULTURAL HEADWATERS DURING STORM EVENTS

Abstract

Stream water concentrations of dissolved organic carbon (DOC), calcium (Ca), potassium (K), magnesium (Mg), sodium (Na), total dissolved nitrogen (TDN), and nitrate nitrogen (NO_3^--N) were examined under 20 storm flow conditions in four watersheds in Western Kenya. Three of the watersheds had been under maize cultivation for 5, 10 and 50 years after forest conversion. The other watershed was forested. The agricultural watersheds discharged the newly fallen rainwater 10-20 minutes more quickly compared to the forest watershed. Three patterns of changes in the concentrations of different solutes were observed as a function of increased stream water discharge and land use. (i) Concentrations of DOC and K increased with larger discharge in all studied watersheds. This suggests a quick transfer of these solutes to the stream through overland flow and preferential flow through soil macropores. The observed hysteretic response for both solutes suggests temporary depletion of terrestrial DOC and K due to soil water flushing. (ii) The Ca, Mg, Na, TDN and NO_3^--N concentrations did not change in the forested watershed, while their concentrations decreased with increasing discharge in the agricultural watersheds. (iii) Baseflow that is rich in Ca, Mg, and Na was diluted by the storm event runoff. Saturated areas along river channels may favor production of dilute quickflow, leading to marked dilution of TDN and NO_3^--N. Based on end-member mixing analysis (EMMA) modeling, groundwater was shown to be the dominant flowpath which was higher

($P<0.05$) in the forest compared to the 10- and 50-year conversion watersheds. The contribution of overland flowpath compared to streamwater was significantly lower ($P<0.05$) in the forest and 5-year watershed than the 50-year watershed.

INTRODUCTION

Headwater streams are important sites of nutrient processing (Peterson *et al*., 2001) and carbon (C) dynamics. They are strongly influenced by the surrounding headwater catchment that is a source of organic matter, nutrients, and sediments (Vannote *et al*., 1980). Headwater catchment characteristics such as geology and land use affect the rate at which solutes are delivered to streams (Omernik, 1976; Richards *et al*., 1996). The importance of rain storms in affecting both hydrological and chemical response of drainage waters has been documented for a variety of catchment types ranging from snow-dominated systems where seasonal snowmelt dynamics play a critical role (Sickman *et al*., 2003) to arid catchments where antecedent moisture conditions are especially important (Castillo *et al*., 2003). Storm events may contribute substantial amounts of solute and sediment export in drainage waters (Mitchell *et al*., 2006).

Tropical regions are characterized by episodic rainfall events during which potentially large amounts of sediments and nutrients can be discharged (Blanco *et al*., 2010). In western Kenya, storm events make up a significant percentage of the total rainfall (Kipkorir, 2002). The amount of materials discharged depends on the complex interaction of different factors including rainfall, vegetation cover, soil conditions, and agricultural management. Agricultural land use typically increases the inputs of sediments and nutrients to streams (Allan *et al*., 1997; Strayer *et al*., 2003). Forest removal contributes greatly to higher stream water discharge and storm runoff (Mumeka, 1986). Deforestation can also dramatically increase sediment runoff (Kreutzweiser and Capell, 2001) and increase the export of nutrients to the streams (Harr and Fredriksen, 1988; Martin *et al*., 2000). The impacts of land use changes on hydrologic processes in the tropics are especially severe because of rapid soil degradation (Spaans *et al*., 1989; Malmer and Grip, 1990). Light and heavy rainfall affects hydrologic processes in different ways. The changes in watershed hydrology, solute dynamics and flowpaths in relation to heavy precipitation has been studied in temperate regions (Jeppesen *et al*., 2011), but less work has been done in the tropics, especially in Africa.

Storm events significantly affect the nutrient runoff and nutrient budget because runoff pathways and residence times of water vary from the beginning to the end of storm events (Zhang *et al*., 2007). Subsurface flow on hill slopes is produced by rapid infiltration of rain which flows to the stream through interconnected macropores or through saturated soil horizons (Beven and Germann, 1982). Partial-area overland flow may occur on certain portions of a watershed where rainfall rates are greater than soil infiltration rates (Betson and Marius, 1969). More commonly, saturation overland flow is generated by precipitation on near-stream areas that have become saturated by a rising water table (Bonell and Gilmour 1978) or a perched water table above a less permeable soil horizon (Germer *et al*., 2010).

These changing water flow paths during storms may activate nutrient-poor or nutrient-rich areas of the watershed. Flow pathways that dominate during storm events determine the surface water chemistry (Bonell, 1993). Changes in NO_3^--N and DOC concentrations may be attributed to flushing from various sources in the soil matrix and locations of the watershed (Brown *et al*., 1999; Inamdar *et al*., 2004). In upland forested catchments of the Colorado Rocky Mountains, stream DOC concentrations peaked on the rising limb of the snowmelt hydrograph, prior to peak discharge, followed by a rapid decrease in the concentrations as snowmelt continued (Hornberger *et al*., 1994). This temporal pattern in DOC concentrations was attributed to the flushing of the near-surface soil DOC pool by the rising water table. Creed and Band (1998) found a similar trajectory in NO_3^--N concentrations during snowmelt discharge from glaciated catchments in the Canadian Shield and attributed this pattern to the flushing of NO_3^--N from near-surface soil layers. In contrast to the flushing of DOC and NO_3^- from near-surface layers, Hill *et al*. (1999) and McHale *et al*. (2002) did not find any evidence of NO_3^--N flushing in Canada and New York, respectively. No information is available that links storm flow to flow paths and nutrient export during storms in watersheds in Africa.

These runoff processes and pathways are complex. Stormflow generation is favored when critical runoff production processes and rainfall thresholds are surpassed (Tromp-Van Meerveld and McDonnell, 2006; James and Roulet 2007). Rapid water delivery to the stream also depends on variability in soil depth (Ross *et al*., 1994) and underlying bedrock topography (Brammer and McDonnell, 1996). Variability in the concentration of solutes in streamwater may be an effective indicator of mapping complex flowpaths during storm runoff (Moore, 1989). Such studies rely on natural tracers for testing the hypothesis of storm flow generation (Ali *et al*., 2010). They assume that stream water is a mixture of discrete solutions that have extreme solute concentrations in comparison to stream flow (Christophersen and Hooper, 1992). For example, soil water DOC is efficiently immobilized in the streambed during base flow, but flushing of

DOC along preferential flow paths away from the stream channel in the riparian zone leads to higher DOC concentrations during higher flow conditions (Fiebig *et al*., 1990). Stream water DOC concentrations may, therefore, be an indicator of contributions from a rapid event-based shallow subsurface flowpath (Brown *et al*., 1999). In order to detect subsurface sources, studies of active and maybe connected flow sources using the geochemical signature of stream and soil waters (Bazenmore *et al*., 1994; Weiler *et al*., 2005) have been carried out. Similarly appropriate tracers include cations, electrical conductivity, nitrate-nitrogen and sulfate (Ali *et al*., 2010).

This study quantifies the effects of forest conversion to agriculture on DOC and nutrient dynamics during storm events, as well as determines the dominant flowpaths. The specific objectives of this study are: (1) to investigate the catchment temporal patterns of DOC and nutrient concentrations during storms, (2) to determine the potential mechanisms controlling the characteristics of DOC and nutrient components during storm events and (3) to identify trends in water sources to stream flow. The effects of continuous agricultural land use on flowpaths were investigated by comparing three headwater catchments following forest conversion to continuous maize production for either 5, 10, or 50 years in Western Kenya to a catchment that has remained forested.

METHODS

The study site

The field measurements were done in Kapchorwa, located in the Nandi district in western Kenya (Figure 1). The site is located 60 km northeast of Lake Victoria at longitude 35°0'0" E and latitude 0°10'0"N. The region belongs to the sub-humid ecological zone characterized by a bimodal rainy season with a mean annual precipitation of 2000 mm (Awiti *et al*, 2004). The "long rain season" is from April to June (~1200 mm) and the "short rain season" from August to October (~800 mm). The site has a mean elevation of 1800m above sea level, a maximum daily temperature of 26°C and a minimum of 11°C (Glenday, 2006).

The Kakamega-Nandi forest in Western Kenya is the country's only remaining tropical rain forest. Massive deforestation has taken place to create land for settlement and farming. About 16% of forest cover was lost between 1986 and 2001 (Awiti *et al*., 2004). The forest forms the easternmost relic of the Guinean-Congolian rainforest belt, which once spanned from East to West Africa. The area around this forest is among the most densely populated rural areas in the world. It had a population density of 778 persons per km^2 in 2009 compared to 73 persons per square kilometer for the entire country (Kenya National Bureau of Statistics, 2010). Consequently the forest is under high anthropogenic pressure, which is mirrored by the decreasing natural forest cover and intensive cultivation (deGraffenried and Shepherd, 2009; Swallow *et al*., 2009). Past deforestation rates in the Kakamega-Nandi forest led to lower forest areas and greater fragmentation of natural, old-growth forest (Lung and Schaab, 2006).

Soils in the Kapchorwa catchment are kaolinitic Acrisols (FAO-UNESCO-ISRIC, 1988), or Ultisols (Soil Survey Staff, 2003). The parent material of these soil is mainly granitic, with some inclusions of Precambrian gneisses (Werner *et al*., 2007) and other undifferentiated basement system rocks at higher elevations (Jaetzold and Schmidt, 1983). Soils in the catchment have 45-

49% clay, 15-25% silt, and 26-40% sand (Kimetu *et al*., 2008). The forest section of the Kapchorwa catchment is part of the Kakamega-Nandi forest with a 30 m closed canopy dominated by evergreen hardwood species. The agricultural catchments studied here have maize as the dominant crop, and have been under maize cultivation since conversion from forest cover. The maize grain yield without fertilizer input in the 5, 10 and 50 year old agricultural catchments are 6.5, 5.5 and 2.5 Mg ha^{-1} $year^{-1}$, respectively (Ngoze *et al*., 2008).

Hydrologic instrumentation and field data collection

All four headwater catchments are located within an area of 6 km^2 and represent a soil degradation gradient that corresponds to years under maize cultivation that has been used in several other studies (Kimetu *et al*., 2008, 2009; Ngoze *et al*., 2008; Moebius-Clune *et al*., 2011). Such chronosequences substitute time for space and must be carefully selected to assure similar properties before the change (Huggett, 1998), including hydrological differences between catchments (Elsenbeer, 2001; Johnson *et al*., 2006). Only clear trends across the entire set of the four catchments are interpreted here. Hydrologic instrumentation was installed in January 2008. The extents of each catchment were determined using a Global Positioning System (GPS). The sizes of the catchments were 12.8 ha for the forest, 14.4 ha for the 5 year old conversion, 9.1 ha for the 10 year conversion and 10.0 ha for the 50 year conversion. A standard V-notch weir was positioned at each catchment outlet for determining stream discharge. Stream stage height was recorded using water capacitance probes (Odyssey Dataflow Systems Pty Ltd, New Zealand) installed at the weir. The probes were programmed to give a reading of the average stream stage every 2-5 minutes. Data from these probes were downloaded biweekly. Rainfall dynamics for each catchment was estimated from a tipping bucket rain gauge connected to a data logger installed 1 m above the ground. The rainfall was measured below the canopy for the forested catchment and above-canopy rainfall for the agricultural catchments.

During storm events, sampling was done simultaneously for streamflow at the weir and runoff (overland flow) at two locations upslope to the position of each weir. Each watershed had 5 peizometers and 5 free draining lysimeters located randomly. The piezometers were sampled biweekly, while the lysimeters were sampled one day after a rainfall event. Typically, the storm events were characterized by rain that lasted between 40 and 70 minutes, amounting to over 8 mm rainfall per single event. The sampling began at the start of the storm event, continued at intervals of 5 minutes up to 30 minutes after that rainfall had stopped. The five longest storms per watershed were considered for this paper (n=20). The water samples were filtered through 0.45-μm pore-size glass-fiber filter, into two separate 50-mL centrifuge vials. We added thymol into the first 50-mL centrifuge vial that was to be used for determination of Ca, Mg, Na, K, TDN and NO_3^--N. We added 10% HCl into the second 50-mL centrifuge vial that was to be used for determination of DOC. The Ca, Mg, K, Na available P and TDP were obtained by Inductively Coupled Plasma Atomic Emission Spectroscopy (ICP-AES, ARCOS, Germany). TDN was analyzed using Shimadzu's Total Nitrogen Module (TNM-1, Shimadzu Scientific Instruments, Maryland, US). DOC analysis was carried out on a Shimadzu Total Organic Carbon-Visionary Series analyzer (TOC-V_{CSH}, Shimadzu Scientific Instruments, Maryland, US) following the procedure described by Qian and Mopper (1996). NO_3^--N was determined on a Seal AQ2-Automated Discreet Analyzer (Seal Analytical, Hampshire, England).

Model and statistical analysis

Solutes that mix conservatively within the system were selected from linear plots of every pairwise combination of solutes (mixing diagrams). The set of end-members whose orthogonal projections best bound the stream water observations were chosen. End-member mixing analysis (EMMA) was performed using a three-component hydrograph separation involving overland flow, soil water, and groundwater, with two tracers DOC and Ca as described by Ogunkoya and Jenkins (1993). We used the model to calculate the proportion of stream water derived from each of the three end members for each sample collected during the storms by solving the following mass-balance expressions:

$$Q_{st} = Q_{gr} + Q_{so} + Q_{ov} \quad (1)$$

$$Q_{st}\,[1]_{st} = Q_{gr}[1]_{gr} + Q_{so}\,[1]_{so} + Q_{ov}[1]_{ov} \quad (2)$$

$$Q_{st}\,[2]_{st} = Q_{gr}[2]_{gr} + Q_{so}\,[2]_{so} + Q_{ov}[2]_{ov} \quad (3)$$

Where Q is the discharge, and *[1]* and *[2]* are the first and second tracers. The subscripts *st*, *gr*, *so*, and *ov* signify stream, ground, soil, and overland areas, respectively.

A repeated measure statistical analysis was performed for the pathways for 19 events. One storm event for the forest that occurred on June 30, 2008 was not included as it was contaminated with an unidentified source of DOC. The analyses was followed with posthoc multiple comparisons using a Tukey correction for multiple comparisons when the catchment effect was significant ($P<0.05$).

RESULTS

The stream discharge started to increase about 10 minutes after the onset of the storm events, followed by a higher discharge rate that showed a rising limb on the hydrograph (Fig. 3.1; summary in Table 3.1). The discharge peaks of the catchment limbs were about 30% higher compared to the pre-event baseflow, respectively. The increase in stream discharge led to increases in the DOC and K solute concentrations. The highest solute concentrations occurred around the peak discharge and were still higher when the hydrograph limb was falling. The DOC and K levels decreased with the falling limb of the discharge after the peak. The agricultural watersheds had similar hydrochemical storm characteristics regardless of the year of conversion. The other four storms in each of the catchments followed the trends described here, as well (see Appendix C).

Table 3.1: A summary of the storm characteristics and solute response in each watershed

	Date of storm event	Duration (minutes)	Rainfall (mm)	Solute response with increasing discharge
Forest	June 30, 2008	54	12.2	DOC and K increasing
	July 21, 2008	44	12.5	
	July 22, 2008	67	8.2	Ca, Mg, Na, TDN and NO_3^--N constant
	July 25, 2008	40	11.5	
	August 1, 2008	70	8.8	
5 year	June 30, 2008	54	11.4	DOC and K increasing
	July 14, 2008	40	11.2	
	July 20, 2008	67	10.0	Ca, Mg, Na, TDN and NO_3^--N decreasing
	July 31, 2008	45	13.8	
	August 1, 2008	43	10.1	
10 year	July 14, 2008	44	13.0	
	July 20, 2008	46	11.5	DOC and K increasing
	July 27, 2008	47	10.2	
	July 31, 2008	63	11.7	Ca, Mg, Na, TDN and NO_3^--N decreasing
	August 2, 2008	52	13.0	
50 year	July 2, 2008	41	11.2	
	July 20, 2008	46	11.3	DOC and K increasing
	July 21, 2008	65	11.5	
	July 31, 2008	60	10.3	Ca, Mg, Na, TDN and NO_3^--N decreasing
	August 2, 2008	50	12.2	

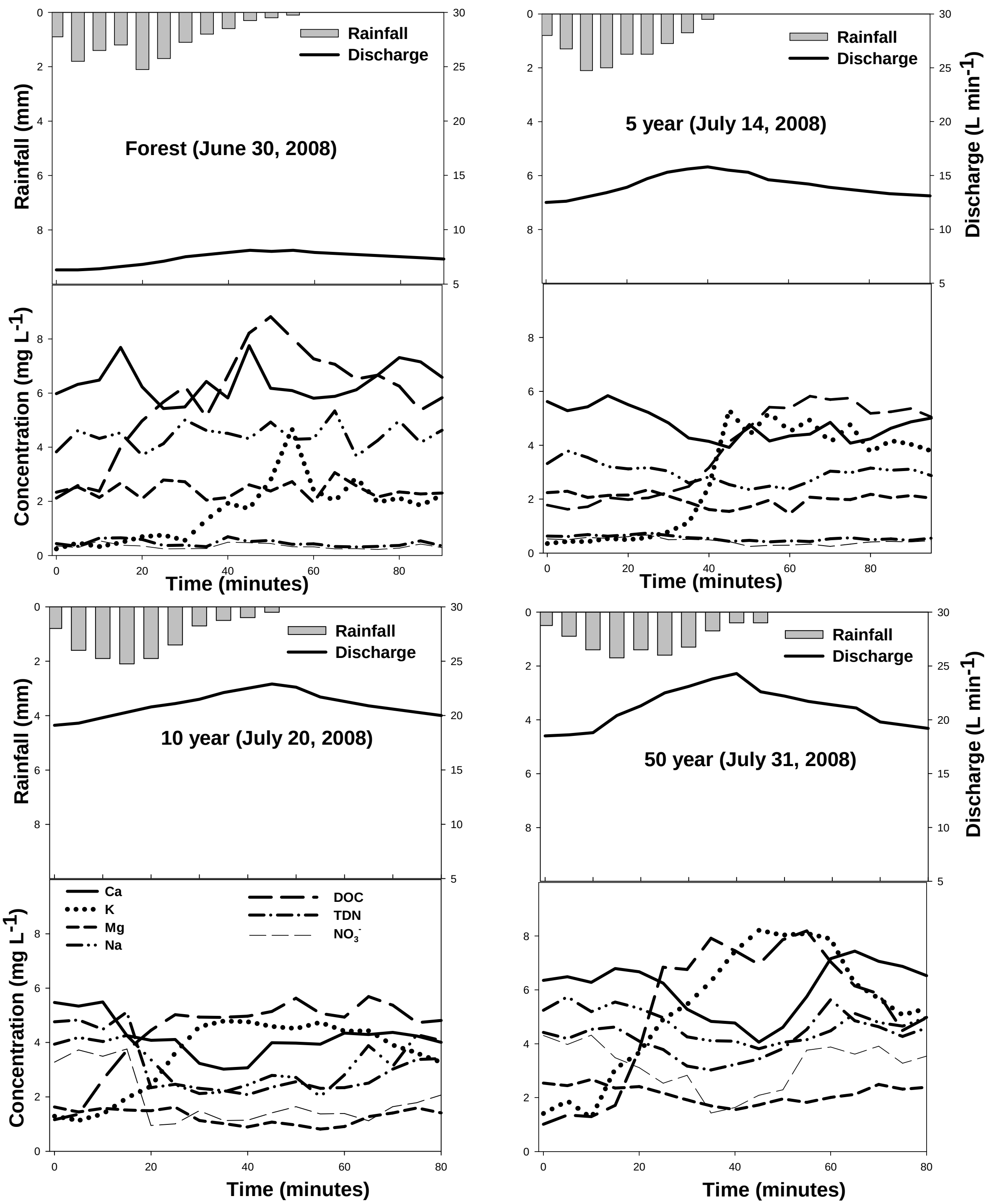

Figure 3.1 Rainfall, discharge and solute concentrations for watershed storms that occurred on various dates (other figures shown in Appendix C1-C4).

Hysteresis patterns may provide clues about the sources of nutrients during storm events. A clockwise hysteresis in the plot of concentration versus discharge occurs when solute concentrations are higher on the rising limb of the storm hydrograph and suggests that solute concentrations in surface event water exceeded those in soil water concentrations (Houser *et al*., 2006). A counterclockwise hysteresis occurs when solute concentrations are higher on the falling limb of the storm hydrograph, and suggests that solute concentrations in soil water exceeded those in surface event water. Intermediate shapes occur when neither limb of the hydrograph exhibits consistently higher solute concentrations. These inferences are generalities but remain informative. For the storm event in the 50-year conversion on July 31, 2008 the shape and rotation of the K hysteresis is similar to the one of DOC (Fig. 3.2). They rotate in counterclockwise direction and present a single loop. Both show an increase in concentration with discharge and a similar flushing behavior towards the end of the storm event. In contrast, the hysteresis patterns for Ca, Mg, Na and TDN were clockwise with both Ca and TDN having loops. The trend in the latter patterns indicates similar decreases in concentration with discharge and a diluting behavior. For this event, there were highly significant correlations between DOC and K (r^2=0.87; P<0.0001; n=17), Na and K (r^2=0.71; P<0.0001; n=17), Mg and K (r^2=0.67; P<0.0001; n=17), Mg and Ca (r^2=0.50; P=0.0006; n=17) and Na and Ca (r^2=0.55; P=0.0006; n=17), but there were no correlations between the other solute concentrations (Fig. 3.3).

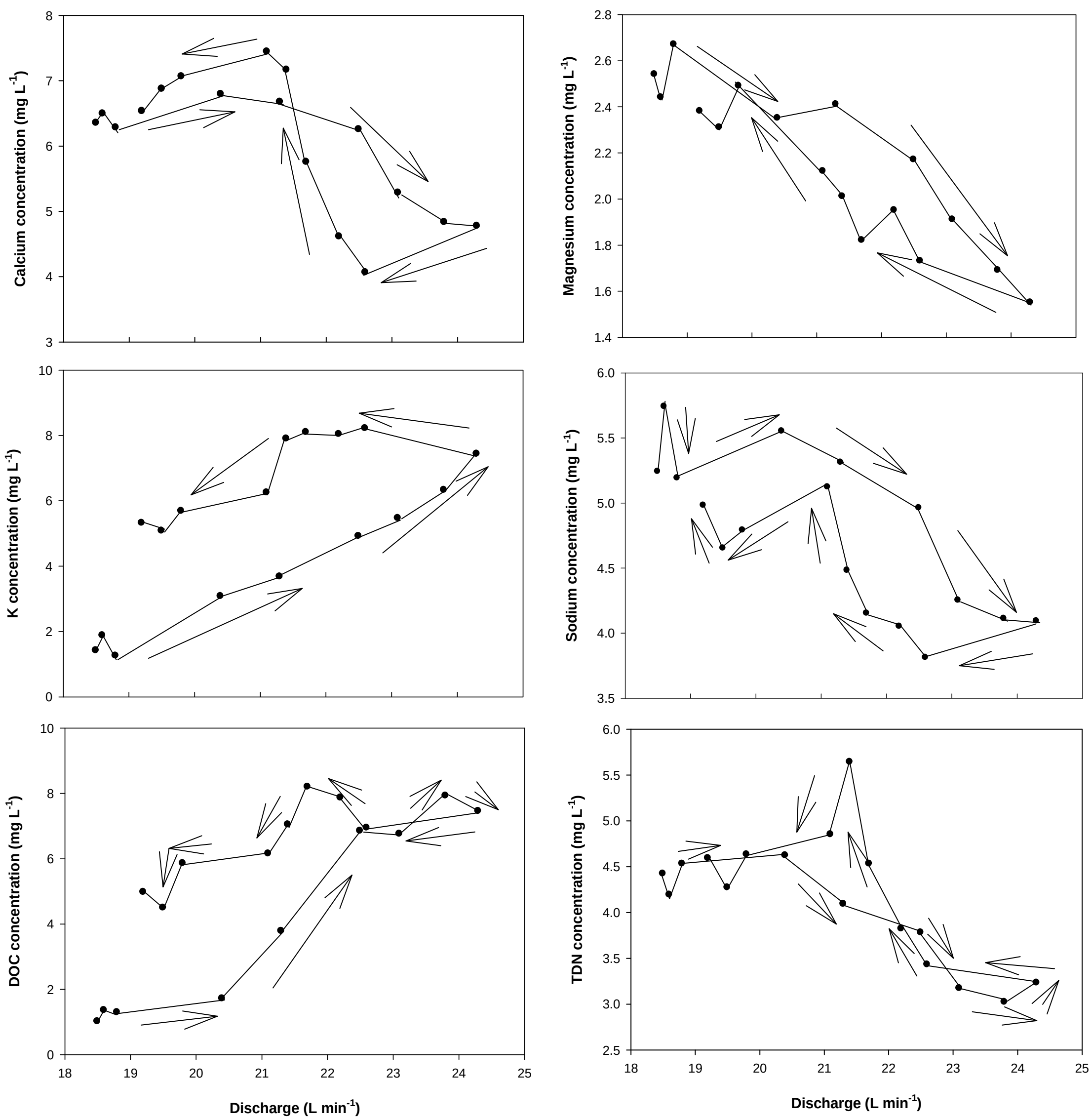

Figure 3.2: Hysteresis of Ca, Mg, K, Na, DOC and TDN in the 50 year conversion watershed for the 45 minute storm that occurred on July 31, 2008.

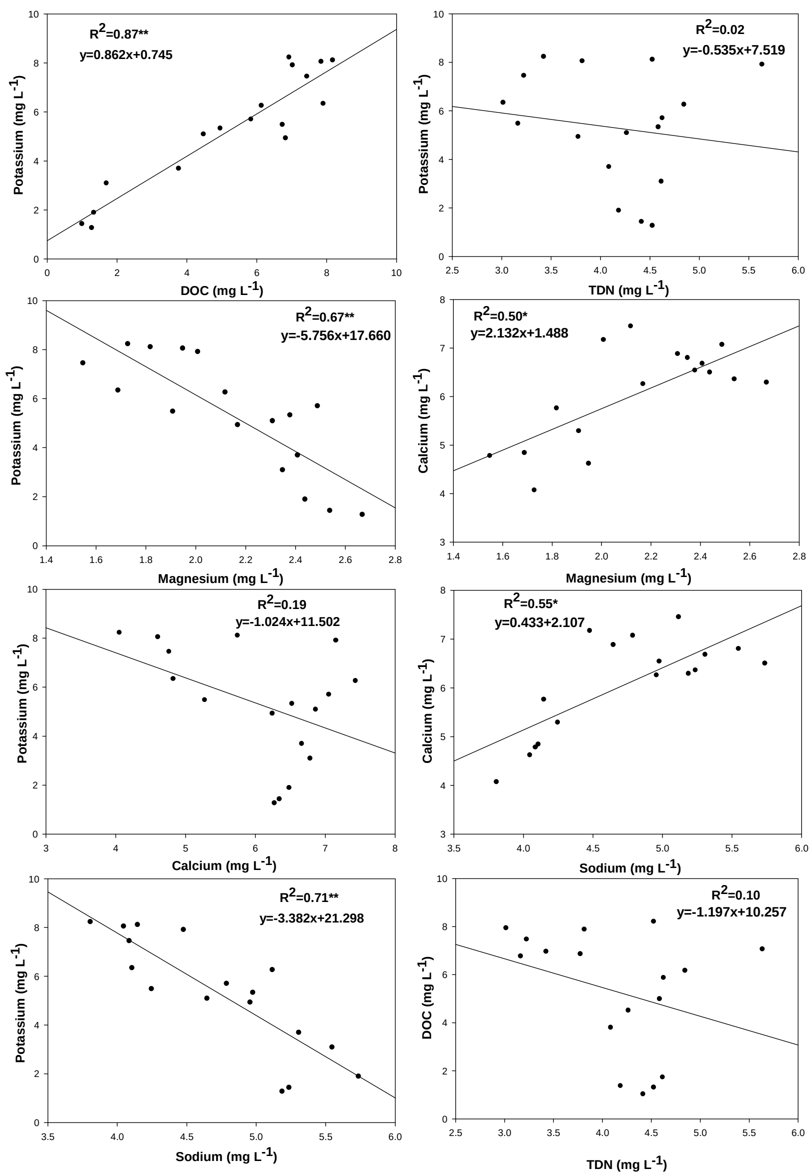

Figure 3.3: Correlations between solutes of the 50 year conversion watershed for the 45 minute storm that occurred on July 31, 2008. ** indicate significant correlations at P<0.0001 (n=17); * indicate significant correlations at P=0.0006 (n=17).

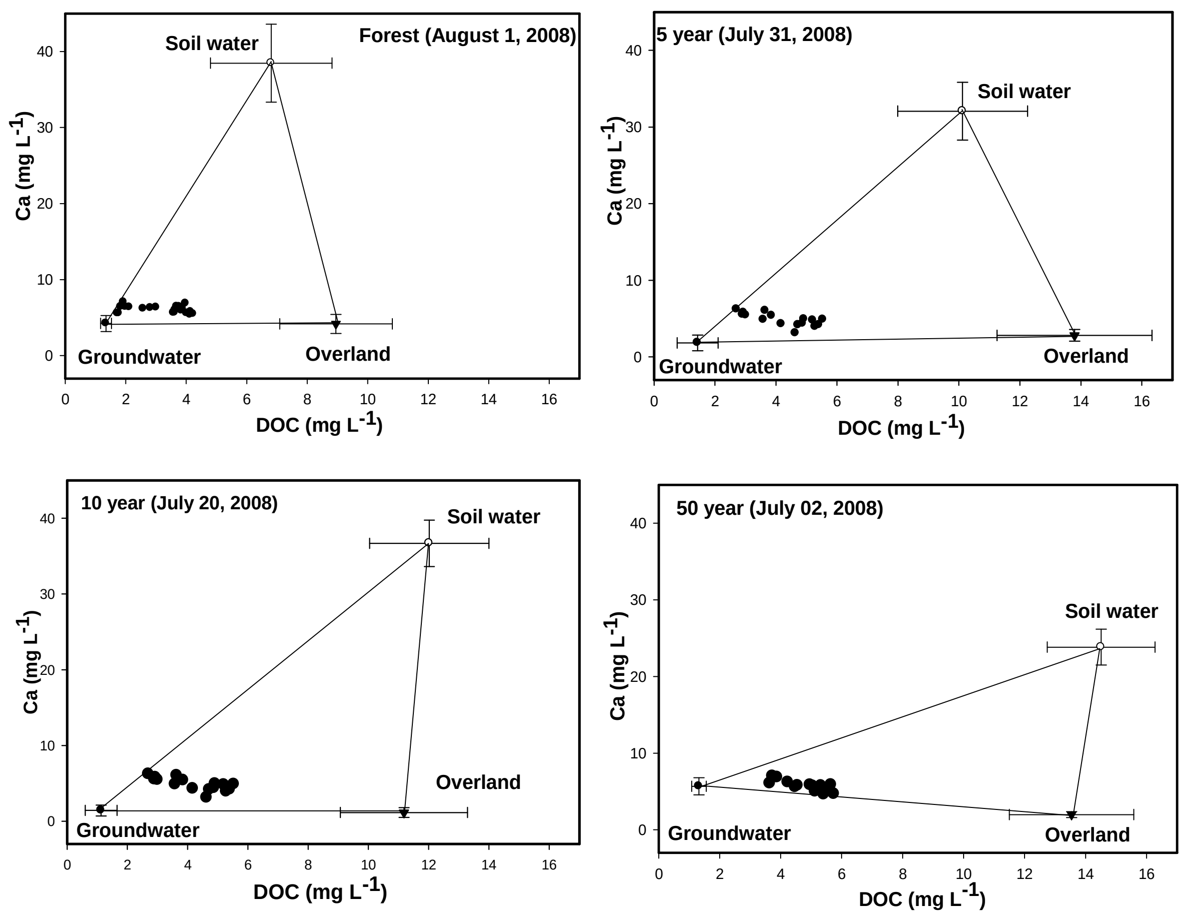

Figure 3.4: Mixing diagram showing DOC and Ca concentrations for stream water and end members in various rainstorms; contributions shown in Figure 3.5 and Table 3.2 (other diagrams shown in Appendix C5-C8).

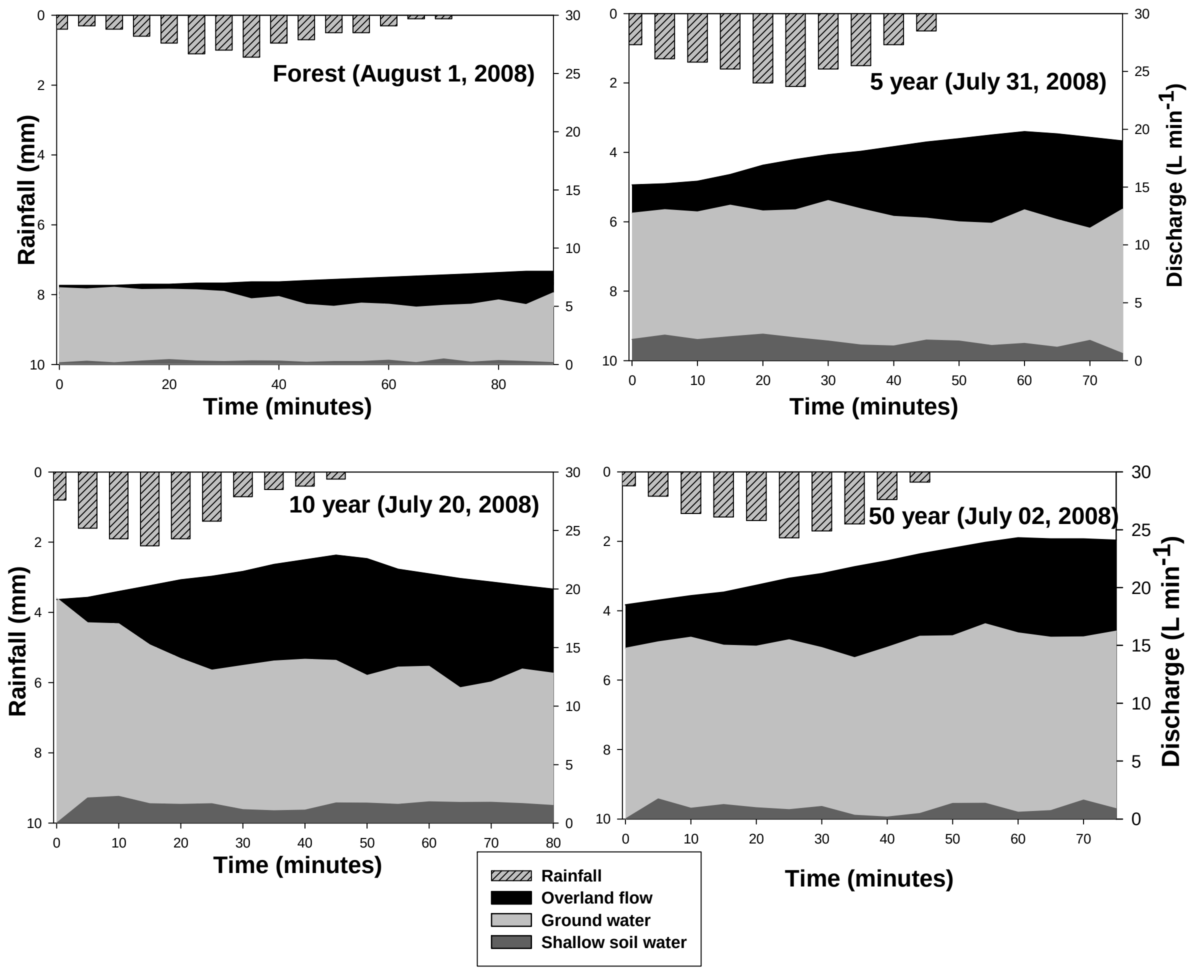

Figure 3.5: Estimated event water contributions for the rainstorms using EMMA; total contributions for all storms shown in Table 3.3 (other storms shown in Appendix C9-C12).

For the EMMA model, DOC and Ca were chosen because of their consistent response to events in the streams. They gave the widest mixing triangle defined by the end members as shown in Fig. 3.4 that allowed computation of the estimated discharge components that are graphically represented in Fig. 3.5. The stream water samples were generally adjacent to the ground water end member in the mixing triangle, with a slight drift towards to overland flow in the longest conversion watershed. The DOC values for overland and soil water components were consistently higher than groundwater (Table 3.2). The contribution of overland flow to stream discharge increased by 25% after forest conversion. In comparison, cultivation for 50 years led to a 73% increase in the contribution of overland flow to stream flow during storm events.

Table 3.2: The percent contribution to the stream flow

	Forest	**5 yr**	**10 yr**	**50 yr**
Groundwater	80.64a	74.10ab	71.55b	71.23b
Soil water	4.91b	7.93a	7.91a	3.68b
Overland flow	14.44b	17.99b	20.53ab	25.04a

Means within a row followed by the same letters are not significantly different from each other at $P < 0.05$ (n=4 for forest, and n=5 for agricultural watersheds).

Table 3.3: Average solute concentrations (mg L^{-1}) in the overland flow, soil water, and ground water from mid-June up to mid-August 2008

	Overland flow	Soil water	Ground water
		DOC	
Forest	8.95aC	7.47bC	1.58cC
5 year	13.28aB	9.67bB	1.66cB
10 year	14.46aA	12.42bA	1.43cC
50 year	15.02aA	13.45bA	1.82cA
		Potassium	
Forest	4.06aC	4.08aAB	0.38bD
5 year	5.41aB	4.62bA	0.51cC
10 year	5.04aB	3.96bAB	0.65cB
50 year	7.65aA	3.42bB	1.25cA
		Calcium	
Forest	4.54bA	38.72aA	4.93bB
5 year	2.73bB	36.21aA	2.19bC
10 year	1.52bC	35.69aA	1.71bD
50 year	2.41cB	24.23aB	5.38bA
		Magnesium	
Forest	0.86cA	9.05aA	2.08bA
5 year	0.95cA	6.92aB	1.48bC
10 year	0.67cB	8.98aA	1.71bB
50 year	0.83cA	7.83aAB	2.23bA
		Sodium	
Forest	1.40bA	0.46cC	3.62aD
5 year	1.37bA	0.71cB	4.01aC
10 year	1.08bB	0.59cBC	5.43aB
50 year	1.09bA	0.94cA	5.79aA
		Total dissolved nitrogen	
Forest	1.83bD	9.06aB	1.02cD
5 year	2.46bC	7.14aC	1.33cC
10 year	3.94cB	12.78aA	5.86bA
50 year	4.68cA	11.85aA	5.61bB

Means within a row (small letters) and a column (capital letters) followed by the same letters are not significantly different from each other at P<0.0001 (n=20 for soil water and groundwater, n=35 for all overland flow)

DISCUSSION

The response time of discharge to the rainstorms was very rapid. The peak discharge in the agricultural watersheds appeared about 40 minutes after commencement of the storm while the response was delayed by between 10 and 15 minutes in the forest watershed. The agricultural soils could have had higher levels of overland flow and shallow throughflow that might have contributed to higher runoff drainage during the storms. The hydrographs had long recession limbs which did not reach pre-event levels by 30 minutes after the end of precipitation. This long recession limb could be caused by slow movement of shallow subsurface or interflow. Giusti and Neal (1993) observed that it took 24 hours before runoff subsided in a subcatchment in Scotland.

DOC and K concentrations significantly increased with increasing discharge regardless of the watershed land use, which is typically reported from headwaters in both tropical and temperate climates (Wilson *et al*., 1991; Inamdar *et al*., 2004; Mitchell *et al*., 2006; Vidon *et al*., 2008 2009; Deyton *et al*., 2009; Germer *et al*., 2009; Raymond and Saiers, 2010). The DOC and K concentrations peaked with discharge in all studied watersheds. This dynamic suggests a quick transfer of DOC and K to the stream as soon as discharge increases due to precipitation. Precipitation characteristics and discharge are therefore the primary determinants of stream DOC and K concentrations during storm events despite differences in the forested and agricultural watersheds. The high solute concentrations are associated with high contributions of storm event water through overland flow. The higher DOC concentrations in overland flow could be explained by an accumulation of DOC in the upper soil which was flushed at the beginning of runoff (Blake *et al*., 2003; Hornberger *et al*., 1994) making the overland flow concentrations much higher than groundwater (Austnes *et al*., 2011). Royer and David (2005) observed that DOC appearing in small streams during storms is derived primarily from allochthonous terrestrial sources. K is also assumed to be abundant at the soil surface and hence in overland flow (Germer *et al*., 2009), and concentrations of K may be related to the length of the flow path (Luxmoore *et al*., 1990). That means, as the flow rate increases, longer path lengths of the transporting water contribute to greater K concentration (Wilson *et al*., 1991). Higher K levels are also associated with enhanced hydrological access (Caissie *et al*., 1996).

The lower DOC and K concentrations during the falling hydrograph indicate that the DOC and K storm response is hysteretic (Butturini *et al*., 2006). This may reflect temporary depletion of the terrestrial DOC and K due to soil water flushing or perhaps changes in timing of runoff contributions from the riparian zone and hill slope during the course of the precipitation event. The pattern of DOC and K concentrations also reflects the evolution of subsurface flow through the upper horizons of the soil. The rainfall possibly leads to increased groundwater levels in areas close to the stream channel that could initiate subsurface flow in soil horizons having lower DOC and K concentrations. At peak flow levels, the contribution of DOC- and K-rich soil horizons to stream flow reaches a maximum as water saturation progresses both vertically in the profile and spatially in areas surrounding the channel. During the recession phase of the hydrograph, saturation decreases and the contribution of DOC-rich horizons diminishes. Accordingly, the DOC and K concentrations in the stream decreased before the discharge decreases.

In contrast to DOC and K, internal weathering appears to be the primary source of Ca, Mg and Na in stream water. During base flow in the Kapchorwa catchments, concentrations of Ca, Mg and Na which are produced through weathering are dominated by deep soil water irrespective of land use. With increasing discharge, both deep and shallow soil water reservoirs contribute to stream concentrations with little contribution from overland flow compared to observations for DOC and K. This is different from results reported by other studies on forests who showed increasing concentrations also of Ca, Mg and Na (Wilson *et al.*, 1991) or NO_3^--N (Houser *et al.*, 2006; Turgeon and Courchesne, 2008) during storm events. In the forest watershed, the constant level of the concentrations of Ca, Mg, Na, TDN and NO_3^--N may partially be attributed to the interception of the precipitation and to relatively higher infiltration and retention by the higher organic matter in the soil (Bruijnzeel, 2004). Also Lal (1983) observed virtually no Hortonian overland flow and soil erosion due to thick undergrowth and leaf litter layer, in a humid tropical forest in western Nigeria. The small proportion of shallow soil water (5% of stream water) may not have been large enough to dilute the solute concentrations in the base flow-dominated stream water within the forest watershed.

In contrast, the Ca, Mg, Na, TDN and NO_3^--N rich base flow in the agricultural watersheds was diluted by the storm surface runoff that contains lower concentrations of these solutes, largely confirming reports on agricultural watersheds (Webb and Walling, 1985; Giusti and Neal, 1993; Hill, 1993; Salmon *et al.*, 2001; Inamdar *et al.*, 2004; Lehrter, 2006; Wiegner *et al.*, 2009). The storms were collected during the height of the main rainy season in the months of June to August 2008. Any soil moisture deficits generated during the November-March dry season have been replenished during the preceding three months of rainfall; and saturated areas along the river channel, at the base of hill slopes and in the heads of the stream valleys may have been expanded. We hypothesize that these conditions favor the production of dilute quick flow from the expanded saturated source areas during the storms, leading to marked dilution of TDN and NO_3^--N. Antecedent wetness are known to affect the hydrological routing and transport of N in the near-stream zone of saturation (Cirmo and McDonnell, 1997).

CONCLUSIONS

Dilution during storm events is the most dominant mechanism in the agricultural waters for Ca, Mg and Na generated internally through weathering in the deeper soil layers. In these agricultural watersheds, the lower Ca, Mg and Na concentrations of shallow soil water dilute the solute contribution from the ground water and lead to a decreasing stream water concentration during storm events. In stark contrast, the abundance of DOC and K near the soil surface lead to greater stream concentrations for DOC and K with increased stream discharge during the storm events owing to overland flow. The changes in concentrations of different solutes in the Kapchorwa watersheds during storm events are to a greater extent controlled by flow paths and differences in nutrient and C reservoirs between top and subsoil than by land use studied here. Therefore, addressing nutrient and DOC losses during storm flow do not require differential management recommendations for forested and cultivated fields of different ages similar to the ones examined in this work.

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CHAPTER 4

SUMMARY AND CONCLUSIONS

Forest conversion to agriculture as well as its subsequent long-term cultivation affected the physical soil properties. Impacts of cultivation on soils included a decrease in SOC, total porosity, field capacity and increased bulk density, whereas moisture retention at field capacity did not change in the short term due to loss of forest cover. The increase of surface runoff of the cultivated watersheds corresponded to the years of conversion. Therefore preservation of forest cover is only one avenue for decreasing storm water runoff and discharge from headwaters. The second avenue is the maintenance of infiltration and water retention in soil. Further research on what extent subsurface changes contributed to the observed runoff responses needs to be undertaken. Further experimentation is required to evaluate whether discharge and runoff can be reduced by SOC build-up, reduced compaction or less sealing of surfaces. Thirdly, there is a need to evaluate on watershed scale, soil management that maintains water retention and decreases runoff and discharge.

The hydrochemistry of headwater streams was affected by forest conversion to continuous maize cultivation. This led to increased C species and nutrient concentrations except for Ca and Mg that could have had geochemical weathering. Mineralization of SOC was higher compared to fluvial C exports. The P losses were negligible, while fluvial N losses need to be addressed to improve crop productivity. The farming activities in the headwaters play a minor role in the pollution of the Lake Victoria basin. Dilution during storm events is the most dominant mechanism in the agricultural waters for Ca, Mg and Na generated internally through weathering in the deeper soil layers. During storm events, the lower Ca, Mg and Na concentrations of shallow soil water dilute the solute contribution from the ground water and lead to a decreasing stream water concentration. However, the abundance of DOC and K near the soil surface lead to greater stream concentrations for DOC and K with increased stream discharge during the storm events owing to overland flow. The changes in solute concentrations during storm events are to a greater extent controlled by flow paths and differences in nutrient and C reservoirs between top and subsoil than by land use. Mitigation of nutrient and DOC losses during storm flow need similar management practices.

APPENDIX A

Raw data pertaining to Chapter 1

Table A1: Data table for Chapter 1, Table 1.1

	0.1 bar	0.33 bar	1bar	3bar	15bar
forest	45.925	36.194	34.56	33.72	31.464
forest	45.37	35.232	32.478	31.53	29.157
forest	44.865	33.449	32.986	31.1	31.189
forest	44.175	34.065	33.757	30.38	29.523
forest	45.1	34.575	33.4	32.71	30.002
5yr	44.03	35.88	35.51	30.87	29.172
5yr	42.97	33.258	32.02	28.43	26.251
5yr	43.41	33.879	31.91	29.18	28.674
5yr	43.94	32.761	32.73	30.21	27.296
5yr	44.18	34.492	32.6	29.12	27.483
10yr	39.97	26.537	21.98	20.773	16.319
10yr	40.54	23.147	24.597	18.98	18.742
10yr	37.85	25.94	24.114	19.739	16.253
10yr	36.96	24.056	22.689	20.328	17.765
10yr	39.55	24.7	23.29	20.55	16.802
50yr	32.774	23.31	19.93	17.549	16.39
50yr	30.226	21.88	22.545	19.274	14.873
50yr	31.138	23.26	21.76	18.036	15.521
50yr	33.052	22.84	23.42	19.865	15.062
50yr	31.385	23.54	21.782	18.801	15.87
	Soil Organic Matter ($mg\ g^{-1}$)	**Soil Organic Carbon ($mg\ g^{-1}$)**	**Bulk density ($g\ cm^{-3}$)**	**Porosity**	
forest	149.46	95.3	0.791	0.702	
forest	147.51	105.2	0.818	0.691	
forest	217.7	124.5	0.785	0.704	
forest	179.1	116.7	0.851	0.679	

forest	160.3	99.8	0.755	0.715
5yr	138.12	71.5	0.905	0.658
5yr	123.2	59.8	0.909	0.657
5yr	140.02	75.0	0.967	0.635
5yr	139.7	70.1	0.953	0.64
5yr	142.6	67.6	0.84	0.683
10yr	81.63	33.9	1.18	0.555
10yr	87.44	40.3	0.921	0.652
10yr	86.81	34.9	0.983	0.629
10yr	84.5	39.7	1.14	0.57
10yr	86.2	33.2	0.95	0.642
50yr	62.09	24.9	1.19	0.551
50yr	76.7	26.9	0.98	0.63
50yr	71.23	30.6	1.22	0.54
50yr	68.5	28.6	1.21	0.543
50yr	71.5	26.5	1.25	0.528

Table A2: Data table for Chapter 1, Figure 1.2

	Forest ($mg\ g^{-1}$)	5 year ($mg\ g^{-1}$)	10 year ($mg\ g^{-1}$)	50 year ($mg\ g^{-1}$)
Random 0-10	80.30	53.81	41.91	40.36
Random 10-30	63.92	45.64	34.98	38.27
Random 30-90	14.23	17.71	19.20	27.77
Random 90-150	11.18	8.19	12.33	9.65
Random 150-240	5.93	5.33	6.74	3.02
25m 0-10	99.64	79.12	47.18	36.30
25m 10-30	46.87	47.35	17.60	34.38
25m 30-90	26.62	19.25	37.81	26.88
25m 90-150	9.13	7.87	13.27	12.86
25m 150-240	10.07	4.59	7.89	6.25
100m 0-10	133.11	93.22	34.76	31.10
100m 10-30	59.99	47.29	30.89	28.51
100m 30-90	29.36	19.25	16.28	15.32
100m 90-150	8.32	10.23	9.60	8.86
100m 150-240	5.16	4.50	4.73	5.81
175m 0-10	104.63	75.35	37.09	24.92
175m 10-30	54.45	36.95	22.34	24.09
175m 30-90	31.07	16.96	13.61	13.18
175m 90-150	11.80	10.43	10.70	10.06
175m 150-240	4.60	5.18	4.99	3.82

Table A3: Data table for Chapter 1, Figure 1.3

Date	Forest rainfall (mm)	Forest Discharge (mm day^{-1})	Date	5 year rainfall (mm)	5year discharge (mm day^{-1})
1/1/2007	0	0.61	1/1/2007	0	0.72
1/2/2007	8.9	0.61	1/2/2007	3.5	0.72
1/3/2007	1.9	0.61	1/3/2007	4.7	0.72
1/4/2007	3.1	0.61	1/4/2007	2.4	0.72
1/5/2007	3.6	0.61	1/5/2007	3.3	0.72
1/6/2007	1.1	0.61	1/6/2007	2	0.72
1/7/2007	0	0.61	1/7/2007	0	0.72
1/8/2007	0	0.61	1/8/2007	0	0.72
1/9/2007	0	0.61	1/9/2007	0	0.72
1/10/2007	1.6	0.61	1/10/2007	1.3	0.72
1/11/2007	6.6	0.61	1/11/2007	6	0.72
1/12/2007	4.3	0.61	1/12/2007	3.7	0.72
1/13/2007	5.4	0.61	1/13/2007	6.7	0.72
1/14/2007	3.3	0.61	1/14/2007	2.9	0.72
1/15/2007	5.6	0.61	1/15/2007	6.4	0.72
1/16/2007	6.9	0.61	1/16/2007	7.2	0.72
1/17/2007	0	0.61	1/17/2007	0	0.71
1/18/2007	0	0.61	1/18/2007	0	0.71
1/19/2007	0	0.61	1/19/2007	0	0.71
1/20/2007	0	0.60	1/20/2007	0	0.71
1/21/2007	0	0.60	1/21/2007	0	0.71
1/22/2007	0	0.60	1/22/2007	0	0.71
1/23/2007	0	0.60	1/23/2007	0	0.71
1/24/2007	0	0.60	1/24/2007	0	0.71
1/25/2007	0	0.60	1/25/2007	0	0.71
1/26/2007	0	0.60	1/26/2007	0	0.71
1/27/2007	0	0.60	1/27/2007	0	0.71
1/28/2007	5.2	0.60	1/28/2007	11.2	1.5
1/29/2007	18.1	0.60	1/29/2007	20	1.5
1/30/2007	8.3	0.60	1/30/2007	7.9	1
1/31/2007	1.8	0.60	1/31/2007	1.8	0.94
2/1/2007	6.6	0.60	2/1/2007	7.3	1
2/2/2007	3.2	0.60	2/2/2007	2.4	0.91
2/3/2007	9.1	0.61	2/3/2007	10.8	1.5
2/4/2007	2.1	0.61	2/4/2007	3.2	0.75
2/5/2007	9.6	0.61	2/5/2007	12.3	1.5

2/6/2007	2.4	0.61	2/6/2007	1.6	0.75
2/7/2007	0	0.61	2/7/2007	0	0.75
2/8/2007	0	0.61	2/8/2007	0	0.75
2/9/2007	4.6	0.61	2/9/2007	5.5	0.8
2/10/2007	0	0.61	2/10/2007	0	0.75
2/11/2007	10	0.61	2/11/2007	9.8	1.3
2/12/2007	0	0.61	2/12/2007	0	0.9
2/13/2007	24.3	0.61	2/13/2007	24.4	2.1
2/14/2007	0	0.61	2/14/2007	0	0.89
2/15/2007	0	0.61	2/15/2007	0	0.88
2/16/2007	0	0.61	2/16/2007	0	0.87
2/17/2007	0	0.61	2/17/2007	0	0.86
2/18/2007	0	0.61	2/18/2007	0	0.85
2/19/2007	0	0.61	2/19/2007	0	0.84
2/20/2007	0	0.61	2/20/2007	0	0.83
2/21/2007	0	0.61	2/21/2007	0	0.82
2/22/2007	0	0.61	2/22/2007	0	0.81
2/23/2007	0	0.61	2/23/2007	0	0.8
2/24/2007	1.6	0.61	2/24/2007	1.3	0.85
2/25/2007	14.6	0.61	2/25/2007	17.1	1.9
2/26/2007	3.1	0.61	2/26/2007	1.3	0.9
2/27/2007	13.7	0.61	2/27/2007	16.5	2
2/28/2007	14	0.61	2/28/2007	16.1	2
3/1/2007	0	0.61	3/1/2007	0	1
3/2/2007	0	0.61	3/2/2007	0	0.99
3/3/2007	0	0.61	3/3/2007	0	0.95
3/4/2007	0	0.61	3/4/2007	0	0.93
3/5/2007	0	0.61	3/5/2007	0	0.91
3/6/2007	0	0.61	3/6/2007	0	0.89
3/7/2007	0	0.61	3/7/2007	0	0.87
3/8/2007	0	0.61	3/8/2007	0	0.85
3/9/2007	0	0.61	3/9/2007	0	0.83
3/10/2007	0	0.61	3/10/2007	0	0.81
3/11/2007	9.5	0.62	3/11/2007	10.6	1.9
3/12/2007	4.3	0.62	3/12/2007	4.9	1.5
3/13/2007	5.2	0.62	3/13/2007	4.5	1.5
3/14/2007	4.6	0.62	3/14/2007	5.8	1.6
3/15/2007	8.4	0.62	3/15/2007	10.1	1.7
3/16/2007	3.4	0.62	3/16/2007	3.4	1.4
3/17/2007	9.7	0.63	3/17/2007	7.2	1.3
3/18/2007	17.7	0.63	3/18/2007	23.5	2.5

3/19/2007	29.3	0.64	3/19/2007	36.1	3
3/20/2007	15.1	0.63	3/20/2007	13.9	2
3/21/2007	0	0.62	3/21/2007	0	1.6
3/22/2007	0	0.62	3/22/2007	0	1.4
3/23/2007	0	0.62	3/23/2007	0	1.2
3/24/2007	0	0.62	3/24/2007	0	1.1
3/25/2007	0	0.62	3/25/2007	0	0.99
3/26/2007	0	0.62	3/26/2007	0	0.98
3/27/2007	0	0.62	3/27/2007	0	0.97
3/28/2007	0	0.62	3/28/2007	0	0.96
3/29/2007	0	0.62	3/29/2007	0	0.95
3/30/2007	0	0.62	3/30/2007	0	0.94
3/31/2007	0	0.62	3/31/2007	0	0.93
4/1/2007	0	0.62	4/1/2007	0	0.92
4/2/2007	0	0.62	4/2/2007	0	0.91
4/3/2007	0	0.62	4/3/2007	0	0.9
4/4/2007	0	0.62	4/4/2007	0	0.89
4/5/2007	0	0.62	4/5/2007	0	0.88
4/6/2007	0	0.62	4/6/2007	0	0.87
4/7/2007	0	0.62	4/7/2007	0	0.87
4/8/2007	0	0.62	4/8/2007	0	0.87
4/9/2007	2.2	0.62	4/9/2007	2.6	0.9
4/10/2007	14.8	0.63	4/10/2007	16.5	2
4/11/2007	24.7	0.65	4/11/2007	39.2	4
4/12/2007	12.5	0.68	4/12/2007	14	2.7
4/13/2007	9.5	0.72	4/13/2007	20	2.8
4/14/2007	19.2	0.74	4/14/2007	30.1	3.8
4/15/2007	5.7	0.78	4/15/2007	6.2	2.6
4/16/2007	37.7	0.78	4/16/2007	32.6	4
4/17/2007	15.4	0.80	4/17/2007	35.4	4.1
4/18/2007	36.5	0.80	4/18/2007	27	3.2
4/19/2007	17.3	0.80	4/19/2007	17.5	2.9
4/20/2007	32.9	0.80	4/20/2007	24.1	3.5
4/21/2007	14.8	0.82	4/21/2007	19.5	2.4
4/22/2007	12.3	0.83	4/22/2007	19.9	2.5
4/23/2007	9.3	0.84	4/23/2007	8.6	2.1
4/24/2007	12.1	0.85	4/24/2007	14.1	2.2
4/25/2007	11.6	0.86	4/25/2007	14.9	2.3
4/26/2007	12	0.86	4/26/2007	14.3	2.4
4/27/2007	11.7	0.86	4/27/2007	12.3	2.3
4/28/2007	13.4	0.87	4/28/2007	14.4	2.5

4/29/2007	14.5	0.87	4/29/2007	12.3	2.4
4/30/2007	7.6	0.87	4/30/2007	11.9	2.3
5/1/2007	10.4	0.88	5/1/2007	7.8	2.2
5/2/2007	11.8	0.88	5/2/2007	11.7	2.3
5/3/2007	15.4	0.88	5/3/2007	13.9	2.4
5/4/2007	19.7	0.88	5/4/2007	17.2	2.5
5/5/2007	10.7	0.88	5/5/2007	7.8	2.3
5/6/2007	19	0.88	5/6/2007	13.1	2.6
5/7/2007	19.5	0.89	5/7/2007	15.9	2.8
5/8/2007	24.3	0.89	5/8/2007	14.2	2.9
5/9/2007	12.4	0.89	5/9/2007	12.9	2.4
5/10/2007	5.7	0.89	5/10/2007	5.6	1.7
5/11/2007	6.5	0.90	5/11/2007	6.8	1.7
5/12/2007	4.4	0.90	5/12/2007	5	1.7
5/13/2007	7.6	0.90	5/13/2007	12.7	2.3
5/14/2007	17.7	0.90	5/14/2007	27.9	4
5/15/2007	10.8	0.91	5/15/2007	4.3	3
5/16/2007	6.9	0.91	5/16/2007	8.8	3.2
5/17/2007	25.9	0.91	5/17/2007	22.3	4
5/18/2007	8	0.91	5/18/2007	16.8	3.5
5/19/2007	0	0.91	5/19/2007	1.8	2.6
5/20/2007	1.9	0.92	5/20/2007	2.7	2
5/21/2007	0	0.92	5/21/2007	0	1.9
5/22/2007	0	0.92	5/22/2007	0	1.8
5/23/2007	0	0.94	5/23/2007	0	1.7
5/24/2007	0	0.94	5/24/2007	0	1.6
5/25/2007	9.8	0.96	5/25/2007	4.9	1.8
5/26/2007	19.5	0.98	5/26/2007	7.1	1.7
5/27/2007	25.6	0.99	5/27/2007	8.2	1.6
5/28/2007	33.3	1.00	5/28/2007	8.6	1.5
5/29/2007	4.5	1.00	5/29/2007	4.8	1.4
5/30/2007	3.9	1.02	5/30/2007	1.5	1.4
5/31/2007	28.3	1.05	5/31/2007	30.6	3.1
6/1/2007	14.7	1.07	6/1/2007	7.2	1.5
6/2/2007	4.8	1.08	6/2/2007	5.5	1.4
6/3/2007	9.8	1.08	6/3/2007	9.1	1.8
6/4/2007	8.5	1.10	6/4/2007	8	1.7
6/5/2007	6.2	1.10	6/5/2007	7.6	1.5
6/6/2007	4.8	1.11	6/6/2007	2	1.2
6/7/2007	3.4	1.12	6/7/2007	6.7	1.3
6/8/2007	1.9	1.12	6/8/2007	2.3	1.3

6/9/2007	9.7	1.13	6/9/2007	18	2.2
6/10/2007	11.8	1.14	6/10/2007	16.9	2.2
6/11/2007	8.8	1.15	6/11/2007	1.8	1.9
6/12/2007	0	1.15	6/12/2007	0	1.6
6/13/2007	8.6	1.16	6/13/2007	7	2
6/14/2007	0	1.16	6/14/2007	0	1.5
6/15/2007	0	1.17	6/15/2007	0	1.4
6/16/2007	4.7	1.17	6/16/2007	5	1.7
6/17/2007	0	1.17	6/17/2007	0	1.3
6/18/2007	0	1.17	6/18/2007	0	1.2
6/19/2007	0	1.17	6/19/2007	0	1.2
6/20/2007	0	1.17	6/20/2007	0	1.2
6/21/2007	0	1.17	6/21/2007	0	1.2
6/22/2007	0	1.17	6/22/2007	0	1.2
6/23/2007	0	1.17	6/23/2007	0	1.2
6/24/2007	0	1.17	6/24/2007	0	1.2
6/25/2007	3.9	1.17	6/25/2007	6.3	1.7
6/26/2007	6.5	1.16	6/26/2007	2	1.3
6/27/2007	9.3	1.16	6/27/2007	11.1	1.9
6/28/2007	10.6	1.15	6/28/2007	10.2	2
6/29/2007	3.8	1.15	6/29/2007	4.5	1.8
6/30/2007	1.3	1.14	6/30/2007	3	1.7
7/1/2007	1.1	1.14	7/1/2007	4	1.7
7/2/2007	11.2	1.14	7/2/2007	14.1	1.9
7/3/2007	1.7	1.13	7/3/2007	1.9	1.2
7/4/2007	19.1	1.13	7/4/2007	19.8	1.3
7/5/2007	0	1.13	7/5/2007	0	1.25
7/6/2007	0	1.13	7/6/2007	0	1.2
7/7/2007	0	1.13	7/7/2007	0	1.15
7/8/2007	0	1.13	7/8/2007	0	1.13
7/9/2007	0	1.13	7/9/2007	0	1.12
7/10/2007	0	1.12	7/10/2007	0	1.11
7/11/2007	0	1.12	7/11/2007	0	1.1
7/12/2007	0	1.11	7/12/2007	0	1.1
7/13/2007	0	1.11	7/13/2007	0	1.1
7/14/2007	0	1.11	7/14/2007	0	1.1
7/15/2007	0	1.10	7/15/2007	0	1.1
7/16/2007	0	1.10	7/16/2007	0	1.1
7/17/2007	0	1.10	7/17/2007	0	1.1
7/18/2007	0	1.10	7/18/2007	0	1.1
7/19/2007	17.8	1.10	7/19/2007	18	2.5

7/20/2007	0	1.10	7/20/2007	0	1.4
7/21/2007	6.2	1.10	7/21/2007	5.5	1.7
7/22/2007	4.5	1.11	7/22/2007	5.1	1.6
7/23/2007	10.6	1.11	7/23/2007	10.1	1.9
7/24/2007	38	1.11	7/24/2007	39.7	3.9
7/25/2007	18.7	1.12	7/25/2007	19.3	2
7/26/2007	0	1.12	7/26/2007	0	1.3
7/27/2007	15.8	1.12	7/27/2007	12.1	1.8
7/28/2007	16.6	1.13	7/28/2007	16.4	1.9
7/29/2007	10.7	1.13	7/29/2007	10.3	1.7
7/30/2007	9.6	1.13	7/30/2007	2.3	1.3
7/31/2007	1.4	1.13	7/31/2007	2.2	1.2
8/1/2007	12.3	1.13	8/1/2007	13.6	1.7
8/2/2007	23.9	1.13	8/2/2007	22.9	2.6
8/3/2007	11.9	1.13	8/3/2007	12.5	1.8
8/4/2007	34.2	1.13	8/4/2007	38	3.6
8/5/2007	0	1.13	8/5/2007	3	2.1
8/6/2007	0	1.14	8/6/2007	0	1.6
8/7/2007	36.2	1.14	8/7/2007	39	3.8
8/8/2007	33.2	1.15	8/8/2007	29.2	3
8/9/2007	0	1.15	8/9/2007	0	1.7
8/10/2007	11.7	1.16	8/10/2007	20.5	2
8/11/2007	12.3	1.16	8/11/2007	12.5	1.8
8/12/2007	9.1	1.17	8/12/2007	9.4	1.6
8/13/2007	22.2	1.17	8/13/2007	22	2.2
8/14/2007	10.4	1.18	8/14/2007	12.4	1.4
8/15/2007	4.8	1.18	8/15/2007	4.5	1.2
8/16/2007	7.6	1.19	8/16/2007	8	1.3
8/17/2007	11.5	1.19	8/17/2007	12.4	1.4
8/18/2007	4.7	1.20	8/18/2007	5.8	1.2
8/19/2007	9.9	1.20	8/19/2007	10.8	1.3
8/20/2007	5.3	1.21	8/20/2007	6.1	1.2
8/21/2007	9	1.21	8/21/2007	11.9	1.5
8/22/2007	7.2	1.22	8/22/2007	3.3	1.2
8/23/2007	5.5	1.22	8/23/2007	9.1	1.5
8/24/2007	1.9	1.22	8/24/2007	3.8	1.3
8/25/2007	4.6	1.22	8/25/2007	5.8	1.5
8/26/2007	7.8	1.22	8/26/2007	3.5	1.4
8/27/2007	5.1	1.23	8/27/2007	5.7	1.5
8/28/2007	2	1.23	8/28/2007	3.7	1.3
8/29/2007	1.8	1.23	8/29/2007	3.8	1.4

8/30/2007	4.9	1.23	8/30/2007	4.9	1.5
8/31/2007	3.8	1.24	8/31/2007	4.3	1.5
9/1/2007	4.6	1.24	9/1/2007	7.4	1.6
9/2/2007	2.7	1.25	9/2/2007	4.9	1.5
9/3/2007	11.3	1.26	9/3/2007	9.8	1.7
9/4/2007	12	1.28	9/4/2007	12.2	1.9
9/5/2007	28	1.32	9/5/2007	29.9	3.9
9/6/2007	7.2	1.38	9/6/2007	9.8	2.4
9/7/2007	4.3	1.38	9/7/2007	3.4	2
9/8/2007	8.9	1.42	9/8/2007	8.8	2.2
9/9/2007	10.7	1.42	9/9/2007	13.2	2.9
9/10/2007	9.7	1.47	9/10/2007	12.4	2.8
9/11/2007	7.8	1.47	9/11/2007	11.2	2.2
9/12/2007	5.1	1.48	9/12/2007	9.3	2
9/13/2007	37.2	1.48	9/13/2007	29	3
9/14/2007	12.9	1.49	9/14/2007	15.5	2.9
9/15/2007	14.3	1.49	9/15/2007	14.1	2.6
9/16/2007	0	1.50	9/16/2007	16.5	2.9
9/17/2007	0	1.50	9/17/2007	7	2
9/18/2007	0	1.51	9/18/2007	0	1.7
9/19/2007	8.7	1.52	9/19/2007	0	1.6
9/20/2007	0	1.53	9/20/2007	0	1.5
9/21/2007	10.1	1.54	9/21/2007	11.7	2
9/22/2007	9.8	1.55	9/22/2007	10	1.9
9/23/2007	5.6	1.56	9/23/2007	7.4	1.7
9/24/2007	12.3	1.58	9/24/2007	12	1.9
9/25/2007	12.7	1.60	9/25/2007	16.7	2.7
9/26/2007	0	1.61	9/26/2007	0	1.8
9/27/2007	0	1.64	9/27/2007	0	1.75
9/28/2007	0	1.67	9/28/2007	0	1.7
9/29/2007	0	1.68	9/29/2007	0	1.65
9/30/2007	0	1.68	9/30/2007	0	1.6
10/1/2007	0	1.69	10/1/2007	0	1.55
10/2/2007	0	1.69	10/2/2007	0	1.5
10/3/2007	11.7	1.70	10/3/2007	8.3	2
10/4/2007	4.8	1.70	10/4/2007	3.7	1.9
10/5/2007	8.6	1.71	10/5/2007	9.1	2
10/6/2007	4.1	1.72	10/6/2007	5.1	1.9
10/7/2007	15	1.72	10/7/2007	15.2	2.2
10/8/2007	10.4	1.72	10/8/2007	10	2.1
10/9/2007	2.9	1.72	10/9/2007	3	2

10/10/2007	4.1	1.72	10/10/2007	6	2
10/11/2007	3.7	1.72	10/11/2007	3.7	2
10/12/2007	0	1.71	10/12/2007	0	1.5
10/13/2007	0	1.71	10/13/2007	0	1.4
10/14/2007	0	1.71	10/14/2007	0	1.35
10/15/2007	0	1.71	10/15/2007	0	1.3
10/16/2007	9.3	1.71	10/16/2007	9.6	2.1
10/17/2007	4.6	1.71	10/17/2007	4.5	1.9
10/18/2007	0	1.70	10/18/2007	0	1.4
10/19/2007	2.2	1.69	10/19/2007	2.2	1.5
10/20/2007	3.7	1.68	10/20/2007	3.9	1.7
10/21/2007	2.4	1.67	10/21/2007	2.4	1.6
10/22/2007	1.1	1.66	10/22/2007	1.3	1.5
10/23/2007	2	1.65	10/23/2007	2.3	1.6
10/24/2007	0	1.64	10/24/2007	0	1.5
10/25/2007	0	1.63	10/25/2007	0	1.3
10/26/2007	0	1.62	10/26/2007	0	1.3
10/27/2007	2.1	1.61	10/27/2007	2.5	1.5
10/28/2007	1.8	1.61	10/28/2007	2.6	1.5
10/29/2007	0	1.60	10/29/2007	0	1.3
10/30/2007	0	1.58	10/30/2007	0	1.3
10/31/2007	0	1.56	10/31/2007	0	1.25
11/1/2007	1.5	1.54	11/1/2007	4.9	1.5
11/2/2007	1.2	1.52	11/2/2007	2.9	1.4
11/3/2007	0.9	1.50	11/3/2007	3.5	1.3
11/4/2007	1.4	1.49	11/4/2007	2.7	1.25
11/5/2007	0	1.47	11/5/2007	0	1.2
11/6/2007	0	1.45	11/6/2007	0	1.15
11/7/2007	0	1.42	11/7/2007	0	1.14
11/8/2007	0	1.39	11/8/2007	0	1.13
11/9/2007	0	1.37	11/9/2007	0	1.12
11/10/2007	0	1.33	11/10/2007	0	1.11
11/11/2007	0	1.29	11/11/2007	0	1.1
11/12/2007	0	1.20	11/12/2007	0	1.06
11/13/2007	0	1.18	11/13/2007	0	1.03
11/14/2007	0	1.17	11/14/2007	0	1.02
11/15/2007	0	1.15	11/15/2007	0	1.02
11/16/2007	0	1.14	11/16/2007	0	1.01
11/17/2007	0	1.13	11/17/2007	0	1.01
11/18/2007	0	1.13	11/18/2007	0	1.01
11/19/2007	0	1.12	11/19/2007	0	1

11/20/2007	0	1.11	11/20/2007	0	1
11/21/2007	0	1.09	11/21/2007	0	1
11/22/2007	0	1.07	11/22/2007	0	0.98
11/23/2007	0	1.06	11/23/2007	0	0.96
11/24/2007	0	1.06	11/24/2007	0	0.94
11/25/2007	0	1.06	11/25/2007	0	0.92
11/26/2007	0	1.05	11/26/2007	0	0.9
11/27/2007	0	1.04	11/27/2007	0	0.88
11/28/2007	0	1.03	11/28/2007	0	0.86
11/29/2007	0	1.01	11/29/2007	0	0.84
11/30/2007	0	1.01	11/30/2007	0	0.83
12/1/2007	0	1.01	12/1/2007	0	0.82
12/2/2007	0	1.00	12/2/2007	0	0.82
12/3/2007	0	0.99	12/3/2007	0	0.81
12/4/2007	0	0.98	12/4/2007	0	0.8
12/5/2007	0	0.97	12/5/2007	0	0.8
12/6/2007	0	0.96	12/6/2007	0	0.78
12/7/2007	0	0.94	12/7/2007	0	0.77
12/8/2007	0	0.92	12/8/2007	0	0.76
12/9/2007	0	0.88	12/9/2007	0	0.75
12/10/2007	0	0.86	12/10/2007	0	0.75
12/11/2007	0	0.83	12/11/2007	0	0.75
12/12/2007	0	0.79	12/12/2007	0	0.75
12/13/2007	0	0.77	12/13/2007	0	0.75
12/14/2007	0	0.74	12/14/2007	0	0.74
12/15/2007	0	0.73	12/15/2007	0	0.74
12/16/2007	0	0.69	12/16/2007	0	0.74
12/17/2007	0	0.66	12/17/2007	0	0.74
12/18/2007	0	0.65	12/18/2007	0	0.74
12/19/2007	0	0.63	12/19/2007	0	0.74
12/20/2007	0	0.62	12/20/2007	0	0.73
12/21/2007	0	0.61	12/21/2007	0	0.73
12/22/2007	0	0.61	12/22/2007	0	0.73
12/23/2007	0	0.61	12/23/2007	0	0.73
12/24/2007	0	0.61	12/24/2007	0	0.73
12/25/2007	0	0.61	12/25/2007	0	0.73
12/26/2007	0	0.61	12/26/2007	0	0.73
12/27/2007	0	0.61	12/27/2007	0	0.73
12/28/2007	0	0.61	12/28/2007	0	0.73
12/29/2007	0	0.61	12/29/2007	0	0.73
12/30/2007	0	0.61	12/30/2007	0	0.73

12/31/2007	0	0.61	12/31/2007	0	0.73
1/1/2008	0	0.61	1/1/2008	0	0.72
1/2/2008	0	0.61	1/2/2008	0	0.72
1/3/2008	0	0.61	1/3/2008	0	0.71
1/4/2008	0	0.61	1/4/2008	0	0.71
1/5/2008	0	0.61	1/5/2008	0	0.71
1/6/2008	0	0.61	1/6/2008	5.7	0.7
1/7/2008	0	0.61	1/7/2008	5.4	0.7
1/8/2008	0	0.61	1/8/2008	3.2	0.7
1/9/2008	0	0.6	1/9/2008	0	0.7
1/10/2008	0	0.6	1/10/2008	0	0.7
1/11/2008	0	0.6	1/11/2008	0	0.69
1/12/2008	0	0.6	1/12/2008	0	0.69
1/13/2008	0	0.6	1/13/2008	0	0.69
1/14/2008	0	0.6	1/14/2008	0	0.69
1/15/2008	0	0.6	1/15/2008	8.1	0.68
1/16/2008	3.8	0.6	1/16/2008	5.8	0.68
1/17/2008	4.6	0.6	1/17/2008	10	0.68
1/18/2008	0	0.6	1/18/2008	0	0.68
1/19/2008	0	0.6	1/19/2008	0	0.67
1/20/2008	0	0.6	1/20/2008	0	0.67
1/21/2008	0	0.6	1/21/2008	0	0.67
1/22/2008	0	0.6	1/22/2008	0	0.67
1/23/2008	0	0.6	1/23/2008	0	0.66
1/24/2008	0	0.6	1/24/2008	0	0.66
1/25/2008	0	0.6	1/25/2008	0	0.66
1/26/2008	0	0.6	1/26/2008	0	0.65
1/27/2008	0	0.6	1/27/2008	0	0.65
1/28/2008	5.9	0.6	1/28/2008	0	0.65
1/29/2008	9.8	0.6	1/29/2008	0	0.65
1/30/2008	0	0.6	1/30/2008	0	0.65
1/31/2008	3.8	0.59	1/31/2008	0	0.64
2/1/2008	0	0.59	2/1/2008	0	0.64
2/2/2008	0	0.59	2/2/2008	0	0.64
2/3/2008	0	0.59	2/3/2008	0	0.64
2/4/2008	0	0.59	2/4/2008	0	0.64
2/5/2008	0	0.59	2/5/2008	0	0.63
2/6/2008	4.8	0.59	2/6/2008	0	0.63
2/7/2008	4.9	0.59	2/7/2008	0	0.63
2/8/2008	6.4	0.59	2/8/2008	0	0.63
2/9/2008	1	0.59	2/9/2008	0	0.63

2/10/2008	0	0.59	2/10/2008	0	0.62
2/11/2008	4.1	0.59	2/11/2008	5.4	0.62
2/12/2008	7.8	0.59	2/12/2008	10.3	0.62
2/13/2008	0	0.59	2/13/2008	0	0.62
2/14/2008	0	0.59	2/14/2008	0	0.61
2/15/2008	0	0.59	2/15/2008	0	0.61
2/16/2008	0	0.59	2/16/2008	0	0.61
2/17/2008	0	0.59	2/17/2008	0	0.61
2/18/2008	0	0.59	2/18/2008	0	0.61
2/19/2008	0	0.59	2/19/2008	0	0.61
2/20/2008	0	0.59	2/20/2008	0	0.6
2/21/2008	0	0.59	2/21/2008	0	0.6
2/22/2008	0	0.59	2/22/2008	0	0.6
2/23/2008	0	0.59	2/23/2008	0	0.6
2/24/2008	0	0.59	2/24/2008	0	0.6
2/25/2008	0	0.59	2/25/2008	0	0.6
2/26/2008	0	0.59	2/26/2008	0	0.6
2/27/2008	7.3	0.59	2/27/2008	0	0.6
2/28/2008	12.1	0.59	2/28/2008	0	0.6
2/29/2008	0	0.59	2/29/2008	0	0.59
3/1/2008	0	0.59	3/1/2008	0	0.59
3/2/2008	0	0.59	3/2/2008	0	0.59
3/3/2008	7.2	0.59	3/3/2008	0	0.59
3/4/2008	0	0.59	3/4/2008	0	0.59
3/5/2008	8.3	0.59	3/5/2008	0	0.59
3/6/2008	0	0.59	3/6/2008	0	0.59
3/7/2008	0	0.59	3/7/2008	0	0.59
3/8/2008	0	0.59	3/8/2008	0	0.59
3/9/2008	0	0.59	3/9/2008	0	0.58
3/10/2008	0	0.59	3/10/2008	0	0.58
3/11/2008	0	0.59	3/11/2008	0	0.58
3/12/2008	0	0.59	3/12/2008	0	0.58
3/13/2008	0	0.59	3/13/2008	0	0.58
3/14/2008	0	0.59	3/14/2008	0	0.58
3/15/2008	10.9	0.59	3/15/2008	0	0.58
3/16/2008	7	0.59	3/16/2008	0	0.58
3/17/2008	10.8	0.59	3/17/2008	0	0.58
3/18/2008	10.6	0.59	3/18/2008	0	0.58
3/19/2008	8.2	0.59	3/19/2008	4.6	0.58
3/20/2008	12.2	0.59	3/20/2008	15.3	0.58
3/21/2008	11	0.59	3/21/2008	6.2	0.59

3/22/2008	8.4	0.59	3/22/2008	4.5	0.59
3/23/2008	5.1	0.59	3/23/2008	7.2	0.59
3/24/2008	8.5	0.6	3/24/2008	5	0.6
3/25/2008	15.1	0.6	3/25/2008	4.4	0.6
3/26/2008	29.1	0.6	3/26/2008	23.6	0.94
3/27/2008	8.4	0.6	3/27/2008	5.9	1
3/28/2008	13.4	0.6	3/28/2008	8.4	1
3/29/2008	8.6	0.6	3/29/2008	10.1	1.4
3/30/2008	15.4	0.6	3/30/2008	14.3	1.4
3/31/2008	16.3	0.6	3/31/2008	11.3	1.3
4/1/2008	6.2	0.6	4/1/2008	20.2	1.4
4/2/2008	7.4	0.6	4/2/2008	8	1
4/3/2008	8.4	0.6	4/3/2008	11.7	1.1
4/4/2008	6.3	0.6	4/4/2008	7.3	1.1
4/5/2008	3.6	0.6	4/5/2008	12.4	1.1
4/6/2008	8.2	0.6	4/6/2008	10.9	1.1
4/7/2008	4.2	0.6	4/7/2008	13.2	1.2
4/8/2008	6.3	0.6	4/8/2008	12.3	1.3
4/9/2008	11.7	0.6	4/9/2008	10.6	1.3
4/10/2008	30.5	0.61	4/10/2008	29.4	2.9
4/11/2008	23.6	0.61	4/11/2008	13.2	1.5
4/12/2008	27.7	0.61	4/12/2008	20.2	2.7
4/13/2008	10.1	0.61	4/13/2008	21.6	2.9
4/14/2008	7.5	0.62	4/14/2008	19.7	2.5
4/15/2008	7.4	0.62	4/15/2008	9.9	1.9
4/16/2008	8.2	0.62	4/16/2008	16.2	2.1
4/17/2008	23.6	0.62	4/17/2008	22.8	3
4/18/2008	25.3	0.62	4/18/2008	27.2	3.3
4/19/2008	25.9	0.62	4/19/2008	25.5	3.2
4/20/2008	14.6	0.62	4/20/2008	17.7	2.5
4/21/2008	8.2	0.62	4/21/2008	12.3	1.9
4/22/2008	5.3	0.62	4/22/2008	11.9	1.8
4/23/2008	9.6	0.63	4/23/2008	13.2	1.9
4/24/2008	5	0.63	4/24/2008	14.5	2.1
4/25/2008	7.8	0.63	4/25/2008	12.4	1.9
4/26/2008	4.8	0.63	4/26/2008	14.4	2.2
4/27/2008	6.2	0.63	4/27/2008	15	2.1
4/28/2008	4.7	0.63	4/28/2008	8.6	1.6
4/29/2008	4.5	0.63	4/29/2008	15.3	2.2
4/30/2008	7.9	0.64	4/30/2008	5.6	1.7
5/1/2008	3	0.64	5/1/2008	6.7	1.5

5/2/2008	5	0.64	5/2/2008	15.6	2.1
5/3/2008	6.9	0.64	5/3/2008	13.1	2.1
5/4/2008	5.2	0.65	5/4/2008	18.2	2.5
5/5/2008	2.5	0.65	5/5/2008	15.9	2.3
5/6/2008	9.6	0.65	5/6/2008	13.2	2.1
5/7/2008	8.4	0.65	5/7/2008	7.9	1.5
5/8/2008	7.9	0.66	5/8/2008	10.4	1.5
5/9/2008	6.7	0.66	5/9/2008	13.9	2
5/10/2008	10.2	0.66	5/10/2008	11.7	1.9
5/11/2008	20	0.66	5/11/2008	12.8	2
5/12/2008	9.7	0.66	5/12/2008	7.8	1.4
5/13/2008	7.5	0.67	5/13/2008	16.7	2.4
5/14/2008	5.2	0.67	5/14/2008	22.4	3.1
5/15/2008	8.8	0.67	5/15/2008	8.7	1.6
5/16/2008	4.5	0.67	5/16/2008	4.3	1.4
5/17/2008	5.3	0.68	5/17/2008	18	2.5
5/18/2008	5.4	0.68	5/18/2008	12.9	2
5/19/2008	7.9	0.69	5/19/2008	13.9	2.1
5/20/2008	4.3	0.69	5/20/2008	10.2	1.8
5/21/2008	6.1	0.7	5/21/2008	0	1.6
5/22/2008	5.6	0.7	5/22/2008	0	1.5
5/23/2008	7.7	0.71	5/23/2008	0	1.4
5/24/2008	5.2	0.71	5/24/2008	11.8	1.9
5/25/2008	8.1	0.71	5/25/2008	16.9	2.3
5/26/2008	9.8	0.72	5/26/2008	18.2	2.5
5/27/2008	7.8	0.73	5/27/2008	2.3	1.5
5/28/2008	16.5	0.73	5/28/2008	6.6	1.4
5/29/2008	8.9	0.74	5/29/2008	9	1.5
5/30/2008	11	0.74	5/30/2008	7.7	1.4
5/31/2008	7.8	0.75	5/31/2008	8.9	1.7
6/1/2008	0	0.76	6/1/2008	12	1.9
6/2/2008	11.1	0.77	6/2/2008	7.6	1.5
6/3/2008	10.1	0.78	6/3/2008	7.2	1.4
6/4/2008	12.2	0.79	6/4/2008	24.8	3.2
6/5/2008	9.7	0.8	6/5/2008	1.4	1.3
6/6/2008	13.4	0.8	6/6/2008	4.9	1.3
6/7/2008	13.9	0.81	6/7/2008	8.6	1.6
6/8/2008	14.8	0.81	6/8/2008	8.2	1.6
6/9/2008	9.4	0.82	6/9/2008	7.1	1.5
6/10/2008	5.8	0.82	6/10/2008	4.9	1.4
6/11/2008	4.6	0.82	6/11/2008	0	1.2

6/12/2008	0	0.82	6/12/2008	0	1.1
6/13/2008	0	0.87	6/13/2008	5	0.86
6/14/2008	0	0.88	6/14/2008	0	0.85
6/15/2008	0	0.89	6/15/2008	0	0.84
6/16/2008	6.2	0.89	6/16/2008	7.1	1.3
6/17/2008	0	0.89	6/17/2008	0	1.2
6/18/2008	7.4	0.9	6/18/2008	0	1.1
6/19/2008	5.6	0.9	6/19/2008	0	1
6/20/2008	0	0.9	6/20/2008	0	0.95
6/21/2008	0	0.9	6/21/2008	19.7	2.5
6/22/2008	4.5	0.9	6/22/2008	1.9	1.1
6/23/2008	0	0.9	6/23/2008	14.1	1.8
6/24/2008	1.9	0.9	6/24/2008	2	0.9
6/25/2008	0	0.9	6/25/2008	3	0.9
6/26/2008	0	0.9	6/26/2008	1.4	0.8
6/27/2008	4.6	0.9	6/27/2008	10.2	1.8
6/28/2008	6.3	0.9	6/28/2008	11	1.9
6/29/2008	7	0.9	6/29/2008	2.1	0.8
6/30/2008	0	0.9	6/30/2008	11.4	2.1
7/1/2008	5.9	0.9	7/1/2008	0	0.9
7/2/2008	6.9	0.9	7/2/2008	9.8	1.4
7/3/2008	5.3	0.9	7/3/2008	0	1.3
7/4/2008	4.6	0.9	7/4/2008	0	1.2
7/5/2008	0	0.92	7/5/2008	0	1.15
7/6/2008	0	0.92	7/6/2008	0	1.1
7/7/2008	0	0.92	7/7/2008	0	1.05
7/8/2008	0	0.92	7/8/2008	0	1
7/9/2008	0	0.92	7/9/2008	0	0.98
7/10/2008	0	0.92	7/10/2008	0	0.96
7/11/2008	5.1	0.92	7/11/2008	0	0.94
7/12/2008	3.5	0.92	7/12/2008	0	0.92
7/13/2008	4.5	0.92	7/13/2008	0	0.9
7/14/2008	7.7	0.92	7/14/2008	11.2	1.8
7/15/2008	12.2	0.92	7/15/2008	0	1.25
7/16/2008	5.3	0.92	7/16/2008	9.1	1.6
7/17/2008	5.6	0.93	7/17/2008	13	2.1
7/18/2008	9.5	0.93	7/18/2008	4.9	1.4
7/19/2008	4.7	0.93	7/19/2008	15	2.1
7/20/2008	2.4	0.93	7/20/2008	10	1.8
7/21/2008	12.5	0.93	7/21/2008	11.9	1.9
7/22/2008	0	0.93	7/22/2008	19.3	2.5

7/23/2008	0	0.93	7/23/2008	18.9	2.4
7/24/2008	0	0.93	7/24/2008	12.5	2
7/25/2008	0	0.94	7/25/2008	23.1	2.9
7/26/2008	0	0.94	7/26/2008	13.7	2.1
7/27/2008	0	0.94	7/27/2008	10.5	1.9
7/28/2008	1	0.94	7/28/2008	16.2	2.3
7/29/2008	7	0.94	7/29/2008	11.6	1.9
7/30/2008	8.4	0.94	7/30/2008	18.5	2.5
7/31/2008	2.6	0.94	7/31/2008	13.8	2.1
8/1/2008	8.8	0.94	8/1/2008	10.1	1.1
8/2/2008	8.4	0.94	8/2/2008	9.3	1.6
8/3/2008	6.2	0.94	8/3/2008	5.2	1.2
8/4/2008	5.7	0.95	8/4/2008	0	1.1
8/5/2008	2.8	0.95	8/5/2008	0	1
8/6/2008	7.6	0.95	8/6/2008	7.1	1.5
8/7/2008	5.5	0.95	8/7/2008	12	2
8/8/2008	6.9	0.95	8/8/2008	6.2	1.7
8/9/2008	9.2	0.95	8/9/2008	11.1	2
8/10/2008	0	0.96	8/10/2008	6.6	1.4
8/11/2008	2.2	0.96	8/11/2008	12.7	2
8/12/2008	0	0.96	8/12/2008	13.4	2.1
8/13/2008	19.3	0.96	8/13/2008	4.4	1.5
8/14/2008	0	0.97	8/14/2008	22.9	2.9
8/15/2008	0	0.97	8/15/2008	11.4	2.1
8/16/2008	7.8	0.97	8/16/2008	14.1	2.3
8/17/2008	8.5	0.97	8/17/2008	20.7	2.8
8/18/2008	4.8	0.97	8/18/2008	10	1.4
8/19/2008	9.1	0.98	8/19/2008	27.1	3.3
8/20/2008	15.6	0.98	8/20/2008	26.4	3.2
8/21/2008	9.9	0.98	8/21/2008	12.9	1.9
8/22/2008	4.4	0.98	8/22/2008	7.8	1.5
8/23/2008	7.5	0.99	8/23/2008	15.6	2.3
8/24/2008	14.5	0.99	8/24/2008	7.6	1.5
8/25/2008	29.8	0.99	8/25/2008	27.2	3.4
8/26/2008	13.3	0.99	8/26/2008	3.8	1.4
8/27/2008	9.9	0.99	8/27/2008	0	1.4
8/28/2008	1.7	1	8/28/2008	0	1
8/29/2008	7.4	1	8/29/2008	14.4	2.3
8/30/2008	8.2	1	8/30/2008	15.3	2.2
8/31/2008	16	1	8/31/2008	22	2.9
9/1/2008	0	1	9/1/2008	19.6	2.7

9/2/2008	9	1	9/2/2008	11.4	2.1
9/3/2008	0	1.02	9/3/2008	12.5	2.3
9/4/2008	17.5	1.03	9/4/2008	13.4	2.5
9/5/2008	0	1.05	9/5/2008	9.4	1.7
9/6/2008	10.2	1.05	9/6/2008	9.8	1.7
9/7/2008	6.4	1.06	9/7/2008	13.4	2.2
9/8/2008	0	1.07	9/8/2008	20.2	2.8
9/9/2008	21.3	1.08	9/9/2008	12.3	1.8
9/10/2008	3.2	1.09	9/10/2008	9.9	1.7
9/11/2008	11	1.1	9/11/2008	4.8	1.2
9/12/2008	15	1.1	9/12/2008	7.4	1.5
9/13/2008	5.5	1.11	9/13/2008	4.3	1
9/14/2008	13.5	1.11	9/14/2008	6.5	1.3
9/15/2008	0	1.12	9/15/2008	8	1.5
9/16/2008	6.2	1.12	9/16/2008	3.7	1.4
9/17/2008	28	1.12	9/17/2008	0	1.3
9/18/2008	23.5	1.12	9/18/2008	0	1.2
9/19/2008	6.4	1.13	9/19/2008	0	1.1
9/20/2008	6.1	1.13	9/20/2008	0	1
9/21/2008	5.4	1.13	9/21/2008	0	0.9
9/22/2008	15	1.14	9/22/2008	4.1	1.2
9/23/2008	4.9	1.14	9/23/2008	14.4	2.8
9/24/2008	21.6	1.15	9/24/2008	10.1	1.7
9/25/2008	9.9	1.15	9/25/2008	8.7	1.5
9/26/2008	0	1.16	9/26/2008	13.5	2.7
9/27/2008	0	1.16	9/27/2008	0	1.3
9/28/2008	0	1.17	9/28/2008	0	1.2
9/29/2008	0	1.2	9/29/2008	0	1.1
9/30/2008	6.5	1.3	9/30/2008	0	1
10/1/2008	11.5	1.35	10/1/2008	0	0.95
10/2/2008	13.8	1.35	10/2/2008	0	0.9
10/3/2008	9.9	1.36	10/3/2008	3.7	1
10/4/2008	10.7	1.36	10/4/2008	6.5	1.4
10/5/2008	12.6	1.36	10/5/2008	5.7	1.2
10/6/2008	15.1	1.36	10/6/2008	10.2	2.3
10/7/2008	8.8	1.36	10/7/2008	5.3	1.1
10/8/2008	9	1.37	10/8/2008	15.3	2.4
10/9/2008	11.8	1.37	10/9/2008	5.2	1.1
10/10/2008	5.8	1.37	10/10/2008	9.1	1.7
10/11/2008	7.9	1.37	10/11/2008	4.3	1.4
10/12/2008	12.8	1.37	10/12/2008	0	1.1

10/13/2008	9.9	1.37	10/13/2008	6.9	1.2
10/14/2008	13.3	1.38	10/14/2008	2	1
10/15/2008	10.7	1.38	10/15/2008	2.6	1
10/16/2008	19.6	1.38	10/16/2008	2.8	1
10/17/2008	16.5	1.38	10/17/2008	1.9	1
10/18/2008	9.7	1.39	10/18/2008	3.7	1
10/19/2008	7.4	1.39	10/19/2008	1.5	1
10/20/2008	8.2	1.38	10/20/2008	9	1.5
10/21/2008	15.7	1.34	10/21/2008	10.1	1.7
10/22/2008	10	1.3	10/22/2008	4.5	1.1
10/23/2008	8.3	1.27	10/23/2008	6.3	1.2
10/24/2008	0	1.24	10/24/2008	7.4	1.5
10/25/2008	5.2	1.21	10/25/2008	2.1	1.1
10/26/2008	1.3	1.16	10/26/2008	3.8	1.1
10/27/2008	0	1.13	10/27/2008	3.9	1.1
10/28/2008	4.9	1.08	10/28/2008	3.2	1
10/29/2008	0	1.06	10/29/2008	2.2	1
10/30/2008	2.2	1.04	10/30/2008	0	0.9
10/31/2008	0	1.02	10/31/2008	0	0.9
11/1/2008	2.1	1	11/1/2008	0	0.9
11/2/2008	2.9	1	11/2/2008	0	0.9
11/3/2008	1.9	1	11/3/2008	0	0.89
11/4/2008	2.5	0.99	11/4/2008	0	0.89
11/5/2008	3.9	0.99	11/5/2008	0	0.88
11/6/2008	3.5	0.98	11/6/2008	0	0.88
11/7/2008	3.7	0.98	11/7/2008	0	0.88
11/8/2008	6.5	0.97	11/8/2008	0	0.87
11/9/2008	4.6	0.97	11/9/2008	0	0.87
11/10/2008	0	0.96	11/10/2008	0	0.87
11/11/2008	0	0.95	11/11/2008	0	0.86
11/12/2008	7.8	0.93	11/12/2008	0	0.86
11/13/2008	2.1	0.91	11/13/2008	0	0.86
11/14/2008	4.7	0.88	11/14/2008	0	0.85
11/15/2008	0	0.86	11/15/2008	0	0.85
11/16/2008	3.3	0.85	11/16/2008	0	0.85
11/17/2008	5.3	0.84	11/17/2008	0	0.84
11/18/2008	0	0.83	11/18/2008	0	0.84
11/19/2008	2.7	0.82	11/19/2008	0	0.84
11/20/2008	0	0.81	11/20/2008	0	0.84
11/21/2008	0	0.79	11/21/2008	0	0.83
11/22/2008	0	0.77	11/22/2008	0	0.83

11/23/2008	0	0.75	11/23/2008	0	0.83
11/24/2008	3.6	0.73	11/24/2008	0	0.83
11/25/2008	0	0.71	11/25/2008	0	0.82
11/26/2008	0	0.69	11/26/2008	0	0.82
11/27/2008	0	0.68	11/27/2008	0	0.81
11/28/2008	0	0.67	11/28/2008	0	0.81
11/29/2008	0	0.66	11/29/2008	0	0.8
11/30/2008	0	0.65	11/30/2008	0	0.79
12/1/2008	0	0.64	12/1/2008	0	0.78
12/2/2008	0	0.64	12/2/2008	0	0.77
12/3/2008	0	0.64	12/3/2008	0	0.76
12/4/2008	0	0.63	12/4/2008	0	0.75
12/5/2008	0	0.63	12/5/2008	0	0.74
12/6/2008	0	0.63	12/6/2008	0	0.73
12/7/2008	0	0.63	12/7/2008	0	0.72
12/8/2008	0	0.63	12/8/2008	0	0.71
12/9/2008	0	0.62	12/9/2008	0	0.7
12/10/2008	0	0.62	12/10/2008	0	0.69
12/11/2008	0	0.62	12/11/2008	0	0.68
12/12/2008	0	0.62	12/12/2008	0	0.67
12/13/2008	0	0.62	12/13/2008	0	0.66
12/14/2008	0	0.61	12/14/2008	0	0.65
12/15/2008	0	0.61	12/15/2008	0	0.64
12/16/2008	0	0.61	12/16/2008	0	0.63
12/17/2008	0	0.61	12/17/2008	0	0.62
12/18/2008	0	0.61	12/18/2008	0	0.61
12/19/2008	0	0.61	12/19/2008	0	0.6
12/20/2008	0	0.61	12/20/2008	0	0.59
12/21/2008	0	0.6	12/21/2008	0	0.58
12/22/2008	0	0.6	12/22/2008	0	0.57
12/23/2008	0	0.6	12/23/2008	0	0.56
12/24/2008	0	0.6	12/24/2008	0	0.55
12/25/2008	0	0.6	12/25/2008	0	0.55
12/26/2008	6.3	0.6	12/26/2008	0	0.55
12/27/2008	0	0.59	12/27/2008	0	0.55
12/28/2008	0	0.59	12/28/2008	0	0.55
12/29/2008	0	0.59	12/29/2008	0	0.55
12/30/2008	0	0.59	12/30/2008	0	0.55
12/31/2008	7.1	0.59	12/31/2008	0	0.55

Date	10 year rainfall (mm)	10 year discharge (mm day^{-1})	Date	50 year rainfall (mm)	50 year discharge (mm day^{-1})
1/1/2007	0	0.73	1/1/2007	0	0.71
1/2/2007	4.1	0.73	1/2/2007	9.1	0.71
1/3/2007	3.5	0.73	1/3/2007	5.1	0.71
1/4/2007	2.2	0.73	1/4/2007	10.1	0.71
1/5/2007	3	0.73	1/5/2007	5.4	0.72
1/6/2007	2.4	0.73	1/6/2007	2.4	0.72
1/7/2007	0	0.73	1/7/2007	0	0.71
1/8/2007	0	0.73	1/8/2007	0	0.71
1/9/2007	0	0.73	1/9/2007	0	0.71
1/10/2007	5.5	0.73	1/10/2007	10.8	0.73
1/11/2007	5	0.73	1/11/2007	5.1	0.72
1/12/2007	3.3	0.73	1/12/2007	3.6	0.72
1/13/2007	4.5	0.73	1/13/2007	7.4	0.73
1/14/2007	2.8	0.73	1/14/2007	6.8	0.72
1/15/2007	6.8	0.73	1/15/2007	4.6	0.72
1/16/2007	8.7	0.73	1/16/2007	5.3	0.72
1/17/2007	0	0.72	1/17/2007	0	0.72
1/18/2007	0	0.72	1/18/2007	0	0.72
1/19/2007	0	0.72	1/19/2007	0	0.71
1/20/2007	0	0.71	1/20/2007	0	0.71
1/21/2007	0	0.71	1/21/2007	0	0.71
1/22/2007	0	0.7	1/22/2007	0	0.71
1/23/2007	0	0.72	1/23/2007	0	0.71
1/24/2007	0	0.7	1/24/2007	0	0.71
1/25/2007	0	0.71	1/25/2007	0	0.7
1/26/2007	0	0.71	1/26/2007	0	0.7
1/27/2007	0	0.71	1/27/2007	0	0.7
1/28/2007	10.1	0.77	1/28/2007	6.8	0.74
1/29/2007	19.5	0.79	1/29/2007	13.6	1
1/30/2007	8.2	0.77	1/30/2007	6	0.8
1/31/2007	2.4	0.75	1/31/2007	3.8	0.76
2/1/2007	6.5	0.75	2/1/2007	4.2	0.77
2/2/2007	4.2	0.75	2/2/2007	5.5	0.78
2/3/2007	11.6	0.81	2/3/2007	6.4	0.79
2/4/2007	3.8	0.79	2/4/2007	11.9	0.9
2/5/2007	11.3	0.82	2/5/2007	9.2	0.85
2/6/2007	2	0.76	2/6/2007	4.8	0.77
2/7/2007	0	0.76	2/7/2007	0	0.73
2/8/2007	0	0.76	2/8/2007	0	0.71

2/9/2007	6.7	0.77	2/9/2007	4.2	0.74
2/10/2007	2.5	0.76	2/10/2007	4.2	0.8
2/11/2007	9.9	0.78	2/11/2007	9.9	0.94
2/12/2007	0	0.76	2/12/2007	5.7	0.82
2/13/2007	29.9	1.24	2/13/2007	16	1
2/14/2007	0	0.9	2/14/2007	16.9	1.1
2/15/2007	0	0.89	2/15/2007	0	0.76
2/16/2007	0	0.88	2/16/2007	0	0.74
2/17/2007	0	0.88	2/17/2007	0	0.73
2/18/2007	0	0.86	2/18/2007	0	0.72
2/19/2007	0	0.85	2/19/2007	0	0.72
2/20/2007	0	0.85	2/20/2007	0	0.71
2/21/2007	0	0.85	2/21/2007	0	0.71
2/22/2007	0	0.85	2/22/2007	0	0.7
2/23/2007	0	0.85	2/23/2007	0	0.7
2/24/2007	1.4	0.77	2/24/2007	8.6	0.86
2/25/2007	17.3	1.03	2/25/2007	11.6	0.96
2/26/2007	1.5	0.81	2/26/2007	1.7	0.79
2/27/2007	16.9	0.92	2/27/2007	11.7	0.97
2/28/2007	19.5	1.23	2/28/2007	14	1
3/1/2007	3.3	0.97	3/1/2007	0	0.74
3/2/2007	0	0.89	3/2/2007	0	0.73
3/3/2007	0	0.92	3/3/2007	0	0.73
3/4/2007	0	0.82	3/4/2007	0	0.72
3/5/2007	0	0.81	3/5/2007	0	0.72
3/6/2007	0	0.81	3/6/2007	0	0.71
3/7/2007	0	0.81	3/7/2007	0	0.7
3/8/2007	0	0.81	3/8/2007	0	0.7
3/9/2007	0	0.8	3/9/2007	0	0.7
3/10/2007	0	0.8	3/10/2007	0	0.7
3/11/2007	10.9	1.54	3/11/2007	7.7	0.85
3/12/2007	5.9	1.54	3/12/2007	8.5	0.89
3/13/2007	6.3	1.64	3/13/2007	5.7	0.83
3/14/2007	5.1	1.54	3/14/2007	8	0.9
3/15/2007	8.9	1.63	3/15/2007	6.3	0.8
3/16/2007	6.6	1.61	3/16/2007	5.2	0.8
3/17/2007	9.2	1.74	3/17/2007	7.7	0.84
3/18/2007	17.5	2.47	3/18/2007	13.9	1.7
3/19/2007	35.5	3.9	3/19/2007	27.3	3.5
3/20/2007	14.4	2.98	3/20/2007	16.8	2
3/21/2007	0	1.75	3/21/2007	0	1.1

3/22/2007	0	1.03	3/22/2007	0	0.96
3/23/2007	0	0.92	3/23/2007	0	0.94
3/24/2007	0	0.87	3/24/2007	0	0.92
3/25/2007	0	0.86	3/25/2007	0	0.88
3/26/2007	0	0.85	3/26/2007	0	0.84
3/27/2007	0	0.84	3/27/2007	0	0.82
3/28/2007	0	0.83	3/28/2007	0	0.8
3/29/2007	0	0.82	3/29/2007	0	0.79
3/30/2007	0	0.82	3/30/2007	0	0.78
3/31/2007	0	0.82	3/31/2007	0	0.77
4/1/2007	0	0.82	4/1/2007	0	0.76
4/2/2007	0	0.82	4/2/2007	0	0.75
4/3/2007	0	0.81	4/3/2007	0	0.74
4/4/2007	0	0.81	4/4/2007	0	0.73
4/5/2007	0	0.8	4/5/2007	0	0.72
4/6/2007	0	0.79	4/6/2007	0	0.72
4/7/2007	0	0.79	4/7/2007	0	0.72
4/8/2007	0	0.79	4/8/2007	0	0.72
4/9/2007	7.8	0.87	4/9/2007	5.3	0.9
4/10/2007	19.1	1.23	4/10/2007	18.6	2.6
4/11/2007	34.3	2.36	4/11/2007	24.8	3.7
4/12/2007	13.3	1.64	4/12/2007	13.9	2
4/13/2007	17.4	1.69	4/13/2007	16.8	2.9
4/14/2007	28	1.75	4/14/2007	28.2	4.2
4/15/2007	5.4	1.95	4/15/2007	6.9	2.3
4/16/2007	30.4	3	4/16/2007	36.2	5.4
4/17/2007	39.8	3.2	4/17/2007	34.1	5.3
4/18/2007	29.4	2.9	4/18/2007	17.8	2.7
4/19/2007	18.3	1.6	4/19/2007	19.4	2.8
4/20/2007	38.1	2.9	4/20/2007	30.1	5.2
4/21/2007	18.9	2.7	4/21/2007	16.2	3.2
4/22/2007	17.2	2.7	4/22/2007	13.6	3
4/23/2007	8.2	1.9	4/23/2007	4	2.1
4/24/2007	13.2	2.2	4/24/2007	5.8	2.9
4/25/2007	14.5	2.3	4/25/2007	16.6	3.2
4/26/2007	14.9	2.4	4/26/2007	10.8	2.5
4/27/2007	13.6	2.5	4/27/2007	13.3	2.7
4/28/2007	14.9	2.6	4/28/2007	11.9	2.4
4/29/2007	39.6	4.2	4/29/2007	10.6	2.5
4/30/2007	27.5	3.6	4/30/2007	16	3.1
5/1/2007	9.9	2.6	5/1/2007	12.9	2.9

5/2/2007	13.2	2.9	5/2/2007	13.7	3
5/3/2007	12.8	3.1	5/3/2007	17.6	3.6
5/4/2007	19.4	3.3	5/4/2007	18.7	3.8
5/5/2007	6.7	2.8	5/5/2007	0	2.3
5/6/2007	18.9	3.3	5/6/2007	16.6	3.4
5/7/2007	15.3	3.1	5/7/2007	21.4	4.4
5/8/2007	21.3	3.3	5/8/2007	20	4
5/9/2007	15.9	3.3	5/9/2007	13.5	3
5/10/2007	4.9	2.9	5/10/2007	7.9	2.5
5/11/2007	5.6	2.7	5/11/2007	7.2	2.2
5/12/2007	2.9	2.36	5/12/2007	5.6	2
5/13/2007	12.7	3.2	5/13/2007	9.3	2.7
5/14/2007	26.9	3.9	5/14/2007	15.2	3.4
5/15/2007	5.8	3	5/15/2007	10.4	3.1
5/16/2007	9.3	3.1	5/16/2007	9.4	2.8
5/17/2007	24.1	3.8	5/17/2007	30.1	5.6
5/18/2007	14.8	3.2	5/18/2007	12.4	3.3
5/19/2007	2	2.5	5/19/2007	10.5	3.2
5/20/2007	3	1.9	5/20/2007	6.3	2.6
5/21/2007	0	1.8	5/21/2007	0	2.4
5/22/2007	0	1.7	5/22/2007	0	2.3
5/23/2007	0	1.7	5/23/2007	0	2.2
5/24/2007	0	1.6	5/24/2007	0	2.1
5/25/2007	5.4	2.4	5/25/2007	7	2.8
5/26/2007	5	2	5/26/2007	7.3	2.8
5/27/2007	6.8	2.1	5/27/2007	19.7	4.4
5/28/2007	7.4	2.2	5/28/2007	24.9	5
5/29/2007	5.1	2.3	5/29/2007	10.4	3
5/30/2007	2.8	1.7	5/30/2007	4.8	2.9
5/31/2007	27.4	3.9	5/31/2007	18.8	4.4
6/1/2007	15.5	3.2	6/1/2007	6.9	3.3
6/2/2007	5.1	2.6	6/2/2007	7.2	3.3
6/3/2007	9.7	2.8	6/3/2007	8.6	3.3
6/4/2007	9.3	3	6/4/2007	11.7	3.9
6/5/2007	10.2	3	6/5/2007	7.2	3.2
6/6/2007	3.8	2.6	6/6/2007	9.7	2.9
6/7/2007	5.5	2.7	6/7/2007	8.9	3.3
6/8/2007	3	2.4	6/8/2007	0	2.3
6/9/2007	17.2	3.3	6/9/2007	6.4	3.3
6/10/2007	18.9	3	6/10/2007	13	4.3
6/11/2007	2.7	2.4	6/11/2007	8.7	3.3

6/12/2007	0	1.75	6/12/2007	0	2
6/13/2007	5.5	2.2	6/13/2007	6	1.9
6/14/2007	0	1.74	6/14/2007	0	1.85
6/15/2007	0	1.34	6/15/2007	0	1.8
6/16/2007	4.1	2	6/16/2007	0	1.75
6/17/2007	0	1.5	6/17/2007	0	1.7
6/18/2007	0	1.4	6/18/2007	0	1.65
6/19/2007	0	1.4	6/19/2007	0	1.6
6/20/2007	0	1.3	6/20/2007	0	1.55
6/21/2007	0	1.2	6/21/2007	0	1.5
6/22/2007	0	1.2	6/22/2007	0	1.47
6/23/2007	0	1.1	6/23/2007	0	1.45
6/24/2007	0	1.1	6/24/2007	0	1.41
6/25/2007	9.7	2.2	6/25/2007	0	1.38
6/26/2007	2.2	1.3	6/26/2007	0	1.35
6/27/2007	10.1	3.1	6/27/2007	0	1.32
6/28/2007	9.2	3.1	6/28/2007	0	1.3
6/29/2007	2	2.4	6/29/2007	0	1.29
6/30/2007	2.2	2.5	6/30/2007	0	1.28
7/1/2007	1.7	2.2	7/1/2007	10.8	3.4
7/2/2007	14.7	3.1	7/2/2007	17.3	3.8
7/3/2007	1.3	2.1	7/3/2007	15	3.9
7/4/2007	18.1	3.4	7/4/2007	0	1.95
7/5/2007	0	2.4	7/5/2007	0	1.9
7/6/2007	0	2.8	7/6/2007	0	1.85
7/7/2007	0	1.6	7/7/2007	0	1.8
7/8/2007	0	1.5	7/8/2007	0	1.75
7/9/2007	0	1.4	7/9/2007	0	1.7
7/10/2007	0	1.4	7/10/2007	0	1.65
7/11/2007	0	1.2	7/11/2007	0	1.6
7/12/2007	0	1.2	7/12/2007	0	1.55
7/13/2007	0	1.2	7/13/2007	0	1.5
7/14/2007	0	1.2	7/14/2007	0	1.47
7/15/2007	0	1.2	7/15/2007	0	1.45
7/16/2007	0	1.2	7/16/2007	0	1.41
7/17/2007	0	1.1	7/17/2007	0	1.4
7/18/2007	0	1.3	7/18/2007	0	1.39
7/19/2007	19.9	3.2	7/19/2007	17	3.4
7/20/2007	0	2	7/20/2007	0	2.2
7/21/2007	6.2	2.6	7/21/2007	7.2	2.7
7/22/2007	7.3	2.7	7/22/2007	10	2.9

7/23/2007	10.4	3	7/23/2007	7.3	2.8
7/24/2007	39.9	5.5	7/24/2007	37	5.8
7/25/2007	14.1	3.6	7/25/2007	15.8	3.3
7/26/2007	2	2.7	7/26/2007	0	2.2
7/27/2007	14.5	3	7/27/2007	14	2.8
7/28/2007	13.2	3	7/28/2007	12	2.8
7/29/2007	12.9	3.1	7/29/2007	11.3	3.1
7/30/2007	6.5	2.8	7/30/2007	11.5	3.1
7/31/2007	2.9	2.5	7/31/2007	2.8	2.5
8/1/2007	14.4	3	8/1/2007	11.4	3.1
8/2/2007	17.6	3.4	8/2/2007	24.6	5.1
8/3/2007	14.1	3.3	8/3/2007	12.2	3.3
8/4/2007	32.6	5.3	8/4/2007	29	5.6
8/5/2007	0	3.6	8/5/2007	0	2.4
8/6/2007	0	3	8/6/2007	0	2.2
8/7/2007	29	3.6	8/7/2007	30	5.7
8/8/2007	33.2	5.4	8/8/2007	38.2	6.3
8/9/2007	0	3.3	8/9/2007	9.8	2.9
8/10/2007	14.9	3.5	8/10/2007	13.4	3.6
8/11/2007	12.2	3.3	8/11/2007	12	3
8/12/2007	10.8	3.2	8/12/2007	10.3	3.2
8/13/2007	18.8	3.5	8/13/2007	22.8	5.3
8/14/2007	11.6	3.2	8/14/2007	9.9	2.7
8/15/2007	3.6	2.5	8/15/2007	0	2.3
8/16/2007	8.6	3	8/16/2007	10.9	3.2
8/17/2007	9.7	3.1	8/17/2007	13.3	3.5
8/18/2007	5	2.7	8/18/2007	0	2.1
8/19/2007	9.9	3	8/19/2007	0	1.95
8/20/2007	6.3	2.8	8/20/2007	0	1.85
8/21/2007	7.5	2.9	8/21/2007	0	1.8
8/22/2007	2.9	2.6	8/22/2007	0	1.75
8/23/2007	8	2.7	8/23/2007	0	1.7
8/24/2007	4.1	1.7	8/24/2007	0	1.65
8/25/2007	4.4	1.8	8/25/2007	0	1.6
8/26/2007	3.9	1.75	8/26/2007	8.9	2.7
8/27/2007	3.3	1.7	8/27/2007	7.4	2.5
8/28/2007	2.8	1.6	8/28/2007	13.1	3.5
8/29/2007	1.8	1.5	8/29/2007	0	2.1
8/30/2007	3.6	1.6	8/30/2007	12.2	3.3
8/31/2007	3.8	1.7	8/31/2007	5.8	2.1
9/1/2007	5.2	1.8	9/1/2007	10.3	3

9/2/2007	7	1.9	9/2/2007	4.6	2.4
9/3/2007	11.6	2.5	9/3/2007	13.8	3.5
9/4/2007	12.6	2.9	9/4/2007	12.8	3.2
9/5/2007	25.6	4.6	9/5/2007	28	4.9
9/6/2007	4.2	2.7	9/6/2007	0	2.2
9/7/2007	4.9	2.1	9/7/2007	7.5	2.1
9/8/2007	8.8	2.8	9/8/2007	8.9	2.3
9/9/2007	1.6	1.9	9/9/2007	10.8	3.6
9/10/2007	9.6	2.2	9/10/2007	9.2	2.6
9/11/2007	9	2.4	9/11/2007	9.9	2.6
9/12/2007	10.8	3	9/12/2007	9.4	2.5
9/13/2007	23.7	4.5	9/13/2007	25.3	5.4
9/14/2007	10.4	2.6	9/14/2007	13.3	3.9
9/15/2007	13.1	3	9/15/2007	15.5	3.9
9/16/2007	0	2.8	9/16/2007	0	2.1
9/17/2007	0	2.6	9/17/2007	0	1.9
9/18/2007	0	2.3	9/18/2007	0	1.7
9/19/2007	0	2.3	9/19/2007	0	1.6
9/20/2007	0	2.3	9/20/2007	0	1.5
9/21/2007	9.5	2.7	9/21/2007	9.5	2.6
9/22/2007	8.5	2.8	9/22/2007	9.9	2.7
9/23/2007	5.3	2.6	9/23/2007	8.8	2.6
9/24/2007	10.1	2.9	9/24/2007	13.8	3.9
9/25/2007	5.9	2.1	9/25/2007	10.5	3.5
9/26/2007	0	2	9/26/2007	0	2.1
9/27/2007	0	1.9	9/27/2007	0	1.9
9/28/2007	0	1.85	9/28/2007	0	1.7
9/29/2007	0	1.8	9/29/2007	0	1.6
9/30/2007	0	1.7	9/30/2007	0	1.5
10/1/2007	0	1.6	10/1/2007	0	1.4
10/2/2007	0	1.5	10/2/2007	0	1.3
10/3/2007	3.8	1.7	10/3/2007	7.9	2.1
10/4/2007	2.8	1.6	10/4/2007	6.7	2
10/5/2007	6.2	1.8	10/5/2007	9.8	2.6
10/6/2007	7.1	1.9	10/6/2007	8.2	2.3
10/7/2007	10.2	2	10/7/2007	13.6	3.6
10/8/2007	7.6	2	10/8/2007	17.5	4.2
10/9/2007	4.5	1.7	10/9/2007	7.3	2.9
10/10/2007	6.1	1.9	10/10/2007	9	2.2
10/11/2007	4.2	1.7	10/11/2007	5.1	2
10/12/2007	0	1.5	10/12/2007	0	2.1

10/13/2007	0	1.4	10/13/2007	0	1.9
10/14/2007	0	1.4	10/14/2007	0	1.8
10/15/2007	0	1.4	10/15/2007	0	1.7
10/16/2007	9.1	2.4	10/16/2007	7.6	3.6
10/17/2007	6.7	2.3	10/17/2007	8.5	3.8
10/18/2007	0	1.6	10/18/2007	0	2
10/19/2007	4.1	1.7	10/19/2007	0	1.8
10/20/2007	7.2	1.8	10/20/2007	4.7	2.5
10/21/2007	1	1.5	10/21/2007	7	3.2
10/22/2007	1.2	1.5	10/22/2007	9.3	3.8
10/23/2007	1.5	1.6	10/23/2007	0	2
10/24/2007	0	1.4	10/24/2007	0	1.9
10/25/2007	0	1.35	10/25/2007	0	1.8
10/26/2007	0	1.3	10/26/2007	0	1.7
10/27/2007	1.3	1.8	10/27/2007	6.9	2.9
10/28/2007	2	1.9	10/28/2007	5.6	2.5
10/29/2007	0	1.5	10/29/2007	0	2
10/30/2007	0	1.4	10/30/2007	0	1.9
10/31/2007	0	1.3	10/31/2007	0	1.8
11/1/2007	1	1.7	11/1/2007	7.6	3.3
11/2/2007	1.6	1.6	11/2/2007	13	4.4
11/3/2007	2.3	1.6	11/3/2007	9.2	3.9
11/4/2007	0	1.4	11/4/2007	6.9	3.3
11/5/2007	0	1.3	11/5/2007	0	2
11/6/2007	0	1.2	11/6/2007	0	1.9
11/7/2007	0	1.19	11/7/2007	0	1.85
11/8/2007	0	1.17	11/8/2007	0	1.81
11/9/2007	0	1.15	11/9/2007	0	1.7
11/10/2007	0	1.13	11/10/2007	0	1.6
11/11/2007	0	1.11	11/11/2007	0	1.5
11/12/2007	0	1.08	11/12/2007	0	1.4
11/13/2007	0	1.05	11/13/2007	0	1.3
11/14/2007	0	1.03	11/14/2007	0	1.1
11/15/2007	0	1.01	11/15/2007	0	1.1
11/16/2007	0	1.01	11/16/2007	0	1
11/17/2007	0	1.01	11/17/2007	0	0.9
11/18/2007	0	1.01	11/18/2007	0	0.85
11/19/2007	0	1	11/19/2007	0	0.84
11/20/2007	0	1	11/20/2007	0	0.83
11/21/2007	0	1	11/21/2007	0	0.82
11/22/2007	0	0.98	11/22/2007	0	0.8

11/23/2007	0	0.96	11/23/2007	0	0.78
11/24/2007	0	0.94	11/24/2007	0	0.77
11/25/2007	0	0.92	11/25/2007	0	0.75
11/26/2007	0	0.9	11/26/2007	0	0.75
11/27/2007	0	0.88	11/27/2007	0	0.74
11/28/2007	0	0.86	11/28/2007	0	0.73
11/29/2007	0	0.84	11/29/2007	0	0.73
11/30/2007	0	0.83	11/30/2007	0	0.73
12/1/2007	0	0.82	12/1/2007	0	0.72
12/2/2007	0	0.82	12/2/2007	0	0.72
12/3/2007	0	0.81	12/3/2007	0	0.72
12/4/2007	0	0.8	12/4/2007	0	0.72
12/5/2007	0	0.8	12/5/2007	0	0.72
12/6/2007	0	0.78	12/6/2007	0	0.72
12/7/2007	0	0.76	12/7/2007	0	0.72
12/8/2007	0	0.75	12/8/2007	0	0.72
12/9/2007	0	0.75	12/9/2007	0	0.72
12/10/2007	0	0.75	12/10/2007	0	0.72
12/11/2007	0	0.75	12/11/2007	0	0.72
12/12/2007	0	0.75	12/12/2007	0	0.72
12/13/2007	0	0.74	12/13/2007	0	0.72
12/14/2007	0	0.74	12/14/2007	0	0.71
12/15/2007	0	0.74	12/15/2007	0	0.71
12/16/2007	0	0.74	12/16/2007	0	0.71
12/17/2007	0	0.74	12/17/2007	0	0.71
12/18/2007	0	0.74	12/18/2007	0	0.71
12/19/2007	0	0.74	12/19/2007	0	0.71
12/20/2007	0	0.73	12/20/2007	0	0.71
12/21/2007	0	0.73	12/21/2007	0	0.71
12/22/2007	0	0.73	12/22/2007	0	0.71
12/23/2007	0	0.73	12/23/2007	0	0.71
12/24/2007	0	0.73	12/24/2007	0	0.71
12/25/2007	0	0.73	12/25/2007	0	0.71
12/26/2007	0	0.73	12/26/2007	0	0.71
12/27/2007	0	0.73	12/27/2007	0	0.71
12/28/2007	0	0.73	12/28/2007	0	0.71
12/29/2007	0	0.73	12/29/2007	0	0.71
12/30/2007	0	0.73	12/30/2007	0	0.71
12/31/2007	0	0.73	12/31/2007	0	0.71
1/1/2008	0.0	0.73	1/1/2008	0	0.71
1/2/2008	0.0	0.72	1/2/2008	0	0.71

1/3/2008	0.0	0.72	1/3/2008	0	0.71
1/4/2008	0.0	0.72	1/4/2008	0	0.71
1/5/2008	0.0	0.71	1/5/2008	0	0.71
1/6/2008	2.4	0.71	1/6/2008	14.4	0.71
1/7/2008	4.3	0.71	1/7/2008	10.6	0.71
1/8/2008	3.5	0.7	1/8/2008	7.4	0.71
1/9/2008	0.0	0.7	1/9/2008	0	0.71
1/10/2008	0.0	0.7	1/10/2008	0	0.71
1/11/2008	0.0	0.7	1/11/2008	0	0.71
1/12/2008	0.0	0.69	1/12/2008	0	0.70
1/13/2008	0.0	0.69	1/13/2008	0	0.70
1/14/2008	0.0	0.69	1/14/2008	0	0.70
1/15/2008	5.2	0.69	1/15/2008	9	0.70
1/16/2008	4.6	0.68	1/16/2008	10.1	0.70
1/17/2008	7.5	0.68	1/17/2008	6	0.70
1/18/2008	0.0	0.68	1/18/2008	8	0.70
1/19/2008	0.0	0.68	1/19/2008	0	0.70
1/20/2008	0.0	0.67	1/20/2008	0	0.70
1/21/2008	0.0	0.67	1/21/2008	0	0.70
1/22/2008	0.0	0.67	1/22/2008	0	0.70
1/23/2008	0.0	0.67	1/23/2008	0	0.70
1/24/2008	0.0	0.66	1/24/2008	0	0.69
1/25/2008	0.0	0.66	1/25/2008	0	0.69
1/26/2008	0.0	0.66	1/26/2008	0	0.69
1/27/2008	0.0	0.65	1/27/2008	0	0.69
1/28/2008	0.0	0.65	1/28/2008	0	0.69
1/29/2008	0.0	0.65	1/29/2008	0	0.69
1/30/2008	0.0	0.65	1/30/2008	0	0.69
1/31/2008	0.0	0.65	1/31/2008	0	0.68
2/1/2008	0.0	0.64	2/1/2008	0	0.68
2/2/2008	0.0	0.64	2/2/2008	0	0.68
2/3/2008	0.0	0.64	2/3/2008	0	0.68
2/4/2008	0.0	0.64	2/4/2008	0	0.68
2/5/2008	0.0	0.64	2/5/2008	0	0.68
2/6/2008	0.0	0.63	2/6/2008	0	0.68
2/7/2008	0.0	0.63	2/7/2008	0	0.68
2/8/2008	0.0	0.63	2/8/2008	0	0.67
2/9/2008	0.0	0.63	2/9/2008	0	0.67
2/10/2008	0.0	0.63	2/10/2008	0	0.67
2/11/2008	0.0	0.62	2/11/2008	0	0.67
2/12/2008	0.0	0.62	2/12/2008	0	0.67

2/13/2008	0.0	0.62	2/13/2008	0	0.67
2/14/2008	0.0	0.62	2/14/2008	0	0.66
2/15/2008	0.0	0.61	2/15/2008	0	0.66
2/16/2008	0.0	0.61	2/16/2008	0	0.66
2/17/2008	0.0	0.61	2/17/2008	0	0.66
2/18/2008	0.0	0.61	2/18/2008	0	0.66
2/19/2008	0.0	0.61	2/19/2008	0	0.66
2/20/2008	0.0	0.61	2/20/2008	0	0.66
2/21/2008	0.0	0.6	2/21/2008	0	0.65
2/22/2008	0.0	0.6	2/22/2008	0	0.65
2/23/2008	0.0	0.6	2/23/2008	0	0.65
2/24/2008	0.0	0.6	2/24/2008	0	0.65
2/25/2008	0.0	0.6	2/25/2008	0	0.65
2/26/2008	0.0	0.6	2/26/2008	0	0.64
2/27/2008	0.0	0.6	2/27/2008	0	0.64
2/28/2008	0.0	0.6	2/28/2008	0	0.64
2/29/2008	0.0	0.6	2/29/2008	0	0.64
3/1/2008	0.0	0.59	3/1/2008	0	0.64
3/2/2008	0.0	0.59	3/2/2008	0	0.63
3/3/2008	0.0	0.59	3/3/2008	0	0.63
3/4/2008	0.0	0.59	3/4/2008	0	0.63
3/5/2008	0.0	0.59	3/5/2008	0	0.63
3/6/2008	0.0	0.59	3/6/2008	0	0.62
3/7/2008	0.0	0.59	3/7/2008	0	0.62
3/8/2008	0.0	0.59	3/8/2008	0	0.62
3/9/2008	0.0	0.59	3/9/2008	0	0.62
3/10/2008	0.0	0.58	3/10/2008	0	0.62
3/11/2008	0.0	0.58	3/11/2008	0	0.60
3/12/2008	0.0	0.58	3/12/2008	0	0.60
3/13/2008	0.0	0.58	3/13/2008	0	0.60
3/14/2008	0.0	0.58	3/14/2008	0	0.60
3/15/2008	0.0	0.58	3/15/2008	0	0.60
3/16/2008	0.0	0.58	3/16/2008	0	0.60
3/17/2008	0.0	0.58	3/17/2008	0	0.60
3/18/2008	3.7	0.58	3/18/2008	12.5	0.59
3/19/2008	6.7	0.58	3/19/2008	9.8	0.59
3/20/2008	10.2	0.6	3/20/2008	7.7	0.59
3/21/2008	6.1	0.61	3/21/2008	8.6	0.59
3/22/2008	6.7	0.62	3/22/2008	9.7	0.59
3/23/2008	5.3	0.63	3/23/2008	10.9	0.60
3/24/2008	6.6	0.63	3/24/2008	13.7	0.60

3/25/2008	12.1	0.68	3/25/2008	11	0.60
3/26/2008	18.1	0.8	3/26/2008	25.2	1.30
3/27/2008	7.5	0.9	3/27/2008	9	0.70
3/28/2008	8.5	1	3/28/2008	12.7	0.95
3/29/2008	10.6	1.5	3/29/2008	10.5	1.20
3/30/2008	10.0	1.3	3/30/2008	11.6	1.30
3/31/2008	11.5	1.3	3/31/2008	10.7	1.10
4/1/2008	17.9	2	4/1/2008	19.1	3.10
4/2/2008	5.0	1.1	4/2/2008	5.5	0.90
4/3/2008	11.8	1.2	4/3/2008	10.4	1.20
4/4/2008	9.2	1.2	4/4/2008	11.7	1.10
4/5/2008	6.4	1.1	4/5/2008	0	1.00
4/6/2008	9.0	1.2	4/6/2008	0	0.90
4/7/2008	18.2	1.5	4/7/2008	15.7	1.90
4/8/2008	13.5	1.7	4/8/2008	17	2.10
4/9/2008	8.4	1.4	4/9/2008	10	1.30
4/10/2008	25.1	3.4	4/10/2008	28.5	4.50
4/11/2008	14.9	1.7	4/11/2008	15	2.20
4/12/2008	19.3	1.8	4/12/2008	18.1	2.50
4/13/2008	14.0	1.7	4/13/2008	12.3	2.10
4/14/2008	15.0	1.8	4/14/2008	0	1.70
4/15/2008	11.0	1.5	4/15/2008	12.8	2.10
4/16/2008	15.3	1.8	4/16/2008	15.1	2.40
4/17/2008	27.7	2.6	4/17/2008	29.4	4.80
4/18/2008	25.0	2.6	4/18/2008	23.5	4.40
4/19/2008	26.1	2.7	4/19/2008	28.1	4.80
4/20/2008	17.9	2.5	4/20/2008	0	1.90
4/21/2008	12.5	1.9	4/21/2008	14.2	1.80
4/22/2008	13.6	2.1	4/22/2008	13.1	2.10
4/23/2008	15.5	2.2	4/23/2008	13.9	2.20
4/24/2008	17.9	2.5	4/24/2008	17.8	2.70
4/25/2008	13.8	2.2	4/25/2008	13.8	2.20
4/26/2008	5.6	1.6	4/26/2008	0	1.70
4/27/2008	11.2	1.8	4/27/2008	18	2.70
4/28/2008	15.5	2.1	4/28/2008	16.7	2.50
4/29/2008	19.3	3	4/29/2008	19.6	3.70
4/30/2008	8.4	2.4	4/30/2008	0	1.70
5/1/2008	3.5	2	5/1/2008	0	1.60
5/2/2008	11.3	2.2	5/2/2008	0	1.40
5/3/2008	15.8	2.4	5/3/2008	17.1	3.40
5/4/2008	13.1	2.3	5/4/2008	18.2	3.50

5/5/2008	13.4	2.3	5/5/2008	13.7	2.70
5/6/2008	15.6	2.5	5/6/2008	17.9	3.70
5/7/2008	6.7	1.7	5/7/2008	0	1.90
5/8/2008	10.0	1.9	5/8/2008	12.9	2.60
5/9/2008	12.4	2.1	5/9/2008	16.4	2.90
5/10/2008	5.0	1.5	5/10/2008	0	2.00
5/11/2008	5.6	1.4	5/11/2008	0	1.80
5/12/2008	8.7	1.6	5/12/2008	12.4	2.60
5/13/2008	8.9	1.7	5/13/2008	12	2.70
5/14/2008	26.5	3.8	5/14/2008	25.6	4.60
5/15/2008	9.3	1.9	5/15/2008	0	1.80
5/16/2008	15.1	2.6	5/16/2008	0	1.60
5/17/2008	12.8	2.2	5/17/2008	15.4	3.50
5/18/2008	10.5	2.1	5/18/2008	13.8	3.50
5/19/2008	8.8	1.7	5/19/2008	0	1.80
5/20/2008	9.4	1.9	5/20/2008	0	1.60
5/21/2008	0.0	1.6	5/21/2008	0	1.50
5/22/2008	0.0	1.4	5/22/2008	0	1.40
5/23/2008	0.0	1.2	5/23/2008	0	1.30
5/24/2008	11.7	2.3	5/24/2008	13	2.80
5/25/2008	19.9	3.2	5/25/2008	17.3	3.60
5/26/2008	19.6	3.3	5/26/2008	23.3	4.50
5/27/2008	9.7	2.1	5/27/2008	14.2	2.90
5/28/2008	10.4	2.2	5/28/2008	11.2	2.70
5/29/2008	8.6	1.9	5/29/2008	10.1	2.60
5/30/2008	8.2	2.1	5/30/2008	0	1.80
5/31/2008	13.5	2.3	5/31/2008	13.2	2.80
6/1/2008	18.3	2.9	6/1/2008	22.8	4.60
6/2/2008	8.7	2.1	6/2/2008	9.9	2.60
6/3/2008	8.1	2	6/3/2008	15.2	2.50
6/4/2008	25.7	3.6	6/4/2008	22.3	4.60
6/5/2008	2.7	1.9	6/5/2008	0	1.90
6/6/2008	5.6	1.8	6/6/2008	0	1.70
6/7/2008	5.4	1.8	6/7/2008	0	1.50
6/8/2008	5.1	1.9	6/8/2008	11.4	2.60
6/9/2008	9.9	2.1	6/9/2008	11.6	2.70
6/10/2008	7.6	2.1	6/10/2008	9.2	2.60
6/11/2008	0.0	1.6	6/11/2008	0	1.90
6/12/2008	0.0	1.4	6/12/2008	0	1.80
6/13/2008	0.0	1.2	6/13/2008	0	1.70
6/14/2008	0.0	1.1	6/14/2008	0	1.60

6/15/2008	0.0	1	6/15/2008	0	1.50
6/16/2008	9.0	1.8	6/16/2008	10.3	2.50
6/17/2008	0.0	1.6	6/17/2008	0	1.80
6/18/2008	0.0	1.4	6/18/2008	0	1.70
6/19/2008	0.0	1.2	6/19/2008	0	1.50
6/20/2008	0.0	1.1	6/20/2008	0	1.30
6/21/2008	13.0	2.3	6/21/2008	0	1.20
6/22/2008	4.1	1.7	6/22/2008	15.1	2.50
6/23/2008	15.5	2.6	6/23/2008	22.8	4.60
6/24/2008	6.1	1.9	6/24/2008	0	1.80
6/25/2008	3.9	1.8	6/25/2008	0	1.60
6/26/2008	3.7	1.8	6/26/2008	0	1.40
6/27/2008	15.0	2.6	6/27/2008	13.8	3.00
6/28/2008	18.6	2.9	6/28/2008	16.1	3.20
6/29/2008	6.0	1.9	6/29/2008	25.6	4.80
6/30/2008	9.8	2.1	6/30/2008	0	1.90
7/1/2008	0.0	1.7	7/1/2008	0	1.70
7/2/2008	9.9	2.2	7/2/2008	11.2	2.80
7/3/2008	0.0	1.7	7/3/2008	0	2.00
7/4/2008	0.0	1.7	7/4/2008	0	1.80
7/5/2008	0.0	1.6	7/5/2008	0	1.80
7/6/2008	0.0	1.5	7/6/2008	0	1.75
7/7/2008	0.0	1.4	7/7/2008	0	1.70
7/8/2008	0.0	1.3	7/8/2008	0	1.65
7/9/2008	0.0	1.3	7/9/2008	0	1.60
7/10/2008	0.0	1.2	7/10/2008	0	1.50
7/11/2008	0.0	1.1	7/11/2008	0	1.40
7/12/2008	0.0	1.1	7/12/2008	0	1.30
7/13/2008	0.0	1	7/13/2008	0	1.20
7/14/2008	13.0	2.3	7/14/2008	15.2	3.10
7/15/2008	0.0	1.7	7/15/2008	0	1.70
7/16/2008	8.0	1.9	7/16/2008	9.3	2.60
7/17/2008	9.8	2.1	7/17/2008	10.9	2.70
7/18/2008	10.5	2.3	7/18/2008	0	1.70
7/19/2008	10.3	2.4	7/19/2008	10.2	2.70
7/20/2008	11.5	2.5	7/20/2008	11.3	2.80
7/21/2008	15.1	2.8	7/21/2008	11.5	2.80
7/22/2008	14.4	2.7	7/22/2008	14.6	3.10
7/23/2008	15.4	2.8	7/23/2008	15.9	3.40
7/24/2008	13.6	2.6	7/24/2008	12.2	3.00
7/25/2008	25.3	3.5	7/25/2008	27.5	4.90

7/26/2008	14.7	2.8	7/26/2008	17	3.50
7/27/2008	10.2	2.5	7/27/2008	0	1.80
7/28/2008	15.1	2.8	7/28/2008	0	1.60
7/29/2008	15.5	2.9	7/29/2008	16.4	3.60
7/30/2008	14.9	2.8	7/30/2008	12.3	3.00
7/31/2008	11.7	2.5	7/31/2008	10.3	2.80
8/1/2008	14.1	2.6	8/1/2008	13.5	3.00
8/2/2008	13.0	2.6	8/2/2008	12.2	2.90
8/3/2008	6.3	1.9	8/3/2008	0	2.00
8/4/2008	0.0	1.7	8/4/2008	0	1.80
8/5/2008	0.0	1.5	8/5/2008	0	1.60
8/6/2008	7.4	1.9	8/6/2008	0	1.40
8/7/2008	15.6	2.8	8/7/2008	12.2	2.80
8/8/2008	12.7	2.7	8/8/2008	13.4	3.00
8/9/2008	9.8	2.1	8/9/2008	0	1.90
8/10/2008	11.0	2.6	8/10/2008	18.3	3.60
8/11/2008	10.1	2.6	8/11/2008	13.5	3.00
8/12/2008	14.9	2.8	8/12/2008	14	3.50
8/13/2008	5.1	2.1	8/13/2008	0	1.90
8/14/2008	23.2	3.4	8/14/2008	24.3	4.90
8/15/2008	6.5	2.4	8/15/2008	0	1.90
8/16/2008	10.9	2.6	8/16/2008	13.3	3.30
8/17/2008	20.2	3.2	8/17/2008	21.6	4.80
8/18/2008	11.0	2.6	8/18/2008	0	2.10
8/19/2008	23.0	3.5	8/19/2008	29.8	5.50
8/20/2008	25.7	3.8	8/20/2008	24.6	5.30
8/21/2008	9.3	2.6	8/21/2008	0	2.00
8/22/2008	8.8	2.5	8/22/2008	0	1.80
8/23/2008	8.4	2.4	8/23/2008	0	1.60
8/24/2008	9.1	2.6	8/24/2008	14.7	3.30
8/25/2008	20.5	3.3	8/25/2008	25.4	5.40
8/26/2008	4.1	1.9	8/26/2008	0	2.00
8/27/2008	0.0	1.7	8/27/2008	0	1.80
8/28/2008	0.0	1.5	8/28/2008	0	1.60
8/29/2008	12.9	2.6	8/29/2008	0	1.40
8/30/2008	13.2	2.7	8/30/2008	25.6	5.40
8/31/2008	21.4	3.7	8/31/2008	24.6	5.30
9/1/2008	12.7	2.7	9/1/2008	13.8	3.00
9/2/2008	5.7	2.1	9/2/2008	14.2	3.10
9/3/2008	5.6	2.1	9/3/2008	13.4	3.00
9/4/2008	7.9	2.2	9/4/2008	0	1.90

9/5/2008	4.7	2.1	9/5/2008	0	1.70
9/6/2008	5.1	2	9/6/2008	0	1.50
9/7/2008	12.9	2.7	9/7/2008	12.2	2.80
9/8/2008	21.5	3.8	9/8/2008	23.5	5.00
9/9/2008	11.1	2.6	9/9/2008	13.6	3.40
9/10/2008	5.1	2	9/10/2008	0	2.00
9/11/2008	10.9	2.6	9/11/2008	22.1	4.80
9/12/2008	9.8	2.5	9/12/2008	0	1.90
9/13/2008	9.5	2.4	9/13/2008	10.9	2.80
9/14/2008	11.0	2.5	9/14/2008	24.1	5.20
9/15/2008	14.1	2.8	9/15/2008	10.1	2.80
9/16/2008	6.3	2.4	9/16/2008	18.3	4.10
9/17/2008	0.0	1.9	9/17/2008	0	2.10
9/18/2008	0.0	1.8	9/18/2008	0	1.90
9/19/2008	0.0	1.7	9/19/2008	0	1.70
9/20/2008	0.0	1.6	9/20/2008	0	1.60
9/21/2008	0.0	1.5	9/21/2008	0	1.50
9/22/2008	6.0	2.3	9/22/2008	0	1.40
9/23/2008	7.6	2.4	9/23/2008	0	1.30
9/24/2008	9.6	2.7	9/24/2008	12.4	2.90
9/25/2008	8.8	2.8	9/25/2008	14.6	3.20
9/26/2008	8.0	2.6	9/26/2008	13.1	3.00
9/27/2008	0.0	1.9	9/27/2008	0	1.90
9/28/2008	0.0	1.7	9/28/2008	0	1.80
9/29/2008	0.0	1.6	9/29/2008	0	1.70
9/30/2008	0.0	1.5	9/30/2008	0	1.60
10/1/2008	0.0	1.4	10/1/2008	0	1.50
10/2/2008	0.0	1.3	10/2/2008	0	1.40
10/3/2008	9.2	2.7	10/3/2008	0	1.30
10/4/2008	6.7	2.5	10/4/2008	11.3	2.80
10/5/2008	7.2	2.6	10/5/2008	15.3	3.40
10/6/2008	12.8	2.8	10/6/2008	18.7	3.60
10/7/2008	4.4	2.1	10/7/2008	0	1.70
10/8/2008	12.4	2.8	10/8/2008	12	2.80
10/9/2008	7.7	2.5	10/9/2008	18.3	3.70
10/10/2008	4.5	2.3	10/10/2008	19.5	3.80
10/11/2008	6.3	2.4	10/11/2008	0	1.90
10/12/2008	0.0	2.1	10/12/2008	0	1.80
10/13/2008	10.4	2.7	10/13/2008	0	1.70
10/14/2008	8.9	2.6	10/14/2008	0	1.60
10/15/2008	5.3	2.3	10/15/2008	0	1.50

10/16/2008	7.5	2.5	10/16/2008	0	1.45
10/17/2008	5.6	2.4	10/17/2008	0	1.40
10/18/2008	5.5	2.4	10/18/2008	15.4	3.40
10/19/2008	5.4	2.3	10/19/2008	0	1.90
10/20/2008	10.5	2.7	10/20/2008	16.6	3.50
10/21/2008	9.1	2.6	10/21/2008	12.8	2.80
10/22/2008	4.9	2.3	10/22/2008	0	1.70
10/23/2008	4.2	2.2	10/23/2008	23.8	5.10
10/24/2008	7.2	2.5	10/24/2008	16.6	3.30
10/25/2008	5.9	2.3	10/25/2008	21.9	4.90
10/26/2008	5.5	2.2	10/26/2008	0	1.90
10/27/2008	8.9	2.4	10/27/2008	0	1.80
10/28/2008	6.0	2.3	10/28/2008	0	1.70
10/29/2008	8.4	2.4	10/29/2008	0	1.60
10/30/2008	0.0	1.7	10/30/2008	20.4	4.7
10/31/2008	0.0	1.6	10/31/2008	0	1.4
11/1/2008	0.0	1.5	11/1/2008	0	1.3
11/2/2008	2.0	1.8	11/2/2008	0	1.2
11/3/2008	2.8	1.9	11/3/2008	0	1.1
11/4/2008	2.2	1.9	11/4/2008	0	1
11/5/2008	1.4	1.3	11/5/2008	14.3	0.95
11/6/2008	0.9	1.1	11/6/2008	13.8	0.93
11/7/2008	2.0	1.4	11/7/2008	0	0.92
11/8/2008	0.0	1.2	11/8/2008	0	0.91
11/9/2008	0.0	1.1	11/9/2008	0	0.9
11/10/2008	0.0	1	11/10/2008	0	0.89
11/11/2008	0.0	0.9	11/11/2008	0	0.88
11/12/2008	0.0	0.93	11/12/2008	0	0.87
11/13/2008	0.0	0.92	11/13/2008	0	0.86
11/14/2008	0.0	0.91	11/14/2008	0	0.85
11/15/2008	0.0	0.89	11/15/2008	0	0.84
11/16/2008	0.0	0.86	11/16/2008	0	0.81
11/17/2008	0.0	0.85	11/17/2008	0	0.8
11/18/2008	0.0	0.83	11/18/2008	0	0.78
11/19/2008	0.0	0.82	11/19/2008	0	0.77
11/20/2008	0.0	0.8	11/20/2008	0	0.75
11/21/2008	0.0	0.79	11/21/2008	0	0.74
11/22/2008	0.0	0.78	11/22/2008	0	0.74
11/23/2008	0.0	0.77	11/23/2008	0	0.73
11/24/2008	0.0	0.77	11/24/2008	0	0.72
11/25/2008	0.0	0.76	11/25/2008	0	0.71

11/26/2008	0.0	0.76	11/26/2008	0	0.71
11/27/2008	0.0	0.75	11/27/2008	0	0.7
11/28/2008	0.0	0.75	11/28/2008	0	0.7
11/29/2008	0.0	0.74	11/29/2008	0	0.69
11/30/2008	0.0	0.74	11/30/2008	0	0.69
12/1/2008	0.0	0.73	12/1/2008	0	0.68
12/2/2008	0.0	0.72	12/2/2008	0	0.68
12/3/2008	0.0	0.71	12/3/2008	0	0.67
12/4/2008	0.0	0.7	12/4/2008	0	0.66
12/5/2008	0.0	0.69	12/5/2008	0	0.65
12/6/2008	0.0	0.68	12/6/2008	0	0.64
12/7/2008	0.0	0.68	12/7/2008	0	0.63
12/8/2008	0.0	0.67	12/8/2008	0	0.63
12/9/2008	0.0	0.66	12/9/2008	0	0.62
12/10/2008	0.0	0.65	12/10/2008	0	0.62
12/11/2008	0.0	0.64	12/11/2008	0	0.61
12/12/2008	0.0	0.63	12/12/2008	0	0.61
12/13/2008	0.0	0.62	12/13/2008	0	0.61
12/14/2008	0.0	0.61	12/14/2008	0	0.6
12/15/2008	0.0	0.6	12/15/2008	0	0.6
12/16/2008	0.0	0.59	12/16/2008	0	0.6
12/17/2008	0.0	0.59	12/17/2008	0	0.59
12/18/2008	0.0	0.58	12/18/2008	0	0.59
12/19/2008	0.0	0.58	12/19/2008	0	0.59
12/20/2008	0.0	0.58	12/20/2008	0	0.58
12/21/2008	0.0	0.58	12/21/2008	0	0.58
12/22/2008	0.0	0.57	12/22/2008	0	0.58
12/23/2008	0.0	0.57	12/23/2008	0	0.58
12/24/2008	0.0	0.57	12/24/2008	0	0.58
12/25/2008	0.0	0.57	12/25/2008	0	0.57
12/26/2008	0.0	0.57	12/26/2008	13.3	0.57
12/27/2008	0.0	0.57	12/27/2008	0	0.57
12/28/2008	0.0	0.56	12/28/2008	0	0.57
12/29/2008	0.0	0.56	12/29/2008	0	0.57
12/30/2008	0.0	0.56	12/30/2008	0	0.57
12/31/2008	0.0	0.56	12/31/2008	0	0.57

APPENDIX B

Raw data pertaining to Chapter 2.

Table B1: Data table for Chapter 2, Table 2.1

	0.33 bar	Bulk density (g cm^{-3})	Total porosity	SOM (%)	SOC (g kg^{-1})
forest	36.194	0.691	0.739	14.946	95.3
forest	35.232	0.718	0.729	14.751	105.2
forest	33.449	0.685	0.742	21.77	124.5
forest	34.065	0.751	0.717	17.91	116.7
forest	34.575	0.655	0.753	16.03	99.8
5yr	35.88	0.905	0.658	13.812	71.5
5yr	33.258	0.909	0.657	12.32	59.8
5yr	33.879	0.967	0.635	14.002	75
5yr	32.761	0.953	0.64	13.97	70.1
5yr	34.492	0.84	0.683	14.26	67.6
10yr	26.537	1.18	0.555	8.163	33.9
10yr	23.147	0.921	0.652	8.744	40.3
10yr	25.94	0.983	0.629	8.681	34.9
10yr	24.056	1.14	0.57	8.45	39.7
10yr	24.7	0.95	0.642	8.62	33.2
50yr	23.31	1.19	0.551	6.209	24.9
50yr	21.88	0.98	0.63	7.67	26.9
50yr	23.26	1.22	0.54	7.123	30.6
50yr	22.84	1.21	0.543	6.85	28.6
50yr	23.54	1.25	0.528	7.15	26.5
	SOC (t ha^{-1})	**Soil N (g kg^{-1})**	**Soil N (t ha^{-1})**	**available Ca (g kg^{-1})**	**available K (g kg^{-1})**
forest	76.24	11.2	8.96	6.760	0.470
forest	84.16	10.6	8.48	6.511	1.433
forest	99.6	11.3	9.04	6.425	0.369
forest	93.36	12.1	9.68	5.909	0.565
forest	79.84	10.5	8.4	5.685	0.623
5yr	65.065	7.3	6.643	5.170	0.256
5yr	54.418	5.8	5.278	3.692	0.394

5yr	68.25	7.7	7.007	5.955	0.897
5yr	63.791	6.6	6.006	5.488	0.754
5yr	61.516	7.1	6.461	4.611	0.603
10yr	34.917	3.1	3.193	1.355	0.153
10yr	41.509	3.9	4.017	2.466	0.306
10yr	35.947	3.1	3.193	2.195	0.198
10yr	40.891	3.2	3.296	1.475	0.354
10yr	34.196	3.4	3.502	1.359	0.138
50yr	29.133	2.2	2.574	3.410	0.399
50yr	31.473	1.9	2.223	2.412	0.389
50yr	35.802	2.6	3.042	3.903	0.532
50yr	33.462	2.1	2.457	2.502	0.492
50yr	31.005	2.3	2.691	2.344	0.393
	available Mg (g kg^{-1})	**available Na (g kg^{-1})**	**available P (g kg^{-1})**	**pH**	
forest	0.643	0.011	0.013	7.26	
forest	0.542	0.017	0.006	7.51	
forest	0.735	0.012	0.025	7.45	
forest	0.893	0.012	0.004	7.54	
forest	0.843	0.080	0.010	7.19	
5yr	0.511	0.014	0.019	6.34	
5yr	0.455	0.010	0.002	6.19	
5yr	0.467	0.053	0.006	6.65	
5yr	0.437	0.011	0.005	6.78	
5yr	0.400	0.012	0.004	6.44	
10yr	0.194	0.013	0.003	6.46	
10yr	0.273	0.011	0.004	6.17	
10yr	0.203	0.010	0.002	6.24	
10yr	0.181	0.008	0.002	6.29	
10yr	0.171	0.009	0.004	6.01	
50yr	0.374	0.011	0.022	5.92	
50yr	0.284	0.009	0.002	5.98	
50yr	0.433	0.015	0.003	5.97	
50yr	0.280	0.010	0.002	5.35	
50yr	0.286	0.010	0.003	5.85	

Table B2: Data table for Chapter 2, Figure 2.1

	0-10 cm (‰)	10-30 cm (‰)	30 -90 cm (‰)	90-150 cm (‰)	150-240 cm (‰)
forest	-25.05	-24.10	-20.76	-17.90	-18.62
forest	-26.42	-23.01	-19.55	-14.36	-16.95
forest	-26.44	-24.14	-20.74	-19.61	-21.98
forest	-26.34	-22.90	-20.33	-17.75	-17.27
5yr	-24.13	-23.23	-20.13	-14.92	-16.68
5yr	-25.60	-23.46	-19.87	-15.57	-17.39
5yr	-25.79	-23.45	-19.61	-17.30	-17.32
5yr	-25.97	-22.44	-18.37	-16.04	-15.69
10yr	-21.46	-20.56	-17.95	-15.56	-16.05
10yr	-22.35	-20.36	-22.24	-18.53	-17.68
10yr	-20.53	-20.62	-17.29	-14.55	-14.50
10yr	-20.52	-19.57	-16.68	-13.51	-14.89
50yr	-19.29	-19.09	-17.54	-15.36	-14.85
50yr	-19.74	-19.40	-17.10	-15.28	-13.68
50yr	-18.71	-18.48	-16.77	-15.21	-14.22
50yr	-18.97	-18.53	-17.63	-16.62	-14.19

Table B3: Data table for Chapter 2, Table 2.2

	$d^{13}C$-CPOC (‰)			$d^{13}C$-CPOC (‰)
forest	-26.608		**5yr**	-28.04
forest	-27.305		**5yr**	-27.218
forest	-28.042		**5yr**	-27.907
forest	-28.083		**5yr**	-26.893
forest	-28.014		**5yr**	-27.321
forest	-28.479		**5yr**	-27.749
forest	-27.441		**5yr**	-27.932
forest	-28.098		**5yr**	-28.268
forest	-27.857		**5yr**	-23.531
forest	-28.414		**5yr**	-27.623
forest	-28.153		**5yr**	-27.999
forest	-27.994		**5yr**	-28.524
forest	-27.757		**5yr**	-27.082
forest	-27.063		**5yr**	-27.779
forest	-27.902		**5yr**	-28.102
forest	-28.138		**5yr**	-27.348
forest	-27.918		**5yr**	-27.874
forest	-26.549		**5yr**	-26.867
forest	-26.471		**5yr**	-26.555
forest	-26.071		**5yr**	-25.598
forest	-27.739		**5yr**	-27.375
forest	-27.499		**5yr**	-27.246
forest	-26.676		**5yr**	-27.418
forest	-26.145		**5yr**	-26.633
10yr	-28.041		**50yr**	-26.602
10yr	-27.933		**50yr**	-26.933
10yr	-27.258		**50yr**	-25.73
10yr	-25.917		**50yr**	-27.242
10yr	-27.664		**50yr**	-26.762
10yr	-27.262		**50yr**	-27.142
10yr	-27.778		**50yr**	-26.645
10yr	-27.89		**50yr**	-27.304
10yr	-27.598		**50yr**	-26.126
10yr	-27.441		**50yr**	-26.422

10yr	-28.327		**50yr**	-27.358
10yr	-27.343		**50yr**	-25.645
10yr	-26.783		**50yr**	-25.333
10yr	-28.569		**50yr**	-26.835
10yr	-27.442		**50yr**	-26.433
10yr	-27.318		**50yr**	-27.033
10yr	-27.182		**50yr**	-26.003
10yr	-26.006		**50yr**	-25.658
10yr	-26.33		**50yr**	-26.001
10yr	-25.976		**50yr**	-25.199
10yr	-27.499		**50yr**	-26.526
10yr	-26.696		**50yr**	-26.468
10yr	-27.281		**50yr**	-26.285
10yr	-27.22		**50yr**	-25.82

	DOC-d13C (‰)	
forest	-28.77	
forest	-28.81	
forest	-28.17	
forest	-28.61	
5yr	-28.42	
5yr	-28.07	
5yr	-28.25	
5yr	-28.25	
10yr	-27.34	
10yr	-26.24	
10yr	-26.79	
10yr	-26.80	
50yr	-22.52	
50yr	-22.14	
50yr	-22.59	
50yr	-23.75	

	NO_3-N – forest (mg L^{-1})	**TDN – forest (mg L^{-1})**	**Ca – forest (mg L^{-1})**	**K – forest (mg L^{-1})**
January-08	0.424	0.557	6.830	0.243
February-08	0.401	0.556	7.048	0.624
March-08	0.412	0.548	7.108	0.442

April-08	0.4148	0.555	7.323	0.812
May-08	0.443	0.558	7.535	0.628
June-08	0.397	0.462	7.492	0.490
July-08	0.345	0.402	7.650	1.067
August-08	0.381	0.428	7.163	0.090
September-08	0.404	0.482	7.062	0
October-08	0.401	0.473	7.162	0
November-08	0.395	0.486	7.138	0
December-08	0.398	0.471	7.208	0
	Mg – forest (mg L^{-1})	**Na – forest (mg L^{-1})**	**CPOC – forest (mg L^{-1})**	**CPON – forest (mg L^{-1})**
January-08	2.840	3.467	0.930	0.014
February-08	2.955	3.557	1.716	0.044
March-08	2.944	3.556	1.102	0.015
April-08	3.067	3.610	1.131	0.058
May-08	3.100	3.379	1.137	0.127
June-08	3.106	3.535	1.050	0.057
July-08	3.143	3.449	1.363	0.240
August-08	2.996	2.285	1.112	0.091
September-08	3.016	2.306	1.341	0.052
October-08	2.986	2.380	1.479	0.238
November-08	2.969	2.260	1.311	0.265

December-08	2.980	2.323	1.129	0.355
	TDP – forest ($mg\ L^{-1}$)	**DOC – forest ($mg\ L^{-1}$)**	**DON – forest ($mg\ L^{-1}$)**	
January-08	0.001	1.635	0.132	
February-08	0	1.551	0.155	
March-08	0.019	1.500	0.135	
April-08	0.028	1.557	0.14	
May-08	0.036	1.440	0.115	
June-08	0.034	1.372	0.065	
July-08	0.015	0.951	0.057	
August-08	0.106	0.981	0.046	
September-08	0.016	1.533	0.078	
October-08	0.021	1.447	0.072	
November-08	0.013	0.984	0.091	
December-08	0.039	0.938	0.073	
	NO_3-N - 5yr ($mg\ L^{-1}$)	**TDN - 5yr ($mg\ L^{-1}$)**	**Ca - 5yr ($mg\ L^{-1}$)**	**K - 5yr ($mg\ L^{-1}$)**
January-08	0.632	0.718	4.920	0.858
February-08	0.685	0.759	5.584	1.051
March-08	0.710	0.787	5.273	1.150
April-08	0.690	0.801	5.627	1.267
May-08	0.591	0.671	5.752	1.258
June-08	0.542	0.605	5.719	1.072

July-08	0.536	0.657	5.873	1.188
August-08	0.577	0.673	5.645	0.403
September-08	0.568	0.646	5.4877	0.353
October-08	0.473	0.577	5.761	0.496
November-08	0.528	0.669	5.351	0.314
December-08	0.499	0.578	5.596	0.212
	Mg - 5yr (mg L^{-1})	**Na - 5yr (mg L^{-1})**	**CPOC - 5yr (mg L^{-1})**	**CPON - 5yr (mg L^{-1})**
January-08	1.720	3.836	1.500	0.099
February-08	1.842	4.011	1.640	0.136
March-08	1.944	4.226	1.897	0.167
April-08	2.020	4.304	1.147	0.066
May-08	2.003	4.325	1.906	0.216
June-08	2.126	4.131	1.249	0.121
July-08	2.161	3.625	1.242	0.1653
August-08	2.032	3.251	1.616	0.126
September-08	2.073	3.271	1.256	0.109
October-08	2.146	3.267	1.302	0.311
November-08	2.039	3.246	1.316	0.117
December-08	1.966	2.91658047	1.309	0.108

	TDP - 5yr ($mg L^{-1}$)	DOC - 5yr ($mg L^{-1}$)	DON - 5yr ($mg L^{-1}$)	
January-08	0.001	1.788	0.087	
February-08	0.006	1.648	0.073	
March-08	0	1.700	0.077	
April-08	0	1.771	0.110	
May-08	0.019	1.975	0.080	
June-08	0.005	1.523	0.063	
July-08	0.010	1.188	0.121	
August-08	0.014	1.132	0.096	
September-08	0	1.458	0.078	
October-08	0.010	1.307	0.104	
November-08	0.005	1.176	0.141	
December-08	0.005	1.044	0.078	
	NO_3-N^- 10yr ($mg L^{-1}$)	TDN - 10yr ($mg L^{-1}$)	Ca - 10yr ($mg L^{-1}$)	K - 10yr ($mg L^{-1}$)
January-08	4.530	4.566	5.364	1.442
February-08	4.767	4.741	5.646	1.565
March-08	4.614	4.820	5.635	1.759

April-08	4.680	4.908	5.890	1.637
May-08	4.952	5.007	5.711	1.635
June-08	4.788	4.731	5.561	1.502
July-08	4.790	4.914	5.760	1.591
August-08	4.890	4.948	5.385	0.300
September-08	4.745	5.003	5.436	0.015
October-08	4.566	4.725	5.275	0.034
November-08	4.514	4.509	5.000	0.016
December-08	4.643	5.015	5.215	0.180
	Mg - 10yr (mg L^{-1})	**Na - 10yr (mg L^{-1})**	**CPOC - 10yr (mg L^{-1})**	**CPON - 10yr (mg L^{-1})**
January-08	1.551	5.185	1.634	0.163
February-08	1.623	5.245	1.730	0.060
March-08	1.641	5.503	1.440	0.160
April-08	1.699	5.583	1.594	0.201
May-08	1.677	5.556	1.536	0.086
June-08	1.626	5.286	1.614	0.129
July-08	1.674	5.505	1.480	0.177
August-08	1.595	4.099	1.282	0.169
September-08	1.603	3.795	1.316	0.110
October-08	1.553	3.458	1.631	0.209
November-08	1.505	3.403	1.266	0.172
December-08	1.542	3.468	1.465	0.274

	TDP - 10yr (mg L^{-1})	DOC - 10yr (mg L^{-1})	DON - 10yr (mg L^{-1})	
January-08	0.034	1.902	0.035	
February-08	0.034	1.728	0.174	
March-08	0.022	1.779	0.106	
April-08	0.046	1.725	0.128	
May-08	0.044	1.665	0.055	
June-08	0.062	1.690	0.043	
July-08	0.054	1.042	0.124	
August-08	0.081	1.060	0.043	
September-08	0.038	1.298	0.238	
October-08	0.066	1.455	0.158	
November-08	0.014	1.297	0.095	
December-08	0.029	1.178	0.212	
	NO_3-N - 50yr (mg L^{-1})	**TDN - 50yr (mg L^{-1})**	**Ca - 50yr (mg L^{-1})**	**K - 50yr (mg L^{-1})**
January-08	4.531	5.331	7.274	1.584
February-08	4.632	5.017	7.164	1.729
March-08	4.563	5.374	7.101	1.601
April-08	4.594	4.892	7.429	1.848
May-08	4.415	4.854	6.964	1.560
June-08	4.764	4.956	7.320	2.042
July-08	4.612	4.643	7.208	2.303
August-08	4.440	4.509	7.235	0.768
September-08	4.336	4.468	7.347	0.385

October-08	4.189	4.299	7.017	0.090
November-08	4.205	4.257	6.846	0.028
December-08	4.217	4.322	6.790	0.281
	Mg - 50yr (mg L^{-1})	**Na - 50yr (mg L^{-1})**	**CPOC - 50yr (mg L^{-1})**	**CPON - 50yr (mg L^{-1})**
January-08	2.570	6.200	1.3165	0.158
February-08	2.624	6.381	1.7563	0.178
March-08	2.551	6.361	1.5477	0.176
April-08	2.690	6.410	1.579	0.179
May-08	2.425	6.392	2.031	0.144
June-08	2.650	6.422	2.318	0.168
July-08	2.632	6.613	1.618	0.161
August-08	2.537	5.060	1.5477	0.188
September-08	2.539	4.548	1.613	0.178
October-08	2.453	4.414	1.392	0.128
November-08	2.385	4.318	1.449	0.106
December-08	2.432	4.321	1.890	0.111
	P - 50yr (mg L^{-1})	**DOC - 50yr (mg L^{-1})**	**DON - 50yr (mg L^{-1})**	
January-08	0.156	1.903	0.200	
February-08	0.278	1.723	0.184	
March-08	0.071	1.802	0.011	
April-08	0.171	1.853	0.198	
May-08	0.180	2.099	0.139	
June-08	0.168	1.470	0.192	
July-08	0.170	1.007	0.031	
August-08	0.221	1.370	0.069	
September-08	0.213	1.580	0.131	

October-08	0.016	1.319	0.1094	
November-08	0.0243	1.229	0.052	
December-08	0.018	1.139	0.105	

Table B4: Data table for Chapter 2 , Figure 2.2

Date	Discharge - forest (mm day^{-1})	DOC - forest (mg L^{-1})	TDN – forest (mg L^{-1})	TDP – forest (mg L^{-1})
1/3/2008	0.61	1.749	0.550	0
1/17/2008	0.60	1.512	0.563	0.003
2/1/2008	0.59	1.561	0.576	0
2/16/2008	0.59	1.540	0.535	0
3/3/2008	0.59	1.518	0.544	0
3/15/2008	0.59	1.483	0.552	0.037
4/2/2008	0.60	1.576	0.554	0
4/16/2008	0.62	1.539	0.556	0.055
5/2/2008	0.64	1.401	0.576	0
5/16/2008	0.68	1.474	0.541	0.068
6/2/2008	0.76	1.648	0.489	0.066
6/16/2008	0.88	1.133	0.438	0.006
7/2/2008	0.91	0.996	0.435	0
7/16/2008	0.93	0.909	0.372	0.029
8/2/2008	0.94	0.956	0.409	0.074
8/16/2008	0.97	1.003	0.446	0.134
9/2/2008	1.02	1.176	0.468	0
9/16/2008	1.12	1.859	0.495	0.031
10/2/2008	1.28	1.646	0.522	0
10/16/2008	1.36	1.271	0.429	0.040
11/3/2008	1.04	1.016	0.509	0.023
11/17/2008	0.84	0.945	0.459	0
12/3/2008	0.65	0.987	0.468	0.061
12/17/2008	0.60	0.888	0.474	0.017

Date	Ca – forest (mg L^{-1})	K – forest (mg L^{-1})	Mg – forest (mg L^{-1})	Na-forest (mg L^{-1})
1/3/2008	6.817	0.244	2.845	3.374
1/17/2008	6.843	0.241	2.836	3.568
2/1/2008	6.968	0.774	2.938	3.504
2/16/2008	7.134	0.462	2.974	3.615
3/3/2008	7.136	0.385	2.956	3.584
3/15/2008	7.083	0.496	2.932	3.530
4/2/2008	7.197	0.770	3.033	3.564
4/16/2008	7.446	0.853	3.099	3.656
5/2/2008	7.528	0.613	3.079	3.748
5/16/2008	7.542	0.641	3.121	3.618
6/2/2008	7.509	0.803	3.112	3.564
6/16/2008	7.477	0.965	3.103	3.510
7/2/2008	7.737	1.269	3.168	3.829
7/16/2008	7.570	0.882	3.120	3.675
8/2/2008	7.303	0.189	3.039	3.025
8/16/2008	7.036	0	2.957	2.376
9/2/2008	7.331	0	3.023	2.284
9/16/2008	6.818	0	3.010	2.327
10/2/2008	7.280	0	2.998	2.369
10/16/2008	7.057	0	2.975	2.389
11/3/2008	7.292	0	3.011	2.282
11/17/2008	6.947	0	2.918	2.232
12/3/2008	7.176	0	2.977	2.283
12/17/2008	7.242	0	2.983	2.363
Date	**discharge - 5yr (mm day^{-1})**	**DOC - 5yr (mg L^{-1})**	**TDN - 5yr (mg L^{-1})**	**TDP - 5yr (mg L^{-1})**
1/3/2008	0.71	1.589	0.723	0
1/17/2008	0.68	2.009	0.714	0.002
2/1/2008	0.64	1.536	0.684	0.011
2/16/2008	0.61	1.774	0.842	0
3/3/2008	0.59	1.67	0.791	0
3/16/2008	0.58	1.729	0.784	0
4/2/2008	1.11	1.729	0.676	0
4/16/2008	2.44	1.79	0.858	0

5/2/2008	1.96	1.834	0.55	0.012
5/16/2008	1.91	2.111	0.782	0.026
6/2/2008	1.74	1.669	0.685	0.008
6/16/2008	1.23	1.316	0.492	0
7/2/2008	1.21	1.276	0.689	0.024
7/16/2008	1.61	1.126	0.635	0
8/2/2008	1.82	0.881	0.660	0
8/16/2008	2.19	1.328	0.684	0.025
9/2/2008	2.11	1.318	0.672	0
9/16/2008	1.36	1.674	0.606	0
10/2/2008	1.43	1.385	0.539	0.015
10/17/2008	1.21	1.221	0.619	0.003
11/3/2008	0.97	1.094	0.581	0.008
11/17/2008	0.84	1.271	0.771	0
12/3/2008	0.76	1.009	0.591	0.003
12/17/2008	0.59	1.087	0.561	0.008
Date	**Ca - 5yr (mg L^{-1})**	**K - 5yr (mg L^{-1})**	**Mg - 5yr (mg L^{-1})**	**Na-5yr (mg L^{-1})**
1/3/2008	4.908	0.828	1.705	3.846
1/17/2008	4.934	0.891	1.737	3.825
2/1/2008	5.032	1.111	1.826	3.972
2/16/2008	5.142	0.984	1.859	4.055
3/3/2008	5.357	1.092	1.989	4.268
3/16/2008	5.193	1.010	1.901	4.186
4/2/2008	5.228	0.978	1.921	4.220
4/16/2008	5.809	1.399	2.065	4.343
5/2/2008	5.771	1.306	1.889	4.240
5/16/2008	5.734	1.212	2.113	4.407
6/2/2008	5.852	1.054	2.163	4.535
6/16/2008	5.532	1.098	2.074	3.559
7/2/2008	5.922	1.087	2.169	3.666
7/16/2008	5.839	1.259	2.157	3.596
8/2/2008	5.546	0.545	1.933	3.375
8/16/2008	5.652	0.293	2.109	3.154
9/2/2008	5.299	0.359	2.053	3.163
9/16/2008	5.526	0.344	2.105	3.184
10/2/2008	5.754	0.330	2.157	3.206

10/17/2008	5.643	0.258	2.134	3.335
11/3/2008	5.196	0.296	2.030	3.009
11/17/2008	5.467	0.334	2.050	3.088
12/3/2008	5.257	0.167	1.990	2.942
12/17/2008	5.077	0.266	1.938	2.886
Date	**Discharge - 10yr (mm day^{-1})**	**DOC - 10yr (mg L^{-1})**	**TDN - 10yr (mg L^{-1})**	**TDP - 10yr (mg L^{-1})**
1/3/2008	0.71	1.887	4.355	0.036
1/17/2008	0.68	2.131	4.8	0.033
2/1/2008	0.64	1.805	4.693	0.035
2/16/2008	0.61	1.642	4.796	0.034
3/3/2008	0.59	1.802	4.73	0.031
3/16/2008	0.59	1.757	4.905	0.015
4/2/2008	1.21	1.96	5.079	0.076
4/16/2008	2.16	1.749	4.812	0.030
5/2/2008	2.19	1.726	4.93	0.038
5/16/2008	1.90	1.807	5.091	0.051
6/2/2008	2.32	1.944	4.678	0.087
6/16/2008	1.58	1.317	4.81	0.026
7/2/2008	1.84	1.204	4.804	0.020
7/16/2008	1.99	0.901	5.01	0.083
8/2/2008	2.48	0.955	4.97	0.082
8/16/2008	2.79	1.147	4.93	0.080
9/2/2008	2.49	1.327	5.148	0.060
9/16/2008	2.17	1.48	4.836	0.013
10/2/2008	2.22	1.835	4.568	0.046
10/17/2008	2.41	1.313	4.86	0.085
11/3/2008	1.76	1.343	4.516	0.013
11/17/2008	0.84	1.51	4.494	0.016
12/3/2008	0.71	1.191	4.963	0.027
12/17/2008	0.58	1.163	5.074	0.034
Date	**Ca - 10yr (mg L^{-1})**	**K - 10yr (mg L^{-1})**	**Mg - 10yr (mg L^{-1})**	**Na-10yr (mg L^{-1})**
1/3/2008	5.233	1.374	1.512	5.128
1/17/2008	5.510	1.728	1.594	5.250
2/1/2008	5.605	1.657	1.612	5.313
2/16/2008	5.693	1.675	1.635	5.381

3/3/2008	5.544	1.777	1.616	5.574
3/16/2008	5.720	1.936	1.665	5.631
4/2/2008	5.896	2.094	1.714	5.688
4/16/2008	5.887	1.693	1.691	5.681
5/2/2008	5.767	1.789	1.684	5.559
5/16/2008	5.651	1.678	1.669	5.553
6/2/2008	5.631	1.525	1.656	5.328
6/16/2008	5.457	1.715	1.582	5.225
7/2/2008	5.688	1.941	1.639	5.473
7/16/2008	5.822	2.034	1.703	5.720
8/2/2008	5.540	0.660	1.633	4.671
8/16/2008	5.257	0	1.563	3.622
9/2/2008	5.522	0.026	1.625	3.874
9/16/2008	5.337	0.003	1.578	3.704
10/2/2008	5.335	0.075	1.580	3.706
10/17/2008	5.223	0	1.531	3.616
11/3/2008	4.977	0.023	1.501	3.557
11/17/2008	5.048	0.002	1.514	3.700
12/3/2008	5.104	0.058	1.528	3.629
12/17/2008	5.342	0.320	1.558	3.714
Date	**discharge - 50yr (mm day^{-1})**	**DOC - 50yr (mg L^{-1})**	**TDN - 50yr (mg L^{-1})**	**TDP - 50yr (mg L^{-1})**
1/3/2008	0.71	1.711	5.27	0.029
1/17/2008	0.70	2.111	5.397	0.294
2/1/2008	0.68	1.789	5.527	0.271
2/16/2008	0.66	1.651	5.505	0.286
3/3/2008	0.63	1.896	5.361	0.068
3/16/2008	0.60	1.709	5.386	0.073
4/2/2008	1.25	2.012	4.927	0.203
4/16/2008	2.82	1.783	4.877	0.157
5/2/2008	2.56	2.138	4.929	0.145
5/16/2008	2.26	2.057	4.98	0.218
6/2/2008	2.85	1.615	4.963	0.182
6/16/2008	2.01	1.265	4.946	0.147
7/2/2008	2.16	1.16	4.778	0.239
7/16/2008	2.29	0.872	4.901	0.109
8/2/2008	2.62	1.385	4.61	0.182
8/16/2008	3.23	1.358	3.904	0.251

9/2/2008	3.04	1.427	4.33	0.217
9/16/2008	2.51	1.765	3.971	0.207
10/2/2008	2.39	1.402	4.187	0.023
10/17/2008	2.40	1.241	4.403	0.010
11/3/2008	1.74	1.186	4.103	0.026
11/17/2008	0.80	1.322	4.591	0.020
12/3/2008	0.67	1.2	4.774	0.009
12/17/2008	0.59	1.075	4.666	0.027
Date	**Ca - 50yr (mg L^{-1})**	**K - 50yr (mg L^{-1})**	**Mg - 50yr (mg L^{-1})**	**Na-50yr (mg L^{-1})**
1/3/2008	7.131	1.864	2.527	6.205
1/17/2008	7.430	1.697	2.617	6.195
2/1/2008	6.989	1.751	2.538	6.255
2/16/2008	7.357	2.126	2.719	6.520
3/3/2008	7.019	1.862	2.527	6.371
3/16/2008	7.182	1.542	2.575	6.350
4/2/2008	7.048	1.724	2.543	6.317
4/16/2008	7.598	1.903	2.755	6.509
5/2/2008	6.749	1.491	2.298	6.365
5/16/2008	7.191	1.633	2.561	6.421
6/2/2008	7.282	1.922	2.624	6.563
6/16/2008	7.373	2.211	2.688	6.706
7/2/2008	7.164	2.312	2.612	6.602
7/16/2008	7.247	2.296	2.649	6.623
8/2/2008	7.239	1.321	2.578	5.626
8/16/2008	7.232	0.347	2.507	4.630
9/2/2008	7.456	0.400	2.581	4.706
9/16/2008	7.216	0.367	2.488	4.579
10/2/2008	7.085	0.184	2.465	4.536
10/17/2008	6.954	0.002	2.442	4.494
11/3/2008	6.825	0.04	2.374	4.252
11/17/2008	6.893	0	2.409	4.462
12/3/2008	6.98	0.224	2.474	4.320
12/17/2008	6.588	0.342	2.387	4.322

Table B5: Data for chapter 2 Figure 2.3

Discharge (mm day^{-1})	DOC (mg L^{-1})	TDN (mg L^{-1})	P (mg L^{-1})	Ca (mg L^{-1})
0.71	1.711	5.27	0.029	7.131
0.7	2.111	5.397	0.294	7.430
0.68	1.789	5.527	0.271	6.989
0.66	1.651	5.505	0.286	7.357
0.63	1.896	5.361	0.068	7.019
0.6	1.709	5.386	0.073	7.182
1.25	2.012	4.927	0.203	7.048
2.82	1.783	4.877	0.157	7.598
2.56	2.138	4.929	0.145	6.749
2.26	2.057	4.98	0.218	7.191
2.85	1.615	4.963	0.182	7.282
2.01	1.265	4.946	0.147	7.373
2.16	1.16	4.778	0.239	7.164
2.29	0.872	4.901	0.109	7.247
2.62	1.385	4.61	0.182	7.239
3.23	1.358	3.904	0.251	7.232
3.04	1.427	4.33	0.217	7.456
2.51	1.765	3.971	0.207	7.214
2.39	1.402	4.187	0.023	7.085
2.4	1.241	4.403	0.010	6.954
1.74	1.186	4.103	0.026	6.825
0.8	1.322	4.591	0.020	6.893
0.67	1.2	4.774	0.009	6.98
0.59	1.075	4.666	0.027	6.588
Discharge (mm day^{-1})	**K (mg L^{-1})**	**Mg (mg L^{-1})**	**Na (mg L^{-1})**	
0.71	1.864	2.527	6.205	
0.7	1.698	2.617	6.195	
0.68	1.751	2.538	6.255	
0.66	2.126	2.719	6.520	
0.63	1.862	2.527	6.371	
0.6	1.542	2.575	6.350	
1.25	1.724	2.543	6.317	
2.82	1.903	2.755	6.509	
2.56	1.491	2.298	6.365	

2.26	1.633	2.561	6.421	
2.85	1.922	2.624	6.563	
2.01	2.211	2.688	6.706	
2.16	2.312	2.612	6.602	
2.29	2.296	2.649	6.623	
2.62	1.321	2.578	5.626	
3.23	0.347	2.507	4.630	
3.04	0.400	2.581	4.706	
2.51	0.367	2.488	4.579	
2.39	0.184	2.465	4.536	
2.4	0.002	2.442	4.494	
1.74	0.041	2.374	4.252	
0.8	0	2.409	4.462	
0.67	0.224	2.474	4.320	
0.59	0.342	2.387	4.322	

APPENDIX C

Raw data and extra graphs pertaining to Chapter 3

Table C1: Data for chapter 3 Figure 3.1

Forest storm (June 30, 2008)					
Actual time	**Time (min)**	**Rainfall (mm)**	**Discharge (L min^{-1})**	**Ca (mg L^{-1})**	**K (mg L^{-1})**
15:25:00	0	0.9	6.3	5.98	0.24
15:30:00	5	1.8	6.3	6.32	0.46
15:35:00	10	1.4	6.4	6.48	0.33
15:40:00	15	1.2	6.6	7.69	0.47
15:45:00	20	2.1	6.8	6.23	0.69
15:50:00	25	1.7	7.1	5.43	0.75
15:55:00	30	1.1	7.5	5.49	0.56
16:00:00	35	0.8	7.7	6.43	1.31
16:05:00	40	0.6	7.9	5.82	1.93
16:10:00	45	0.3	8.1	7.75	1.73
16:15:00	50	0.2	8	6.18	2.79
16:20:00	55	0.1	8.1	6.09	4.68
16:25:00	60	0	7.9	5.81	2.43
16:30:00	65	0	7.8	5.88	2.01
16:35:00	70	0	7.7	6.12	2.88
16:40:00	75	0	7.6	6.67	1.97
16:45:00	80	0	7.5	7.31	2.12
16:50:00	85	0	7.4	7.15	1.85
16:55:00	90	0	7.3	6.58	2.23
Time (min)	**Mg (mg L^{-1})**	**Na (mg L^{-1})**	**DOC (mg L^{-1})**	**TDN (mg L^{-1})**	**NO_3 (mg L^{-1})**
0	2.34	3.83	2.12	0.44	0.35
5	2.53	4.61	2.58	0.34	0.29
10	2.14	4.32	2.37	0.64	0.54
15	2.67	4.53	3.99	0.65	0.38
20	2.09	3.71	4.97	0.59	0.35
25	2.79	4.13	5.67	0.37	0.24
30	2.72	5.01	6.24	0.38	0.25

35	2.05	4.62	5.13	0.32	0.26
40	2.14	4.51	6.64	0.69	0.49
45	2.61	4.31	8.21	0.51	0.47
50	2.38	4.93	8.82	0.56	0.44
55	2.73	4.29	8.04	0.41	0.32
60	1.96	4.32	7.26	0.43	0.32
65	3.06	5.34	7.06	0.33	0.24
70	2.57	3.67	6.52	0.31	0.25
75	2.16	4.25	6.66	0.34	0.22
80	2.35	4.98	6.25	0.37	0.27
85	2.27	4.17	5.37	0.54	0.42
90	2.31	4.63	5.83	0.35	0.29
5 year (July 14, 2008)					
	Rainfall (mm)	**Time (min)**	**Discharge (L min^{-1})**	**Ca (mg L^{-1})**	**K (mg L^{-1})**
	0.8	0	12.5	5.62	0.35
	1.3	5	12.6	5.28	0.43
	2.1	10	13	5.43	0.42
	2	15	13.4	5.84	0.53
	1.5	20	13.9	5.51	0.49
	1.5	25	14.7	5.22	0.57
	1.1	30	15.3	4.83	0.79
	0.7	35	15.6	4.27	1.13
	0.2	40	15.8	4.14	2.44
		45	15.5	3.92	5.31
		50	15.3	4.77	4.38
		55	14.6	4.16	5.21
		60	14.4	4.35	4.51
		65	14.2	4.41	4.94
		70	13.9	4.85	4.11
		75	13.7	4.08	4.76
		80	13.5	4.24	3.75
		85	13.3	4.63	4.17
		90	13.2	4.87	4.03
		95	13.1	5.01	3.79

Time (min)	Mg ($mg L^{-1}$)	Na ($mg L^{-1}$)	DOC ($mg L^{-1}$)	TDN ($mg L^{-1}$)	NO_3 ($mg L^{-1}$)
0	2.24	3.32	1.78	0.63	0.52
5	2.29	3.79	1.62	0.61	0.49
10	2.06	3.54	1.72	0.68	0.58
15	2.14	3.21	2.06	0.62	0.54
20	2.15	3.12	1.98	0.67	0.61
25	2.34	3.17	2.05	0.74	0.67
30	2.11	3.04	2.25	0.65	0.49
35	1.87	2.59	2.47	0.56	0.51
40	1.61	2.82	3.17	0.54	0.48
45	1.54	2.54	4.13	0.43	0.42
50	1.71	2.35	4.66	0.47	0.24
55	1.96	2.48	5.41	0.41	0.28
60	1.46	2.37	5.38	0.45	0.29
65	2.07	2.66	5.82	0.42	0.33
70	2.01	3.04	5.69	0.53	0.24
75	1.98	2.98	5.75	0.56	0.33
80	2.18	3.15	5.18	0.49	0.41
85	2.05	3.07	5.24	0.52	0.43
90	2.13	3.11	5.36	0.47	0.41
95	2.03	2.87	5.04	0.55	0.46
10 year (July 20, 2008)					
	Rainfall (mm)	**Time (min)**	**Discharge ($L min^{-1}$)**	**Ca ($mg L^{-1}$)**	**K ($mg L^{-1}$)**
	0.8	0	19.1	5.47	1.29
	1.6	5	19.3	5.34	1.13
	1.9	10	19.8	5.49	1.37
	2.1	15	20.3	4.25	1.96
	1.9	20	20.8	4.08	2.39
	1.4	25	21.1	4.11	3.61
	0.7	30	21.5	3.23	4.58
	0.5	35	22.1	3.02	4.79
	0.4	40	22.5	3.07	4.76
	0.2	45	22.9	3.99	4.59
		50	22.6	3.98	4.51
		55	21.7	3.94	4.74
		60	21.3	4.35	4.42
		65	20.9	4.29	4.43
		70	20.6	4.37	3.91

		75	20.3	4.24	3.61
		80	20	4.01	3.27
Time (min)	**Mg (mg L^{-1})**	**Na (mg L^{-1})**	**DOC (mg L^{-1})**	**TDN (mg L^{-1})**	**NO_3 (mg L^{-1})**
0	1.63	3.94	1.16	4.76	3.28
5	1.44	4.18	1.36	4.83	3.73
10	1.58	4.03	2.63	4.48	3.49
15	1.51	4.26	3.71	5.12	3.76
20	1.49	3.37	4.45	2.34	0.95
25	1.62	2.45	5.02	2.46	1.01
30	1.13	2.12	4.93	2.31	1.49
35	1.02	2.18	4.92	2.23	1.13
40	0.89	2.44	4.97	2.08	1.14
45	1.07	2.79	5.14	2.35	1.41
50	0.96	2.71	5.63	2.56	1.64
55	0.81	2.01	5.07	2.31	1.37
60	0.91	2.81	4.93	2.34	1.39
65	1.27	3.88	5.69	2.51	1.12
70	1.41	3.12	5.37	3.02	1.64
75	1.59	4.29	4.73	3.37	1.79
80	1.41	4.07	4.81	3.41	2.07
50 year (July 31, 2008)					
	Rainfall (mm)	**Time (min)**	**Discharge (L min^{-1})**	**Ca (mg L^{-1})**	**K (mg L^{-1})**
	0.5	0	18.5	6.35	1.41
	0.9	5	18.6	6.49	1.87
	1.4	10	18.8	6.28	1.25
	1.7	15	20.4	6.79	3.07
	1.4	20	21.3	6.67	3.67
	1.6	25	22.5	6.25	4.91
	1.3	30	23.1	5.28	5.46
	0.7	35	23.8	4.83	6.32
	0.4	40	24.3	4.77	7.43
	0.4	45	22.6	4.06	8.21
		50	22.2	4.61	8.03
		55	21.7	5.75	8.09
		60	21.4	7.16	7.89
		65	21.1	7.44	6.24
		70	19.8	7.06	5.68

		75	19.5	6.87	5.07
		80	19.2	6.53	5.31

Time (min)	**Mg (mg L^{-1})**	**Na (mg L^{-1})**	**DOC (mg L^{-1})**	**TDN (mg L^{-1})**	**NO_3 (mg L^{-1})**
0	2.54	5.24	1.01	4.42	4.31
5	2.44	5.74	1.35	4.19	3.97
10	2.67	5.19	1.29	4.53	4.32
15	2.35	5.55	1.71	4.62	3.48
20	2.41	5.31	3.78	4.09	3.11
25	2.17	4.96	6.84	3.78	2.53
30	1.91	4.25	6.75	3.17	2.83
35	1.69	4.11	7.92	3.02	1.43
40	1.55	4.09	7.45	3.23	1.63
45	1.73	3.81	6.94	3.43	2.09
50	1.95	4.05	7.86	3.82	2.29
55	1.82	4.15	8.19	4.53	3.76
60	2.01	4.48	7.04	5.64	3.88
65	2.12	5.12	6.15	4.85	3.61
70	2.49	4.79	5.85	4.63	3.91
75	2.31	4.65	4.49	4.27	3.27
80	2.38	4.98	4.97	4.59	3.54

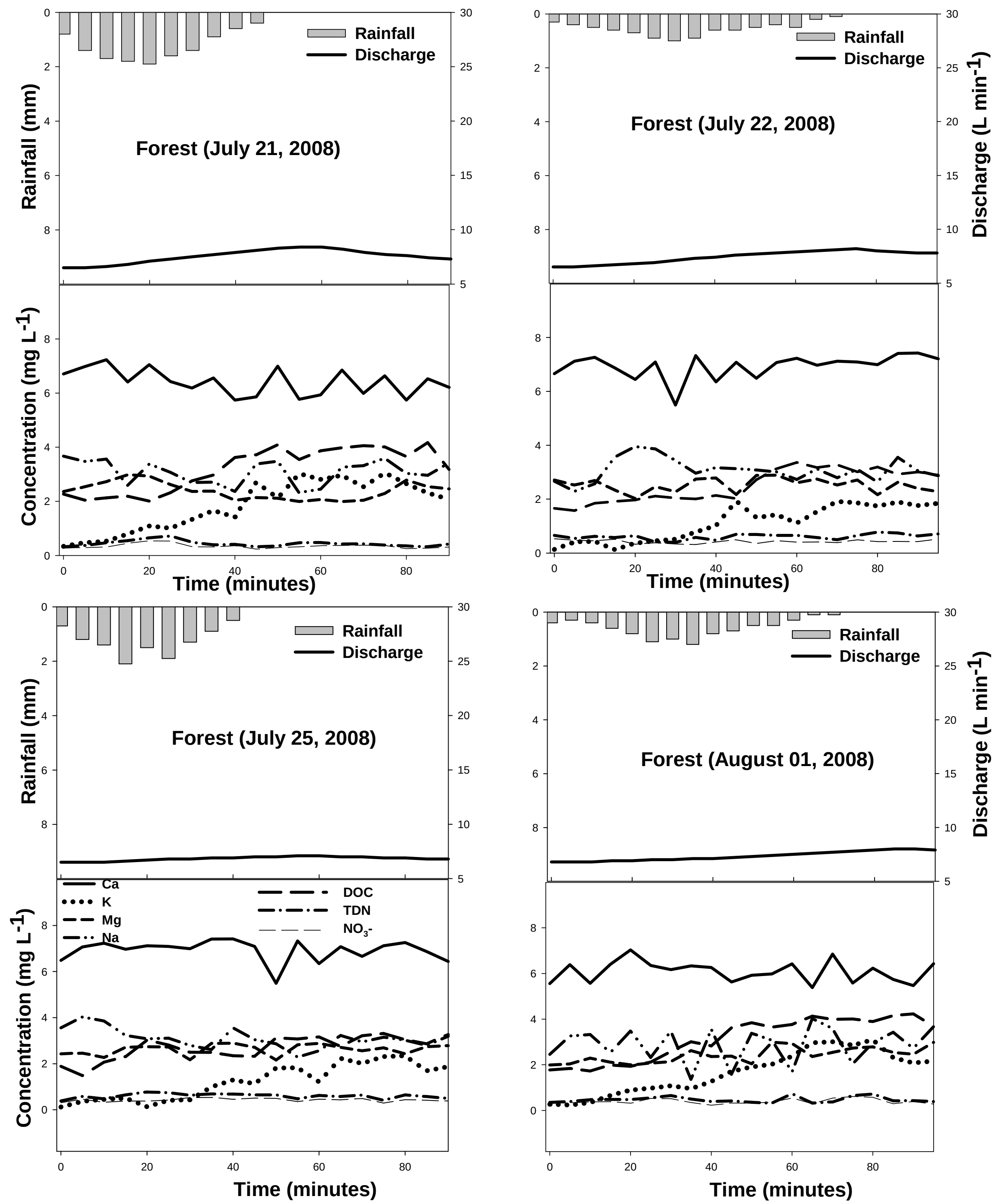

Figure C1. Rainfall, discharge and solute concentrations for forest watershed storms

Table C2: Data for Figure C1

Forest (July 21, 2008)					
	Rainfall (mm)	Time (min)	Discharge (L/min)	Ca (mg/L)	K (mg/L)
	0.8	0	6.5	6.71	0.34
	1.4	5	6.5	6.98	0.47
	1.7	10	6.6	7.23	0.53
	1.8	15	6.8	6.41	0.79
	1.9	20	7.1	7.05	1.09
	1.6	25	7.3	6.42	1.01
	1.4	30	7.5	6.19	1.33
	0.9	35	7.7	6.56	1.66
	0.6	40	7.9	5.74	1.42
	0.4	45	8.1	5.86	2.71
		50	8.3	6.99	2.12
		55	8.4	5.77	3.02
		60	8.4	5.93	2.81
		65	8.2	6.85	2.96
		70	7.9	5.99	2.54
		75	7.7	6.64	3.05
		80	7.6	5.74	2.65
		85	7.4	6.53	2.31
		90	7.3	6.21	2.08
Time(min)	Mg (mg/L)	Na (mg/L)	DOC (mg/L)	TDN (mg/L)	NO3 (mg/L)
0	2.36	3.67	2.27	0.32	0.27
5	2.54	3.47	2.04	0.37	0.29
10	2.73	3.56	2.13	0.47	0.31
15	2.98	2.59	2.19	0.55	0.45
20	2.93	3.38	2.01	0.65	0.54
25	2.62	3.07	2.32	0.72	0.53
30	2.36	2.69	2.76	0.49	0.32
35	2.38	2.71	2.97	0.39	0.31
40	2.04	2.36	3.62	0.41	0.36
45	2.14	3.38	3.72	0.32	0.23
50	2.11	3.48	4.09	0.35	0.29

55	1.99	2.32	3.54	0.47	0.32
60	2.07	2.45	3.87	0.48	0.36
65	1.99	3.26	3.98	0.42	0.37
70	2.04	3.32	4.06	0.43	0.38
75	2.29	3.59	4.01	0.38	0.37
80	2.78	3.03	3.65	0.35	0.25
85	2.54	2.96	4.17	0.32	0.27
90	2.46	3.42	3.18	0.42	0.31
Forest (July 22, 2008)					
	Rainfall (mm)	**Time (min)**	**Discharge (L/min)**	**Ca (mg/L)**	**K (mg/L)**
	0.3	0	6.5	6.66	0.13
	0.4	5	6.5	7.12	0.41
	0.5	10	6.6	7.26	0.43
	0.6	15	6.7	6.87	0.12
	0.7	20	6.8	6.44	0.36
	0.9	25	6.9	7.09	0.45
	1	30	7.1	5.49	0.51
	0.9	35	7.3	7.33	0.78
	0.6	40	7.4	6.35	1.01
	0.6	45	7.6	7.08	1.93
	0.5	50	7.7	6.49	1.31
	0.4	55	7.8	7.07	1.42
	0.5	60	7.9	7.23	1.11
	0.2	65	8	6.97	1.53
	0.1	70	8.1	7.12	1.91
		75	8.2	7.09	1.86
		80	8	6.99	1.74
		85	7.9	7.41	1.89
		90	7.8	7.42	1.76
		95	7.8	7.21	1.84

Time(min)	Mg (mg/L)	Na (mg/L)	DOC (mg/L)	TDN (mg/L)	NO3 (mg/L)
0	2.71	2.66	1.66	0.65	0.53
5	2.52	2.29	1.57	0.54	0.47
10	2.69	2.57	1.85	0.62	0.45
15	2.33	3.56	1.91	0.57	0.51
20	2.02	3.95	1.97	0.64	0.32
25	2.46	3.86	2.11	0.41	0.38
30	2.27	3.43	2.04	0.39	0.33
35	2.74	2.96	2	0.58	0.31
40	2.78	3.17	2.14	0.47	0.41
45	2.17	3.13	2.02	0.69	0.49
50	2.88	3.08	2.72	0.68	0.35
55	2.89	3.01	3.13	0.65	0.46
60	2.61	2.73	3.36	0.65	0.4
65	2.74	3.12	3.17	0.57	0.41
70	2.52	2.79	3.27	0.49	0.38
75	2.71	3.1	3.01	0.65	0.49
80	2.16	2.63	3.19	0.77	0.42
85	2.62	3.55	2.92	0.74	0.43
90	2.39	3.04	3.01	0.63	0.42
95	2.28	2.86	2.89	0.71	0.52
Forest (July 25, 2008)					
	Rainfall (mm)	**Time (min)**	**Discharge (L/min)**	**Ca (mg/L)**	**K (mg/L)**
	0.7	0	6.5	6.49	0.12
	1.2	5	6.5	7.07	0.36
	1.4	10	6.5	7.23	0.45
	2.1	15	6.6	6.97	0.51
	1.5	20	6.7	7.12	0.13
	1.9	25	6.8	7.09	0.41
	1.3	30	6.8	6.99	0.43
	0.9	35	6.9	7.41	0.99
	0.5	40	6.9	7.42	1.29
		45	7	7.09	1.13
		50	7	5.49	1.81
		55	7.1	7.33	1.82

		60	7.1	6.35	1.21
		65	7	7.08	2.23
		70	7	6.66	2.01
		75	6.9	7.12	2.31
		80	6.9	7.26	2.34
		85	6.8	6.87	1.69
		90	6.8	6.44	1.87
Time(min)	**Mg (mg/L)**	**Na (mg/L)**	**DOC (mg/L)**	**TDN (mg/L)**	**NO3 (mg/L)**
0	2.43	3.56	1.89	0.39	0.31
5	2.46	4.03	1.48	0.58	0.46
10	2.27	3.85	2.07	0.47	0.32
15	2.71	3.23	2.31	0.65	0.38
20	2.74	3.08	3.02	0.77	0.38
25	2.72	3.11	2.81	0.74	0.42
30	2.17	2.79	2.49	0.63	0.53
35	2.88	2.61	2.49	0.69	0.54
40	2.89	3.55	2.34	0.68	0.45
45	2.71	3.04	2.32	0.65	0.51
50	2.16	2.86	3.12	0.65	0.49
55	2.82	2.29	3.07	0.47	0.35
60	2.88	2.56	3.16	0.62	0.46
65	2.71	3.23	2.75	0.57	0.43
70	2.56	2.95	3.21	0.64	0.49
75	2.69	3.15	3.31	0.41	0.29
80	2.43	3.02	3.04	0.65	0.44
85	2.74	2.79	2.86	0.57	0.41
90	2.78	3.19	3.27	0.49	0.38
Forest (August 01, 2008)					
	Rainfall (mm)	**Time (min)**	**Discharge (L/min)**	**Ca (mg/L)**	**K (mg/L)**
	0.4	0	6.8	5.56	0.27
	0.3	5	6.8	6.39	0.23
	0.4	10	6.8	5.57	0.34
	0.6	15	6.9	6.4	0.65
	0.8	20	6.9	7.03	0.89

	1.1	25	7	6.35	0.97
	1	30	7	6.17	1.08
	1.2	35	7.1	6.33	0.95
	0.8	40	7.1	6.26	1.27
	0.7	45	7.2	5.63	1.71
	0.5	50	7.3	5.92	1.9
	0.5	55	7.4	5.98	2.02
	0.3	60	7.5	6.42	2.37
	0.1	65	7.6	5.38	2.96
	0.1	70	7.7	6.85	3.01
		75	7.8	5.58	2.85
		80	7.9	6.23	3.09
		85	8	5.74	2.31
		90	8	5.47	2.08
		95	7.9	6.43	2.16
Time(min)	**Mg (mg/L)**	**Na (mg/L)**	**DOC (mg/L)**	**TDN (mg/L)**	**NO3 (mg/L)**
0	1.99	2.45	1.77	0.35	0.31
5	2.04	3.26	1.84	0.39	0.33
10	2.29	3.32	1.73	0.47	0.37
15	2.11	2.53	1.99	0.48	0.38
20	1.99	3.48	1.93	0.47	0.31
25	2.07	2.32	2.12	0.55	0.53
30	2.14	3.47	2.58	0.65	0.51
35	2.62	1.36	3.01	0.49	0.34
40	2.36	3.56	2.82	0.39	0.23
45	2.38	1.59	3.62	0.42	0.32
50	2.04	3.38	3.84	0.35	0.31
55	2.98	3.07	3.64	0.32	0.36
60	2.93	1.69	3.77	0.73	0.54
65	2.36	4.02	4.13	0.32	0.29
70	2.54	3.59	3.98	0.37	0.54
75	2.73	2.04	4.01	0.65	0.61
80	2.78	2.96	3.89	0.72	0.57
85	2.54	3.42	4.15	0.42	0.29
90	2.46	2.72	4.23	0.43	0.39
95	2.98	3.67	3.69	0.38	0.28

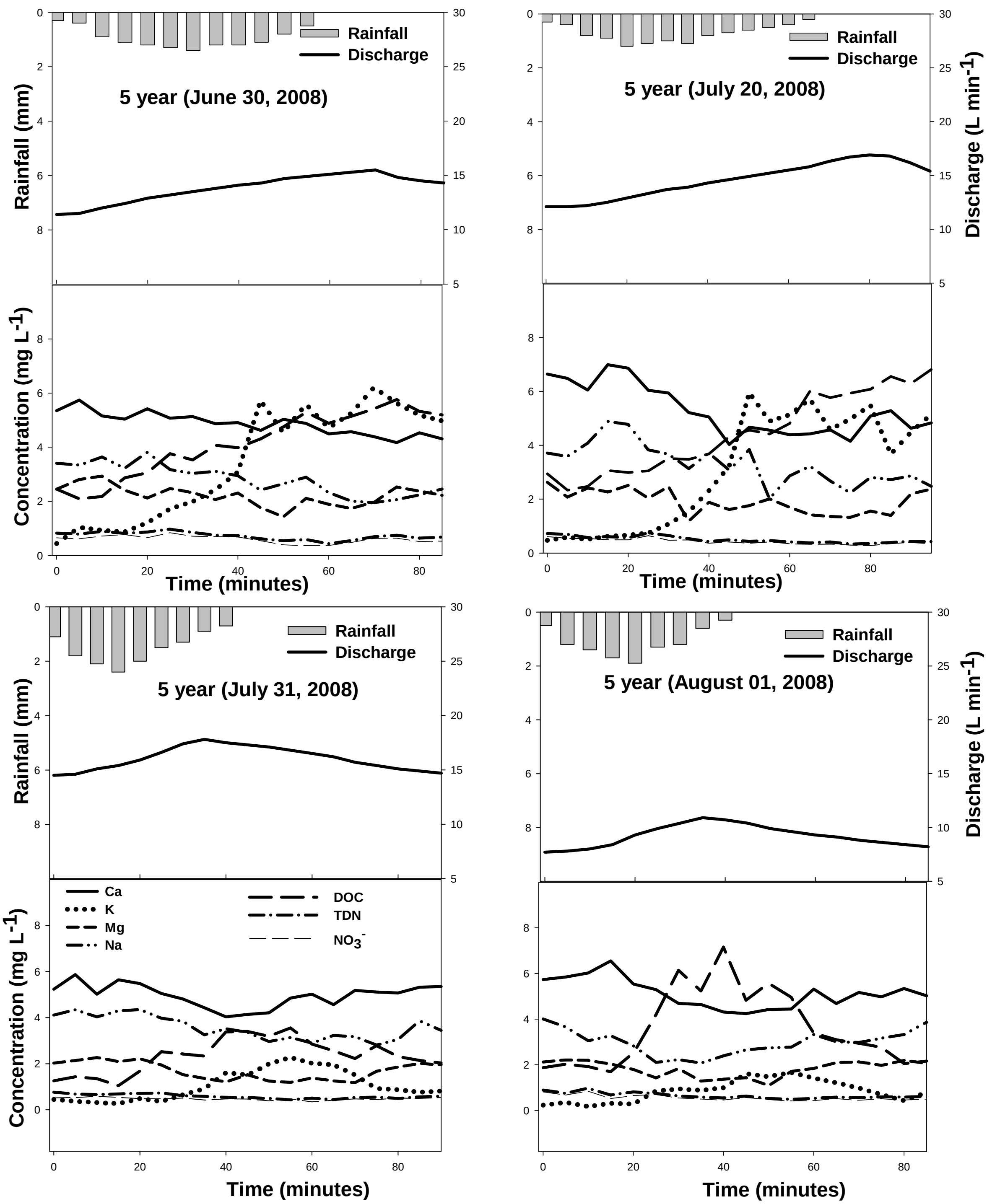

Figure C2. Rainfall, discharge and solute concentrations for 5 year old watershed storms

Table C3: Data for Figure C2

5 year (June 30, 2008)					
	Rainfall (mm)	Time (min)	Discharge (L/min)	Ca (mg/L)	K (mg/L)
	0.3	0	11.4	5.35	0.44
	0.4	5	11.5	5.74	1.04
	0.9	10	12	5.16	0.93
	1.1	15	12.4	5.04	0.87
	1.2	20	12.9	5.42	1.21
	1.3	25	13.2	5.07	1.72
	1.4	30	13.5	5.13	1.99
	1.2	35	13.8	4.87	2.43
	1.2	40	14.1	4.91	3.08
	1.1	45	14.3	4.62	5.72
	0.8	50	14.7	5.03	4.54
	0.5	55	14.9	4.88	5.59
		60	15.1	4.49	4.71
		65	15.3	4.57	5.25
		70	15.5	4.39	6.21
		75	14.8	4.17	5.62
		80	14.5	4.53	5.18
		85	14.3	4.31	4.97
5 year (June 30, 2008)					
Time(min)	Mg (mg/L)	Na (mg/L)	DOC (mg/L)	TDN (mg/L)	NO3 (mg/L)
0	2.45	3.41	2.45	0.83	0.65
5	2.81	3.34	2.09	0.79	0.61
10	2.93	3.64	2.18	0.89	0.72
15	2.41	3.22	2.87	0.81	0.77
20	2.12	3.81	3.05	0.87	0.65
25	2.47	3.17	3.76	0.97	0.84
30	2.32	3.03	3.53	0.85	0.71
35	2.06	3.11	4.07	0.75	0.69
40	2.31	2.94	3.98	0.73	0.68
45	1.76	2.41	4.31	0.61	0.54
50	1.43	2.65	4.75	0.54	0.39
55	2.11	2.89	5.29	0.59	0.36

60	1.89	2.32	4.88	0.43	0.37
65	1.74	2.01	5.14	0.55	0.48
70	1.97	1.95	5.42	0.69	0.63
75	2.53	2.06	5.76	0.75	0.64
80	2.38	2.24	5.32	0.64	0.51
85	2.22	2.46	5.19	0.68	0.53

5year (July 20, 2008)

	Rainfall (mm)	**Time (min)**	**Discharge (L/min)**	**Ca (mg/L)**	**K (mg/L)**
	0.3	0	12.1	6.64	0.47
	0.4	5	12.1	6.48	0.58
	0.8	10	12.2	6.05	0.51
	0.9	15	12.5	6.99	0.62
	1.2	20	12.9	6.86	0.66
	1.1	25	13.3	6.04	0.74
	1	30	13.7	5.94	1.07
	1.1	35	13.9	5.21	1.53
	0.8	40	14.3	5.05	2.31
	0.7	45	14.6	4.03	3.22
	0.6	50	14.9	4.67	5.95
	0.5	55	15.2	4.56	4.89
	0.4	60	15.5	4.39	5.13
	0.2	65	15.8	4.42	5.71
		70	16.3	4.57	4.58
		75	16.7	4.15	4.97
		80	16.9	5.08	5.48
		85	16.8	5.28	3.67
		90	16.2	4.63	4.48
		95	15.4	4.83	5.15

5year (July 20, 2008)

Time(min)	**Mg (mg/L)**	**Na (mg/L)**	**DOC (mg/L)**	**TDN (mg/L)**	**NO3 (mg/L)**
0	2.62	3.71	2.94	0.72	0.61
5	2.07	3.58	2.33	0.69	0.54
10	2.41	4.08	2.47	0.57	0.54
15	2.26	4.88	3.06	0.61	0.49

20	2.51	4.77	2.98	0.56	0.48
25	2.03	3.83	3.05	0.74	0.64
30	2.46	3.67	3.51	0.64	0.47
35	1.18	3.13	3.47	0.53	0.48
40	1.88	3.71	3.68	0.42	0.36
45	1.61	3.07	4.31	0.49	0.41
50	1.76	3.84	4.56	0.43	0.36
55	2.01	2.01	4.41	0.46	0.41
60	1.69	2.86	4.81	0.41	0.34
65	1.42	3.22	6.01	0.37	0.32
70	1.35	2.67	5.76	0.41	0.33
75	1.32	2.23	5.93	0.33	0.29
80	1.55	2.81	6.08	0.35	0.27
85	1.39	2.72	6.55	0.39	0.35
90	2.19	2.86	6.29	0.43	0.39
95	2.37	2.47	6.81	0.42	0.34
5 year (July 31, 2008)					
	Rainfall (mm)	**Time (min)**	**Discharge (L/min)**	**Ca (mg/L)**	**K (mg/L)**
	1.10	0	14.5	5.23	0.45
	1.80	5	14.6	5.87	0.36
	2.10	10	15.1	5.02	0.31
	2.40	15	15.4	5.64	0.27
	2.00	20	15.9	5.48	0.48
	1.50	25	16.6	5.05	0.36
	1.30	30	17.4	4.81	0.65
	0.90	35	17.8	4.43	0.91
	0.70	40	17.5	4.04	1.61
		45	17.3	4.14	1.51
		50	17.1	4.21	1.99
		55	16.8	4.85	2.27
		60	16.5	5.02	2.02
		65	16.2	4.57	1.95
		70	15.7	5.18	1.51
		75	15.4	5.11	0.92
		80	15.1	5.07	0.87

		85	14.9	5.32	0.76
		90	14.7	5.35	0.81
5 year (July 31, 2008)					
Time(min)	**Mg (mg/L)**	**Na (mg/L)**	**DOC (mg/L)**	**TDN (mg/L)**	**NO3 (mg/L)**
0	2.03	4.11	1.26	0.76	0.52
5	2.14	4.34	1.43	0.68	0.53
10	2.27	4.03	1.35	0.66	0.58
15	2.09	4.29	1.04	0.69	0.54
20	2.21	4.35	1.68	0.71	0.48
25	1.94	3.97	2.52	0.73	0.47
30	1.52	3.84	2.42	0.61	0.51
35	1.36	3.25	2.33	0.58	0.42
40	1.21	3.52	3.38	0.54	0.47
45	1.52	3.36	3.4	0.53	0.46
50	1.24	2.96	3.19	0.49	0.39
55	1.19	3.14	3.55	0.43	0.47
60	1.38	2.89	2.85	0.51	0.34
65	1.25	3.23	2.56	0.44	0.42
70	1.17	3.17	2.22	0.53	0.47
75	1.67	2.81	2.78	0.55	0.44
80	1.86	3.05	2.31	0.49	0.51
85	2.01	3.86	2.14	0.56	0.49
90	1.95	3.44	2.03	0.59	0.53
5 year (August 01, 2008)					
	Rainfall (mm)	**Time (min)**	**Discharge (L/min)**	**Ca (mg/L)**	**K (mg/L)**
	0.5	0	7.7	5.73	0.23
	1.2	5	7.8	5.84	0.35
	1.4	10	8	6.02	0.17
	1.7	15	8.4	6.55	0.31
	1.9	20	9.3	5.54	0.28
	1.3	25	9.9	5.29	0.85
	1.2	30	10.4	4.69	0.94
	0.6	35	10.9	4.64	0.88
	0.3	40	10.7	4.31	0.99

		45	10.4	4.24	1.61
		50	9.9	4.42	1.48
		55	9.6	4.44	1.66
		60	9.3	5.32	1.41
		65	9.1	4.68	1.21
		70	8.8	5.17	0.98
		75	8.6	4.98	0.69
		80	8.4	5.34	0.43
		85	8.2	5.02	0.78
5 year (August 01, 2008)					
Time(min)	**Mg (mg/L)**	**Na (mg/L)**	**DOC (mg/L)**	**TDN (mg/L)**	**NO3 (mg/L)**
0	2.12	4.01	1.87	0.89	0.81
5	2.21	3.65	2.03	0.75	0.67
10	2.19	3.05	1.91	0.97	0.84
15	2.03	3.27	1.69	0.67	0.52
20	1.79	2.83	2.51	0.81	0.65
25	1.42	2.1	4.18	0.74	0.69
30	1.83	2.22	6.14	0.63	0.54
35	1.28	2.07	5.23	0.58	0.49
40	1.37	2.39	7.15	0.54	0.45
45	1.43	2.65	4.83	0.63	0.56
50	1.09	2.74	5.57	0.52	0.47
55	1.71	2.77	4.95	0.48	0.41
60	1.84	3.32	3.39	0.53	0.43
65	2.09	3.01	3.09	0.58	0.52
70	2.13	2.97	2.94	0.55	0.44
75	1.97	3.16	2.76	0.59	0.51
80	2.19	3.32	2.05	0.58	0.45
85	2.06	3.86	2.16	0.61	0.49

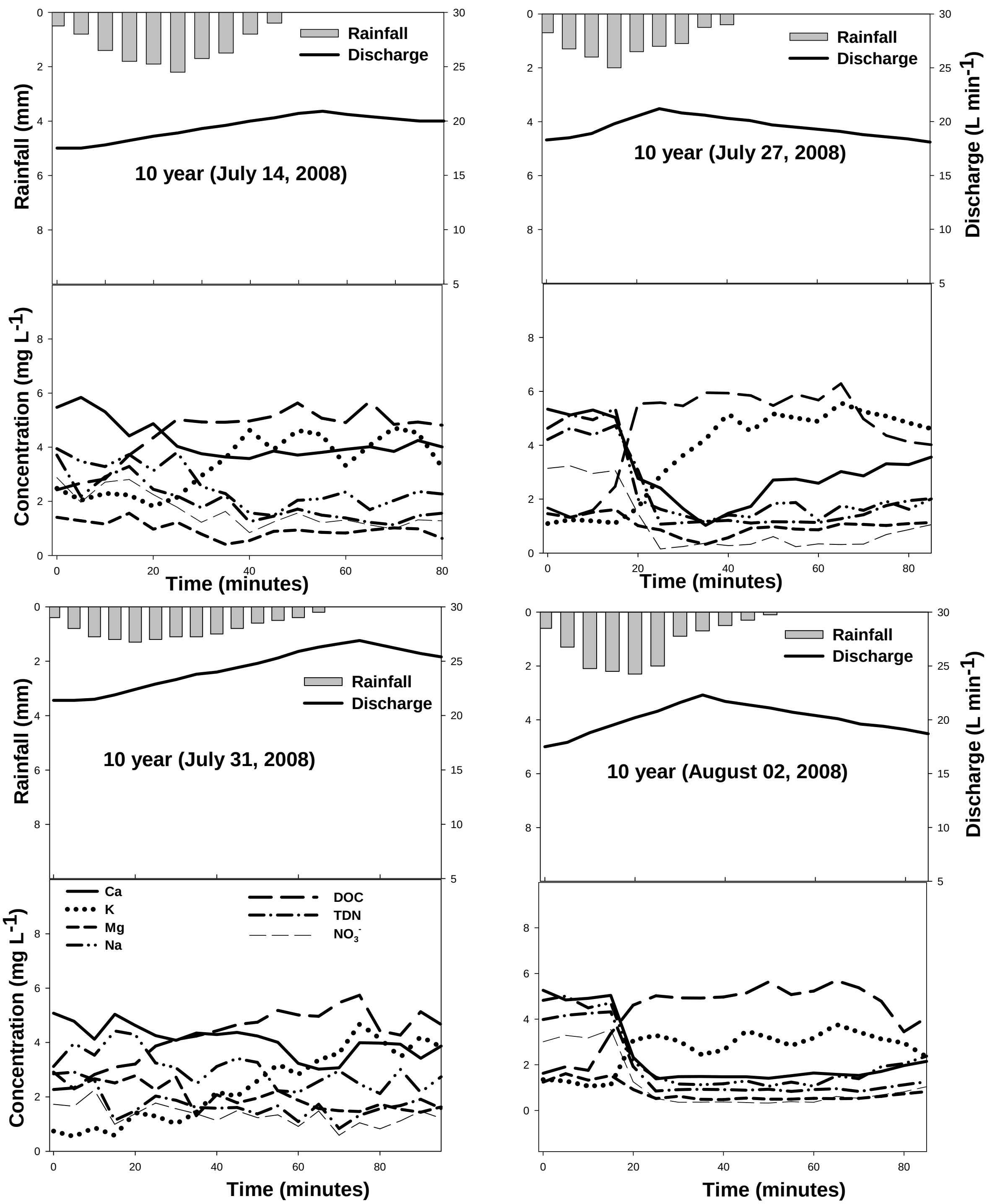

Figure C3. Rainfall, discharge and solute concentrations for 10 year old watershed storms

Table C4: Data for Figure C3

10 year (July14, 2008)					
	Rainfall (mm)	Time (min)	Discharge (L/min)	Ca (mg/L)	K (mg/L)
	0.5	0	17.5	5.47	2.48
	0.8	5	17.5	5.84	2.04
	1.4	10	17.8	5.31	2.29
	1.8	15	18.2	4.42	2.23
	1.9	20	18.6	4.87	1.82
	2.2	25	18.9	4.03	2.15
	1.7	30	19.3	3.76	2.94
	1.5	35	19.6	3.64	3.59
	0.8	40	20	3.58	4.63
	0.4	45	20.3	3.86	3.91
		50	20.7	3.71	4.62
		55	20.9	3.81	4.46
		60	20.6	3.92	3.32
		65	20.4	4.02	4.07
		70	20.2	3.84	4.71
		75	20	4.25	4.53
		80	20	4.01	3.26
10 year (July 14, 2008)					
Time(min)	Mg (mg/L)	Na (mg/L)	DOC (mg/L)	TDN (mg/L)	NO3 (mg/L)
0	1.41	3.95	2.43	3.71	2.88
5	1.28	3.47	2.67	2.18	1.97
10	1.16	3.28	2.83	2.91	2.71
15	1.56	3.73	3.71	3.29	2.81
20	0.97	3.12	4.35	2.44	2.25
25	1.22	3.81	5.02	2.19	1.78
30	0.79	2.55	4.93	1.76	1.22
35	0.41	2.28	4.92	2.22	1.63
40	0.55	1.57	4.97	1.25	0.84
45	0.89	1.48	5.14	1.45	1.24
50	0.94	2.04	5.63	1.71	1.56
55	0.85	2.09	5.07	1.49	1.21
60	0.83	2.35	4.91	1.38	1.31
65	0.94	1.69	5.69	1.22	1.13

70	1.02	2.03	4.84	1.13	0.98
75	0.98	2.36	4.93	1.47	1.32
80	0.63	2.27	4.81	1.56	1.28
10 year (July 27, 2008)					
	Rainfall (mm)	**Time (min)**	**Discharge (L/min)**	**Ca (mg/L)**	**K (mg/L)**
	0.7	0	18.3	5.34	1.09
	1.3	5	18.5	5.12	1.23
	1.6	10	18.9	5.31	1.19
	2	15	19.8	5.03	1.11
	1.4	20	20.5	2.77	1.67
	1.2	25	21.2	2.41	2.89
	1.1	30	20.8	1.65	3.62
	0.5	35	20.6	1.03	4.22
	0.4	40	20.3	1.47	5.17
		45	20.1	1.73	4.51
		50	19.7	2.71	5.16
		55	19.5	2.74	5.01
		60	19.3	2.59	4.88
		65	19.1	3.02	5.57
		70	18.8	2.86	5.24
		75	18.6	3.31	5.08
		80	18.4	3.28	4.83
		85	18.1	3.56	4.61
10 year (July 27, 2008)					
Time(min)	**Mg (mg/L)**	**Na (mg/L)**	**DOC (mg/L)**	**TDN (mg/L)**	**NO3 (mg/L)**
0	1.46	4.63	1.67	4.21	3.14
5	1.32	5.12	1.33	4.63	3.23
10	1.51	4.94	1.59	4.38	2.95
15	1.61	5.36	2.47	4.73	3.06
20	1.01	1.99	5.54	3.07	1.47
25	0.85	1.62	5.58	1.07	0.15
30	0.51	1.39	5.46	1.12	0.24
35	0.32	1.15	5.95	1.17	0.36
40	0.57	1.41	5.93	1.21	0.27

45	0.92	1.33	5.84	1.11	0.32
50	0.97	1.83	5.47	1.16	0.61
55	0.88	1.87	5.89	1.15	0.23
60	0.86	1.21	5.67	1.13	0.34
65	1.08	1.75	6.29	1.27	0.31
70	1.06	1.58	4.98	1.42	0.33
75	1.02	1.92	4.36	1.76	0.68
80	1.09	1.62	4.12	1.94	0.87
85	1.13	2.01	4.01	2.02	1.05

10 year (July 31, 2008)

	Rainfall (mm)	Time (min)	Discharge (L/min)	Ca (mg/L)	K (mg/L)
	0.4	0	21.4	5.08	0.74
	0.8	5	21.4	4.78	0.54
	1.1	10	21.5	4.12	0.87
	1.2	15	21.9	5.04	0.58
	1.3	20	22.4	4.63	1.42
	1.2	25	22.9	4.25	1.29
	1.1	30	23.3	4.08	1.01
	1.1	35	23.8	4.35	1.43
	1	40	24	4.29	2.17
	0.8	45	24.4	4.37	2.02
	0.6	50	24.8	4.24	2.59
	0.5	55	25.3	4.01	3.19
	0.4	60	25.9	3.23	2.82
	0.2	65	26.3	3.02	3.36
		70	26.6	3.07	3.61
		75	26.9	3.99	4.67
		80	26.5	3.98	4.15
		85	26.1	3.94	3.45
		90	25.7	3.42	4.21
		95	25.4	3.87	3.84

10 year (July 31, 2008)					
Time(min)	Mg (mg/L)	Na (mg/L)	DOC (mg/L)	TDN (mg/L)	NO3 (mg/L)
0	2.91	3.12	2.27	2.85	1.73
5	2.29	3.97	2.33	2.91	1.65
10	2.67	3.53	2.82	2.62	2.25
15	2.51	4.42	3.09	1.14	0.99
20	2.78	4.29	3.21	1.49	1.38
25	2.25	3.25	3.87	2.03	1.77
30	2.73	3.07	4.11	1.87	1.56
35	1.31	2.47	4.24	1.61	1.38
40	2.08	3.12	4.43	1.58	1.13
45	1.78	3.41	4.65	1.61	1.49
50	1.95	3.26	4.75	1.37	1.23
55	2.23	2.23	5.18	1.67	1.34
60	1.87	2.17	5.01	1.09	0.91
65	1.57	2.57	4.96	1.73	1.48
70	1.49	2.96	5.46	0.84	0.59
75	1.46	2.47	5.74	1.32	1.05
80	1.72	2.12	4.43	1.56	0.82
85	1.54	3.02	4.27	1.68	1.12
90	1.43	2.17	5.13	1.91	1.47
95	1.63	2.74	4.66	1.57	1.21

10 year (August 02, 2008)					
	Rainfall (mm)	Time (min)	Discharge (L/min)	Ca (mg/L)	K (mg/L)
	0.60	0	17.5	5.26	1.35
	1.30	5	17.9	4.84	1.29
	2.10	10	18.8	4.91	1.06
	2.20	15	19.5	5.04	1.12
	2.30	20	20.2	2.32	3.08
	2.00	25	20.8	1.39	3.28
	0.90	30	21.6	1.48	3.05
	0.70	35	22.3	1.49	2.45
	0.50	40	21.7	1.47	2.63

	0.3	45	21.4	1.47	3.48
	0.1	50	21.1	1.41	3.19
		55	20.7	1.52	2.84
		60	20.4	1.64	3.17
		65	20.1	1.58	3.76
		70	19.6	1.53	3.43
		75	19.4	1.71	3.13
		80	19.1	1.97	2.95
		85	18.7	2.15	2.34
5 year (August 01, 2008)					
Time(min)	**Mg (mg/L)**	**Na (mg/L)**	**DOC (mg/L)**	**TDN (mg/L)**	**NO3 (mg/L)**
0	1.24	4.82	1.63	3.98	3.01
5	1.61	5.01	1.91	4.16	3.29
10	1.32	4.49	1.75	4.25	3.17
15	1.53	4.71	3.36	4.32	3.54
20	0.91	2.12	4.61	1.93	1.26
25	0.52	1.45	5.02	0.85	0.52
30	0.62	1.16	4.93	0.91	0.35
35	0.48	1.12	4.92	0.92	0.36
40	0.47	1.17	4.97	0.91	0.37
45	0.54	1.29	5.14	0.88	0.34
50	0.49	1.06	5.63	0.93	0.32
55	0.49	1.24	5.07	0.83	0.38
60	0.53	1.06	5.23	0.91	0.35
65	0.51	1.51	5.69	0.95	0.61
70	0.53	1.39	5.37	0.83	0.53
75	0.62	1.92	4.78	0.98	0.68
80	0.73	2.05	3.45	1.12	0.82
85	0.82	2.38	4.06	1.25	1.04

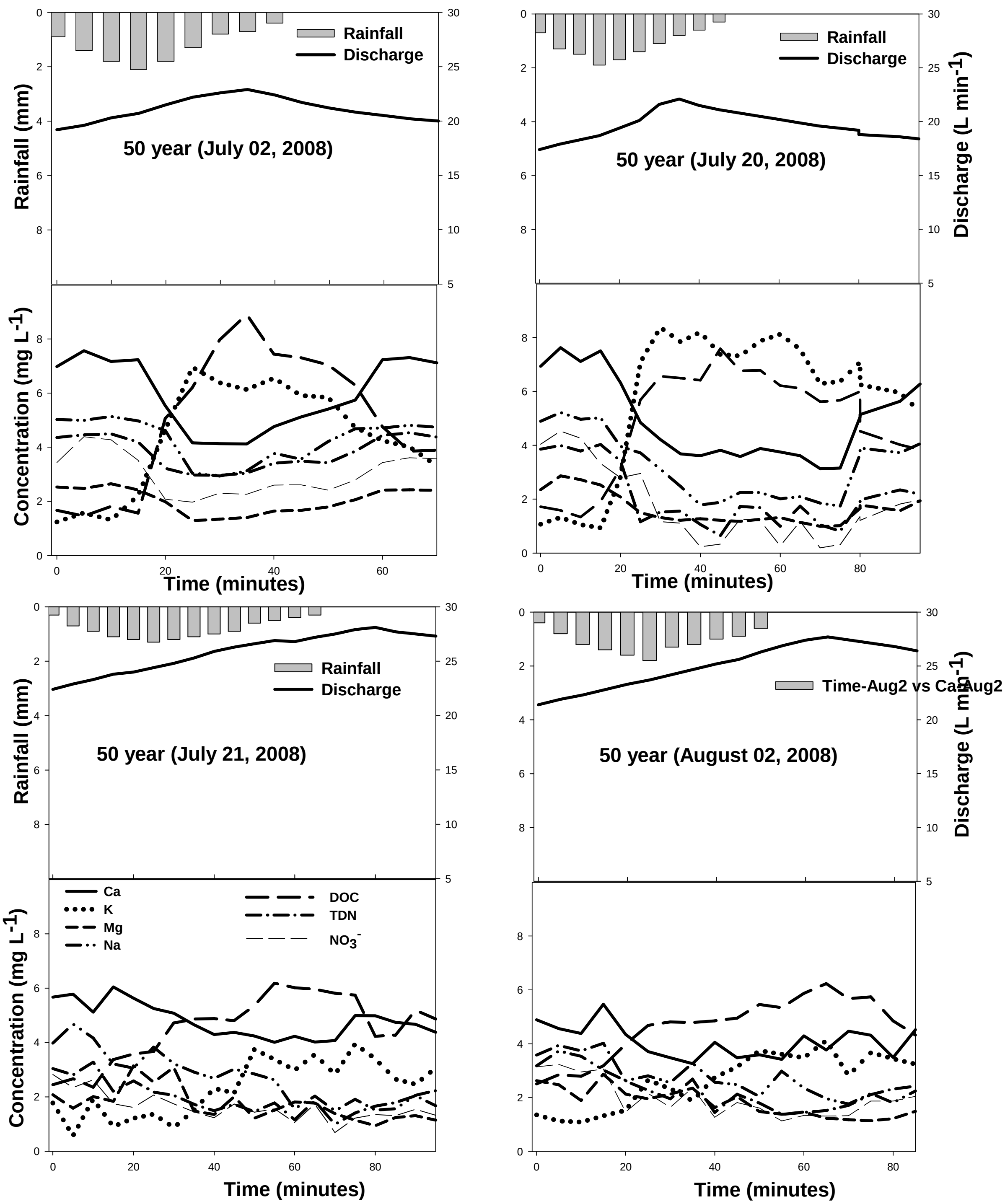

Figure C4. Rainfall, discharge and solute concentrations for 50 year watershed storms

Table C5: Data for Figure C4

50 year (July 02, 2008)					
	Rainfall (mm)	**Time (min)**	**Discharge (L/min)**	**Ca (mg/L)**	**K (mg/L)**
	0.90	0	19.2	6.98	1.24
	1.40	5	19.6	7.56	1.57
	1.80	10	20.3	7.17	1.31
	2.10	15	20.7	7.23	2.21
	1.80	20	21.5	5.53	4.65
	1.30	25	22.2	4.16	6.95
	0.80	30	22.6	4.13	6.38
	0.70	35	22.9	4.12	6.13
	0.40	40	22.4	4.76	6.55
		45	21.7	5.12	5.91
		50	21.2	5.41	5.84
		55	20.8	5.74	4.73
		60	20.5	7.23	4.24
		65	20.2	7.31	4.01
		70	20.0	7.12	3.31
50 year (July 02, 2008)					
Time(min)	**Mg (mg/L)**	**Na (mg/L)**	**DOC (mg/L)**	**TDN (mg/L)**	**NO3 (mg/L)**
0	2.53	5.02	1.67	4.36	3.43
5	2.47	4.99	1.45	4.45	4.39
10	2.65	5.13	1.81	4.49	4.27
15	2.42	4.97	1.56	4.19	3.51
20	1.98	4.61	5.06	3.22	2.08
25	1.29	3.04	6.2	2.97	1.97
30	1.34	2.93	7.96	2.96	2.3
35	1.4	3.12	8.9	3.04	2.26
40	1.64	3.77	7.44	3.41	2.6
45	1.67	3.56	7.3	3.48	2.61
50	1.79	4.21	7.04	3.42	2.41
55	2.06	4.68	6.29	3.85	2.79
60	2.41	4.71	4.76	4.44	3.43
65	2.43	4.81	3.85	4.53	3.61
70	2.4	4.74	3.89	4.37	3.57

50 year (July 20, 2008)					
	Rainfall (mm)	**Time (min)**	**Discharge (L/min)**	**Ca (mg/L)**	**K (mg/L)**
	0.70	0	17.4	6.93	1.07
	1.30	5	17.9	7.62	1.32
	1.50	10	18.3	7.11	1.05
	1.90	15	18.7	7.5	0.93
	1.70	20	19.4	6.32	2.82
	1.40	25	20.1	4.84	7.08
	1.10	30	21.6	4.21	8.37
	0.80	35	22.1	3.68	7.84
	0.60	40	21.5	3.61	8.2
	0.3	45	21.1	3.81	7.37
		50	20.8	3.58	7.31
		55	20.5	3.88	7.87
		60	20.2	3.75	8.12
		65	19.9	3.61	7.56
		70	19.6	3.13	6.28
		75	19.4	3.15	6.37
		80	19.2	5.05	7.08
		80	18.8	5.14	6.24
		90	18.6	5.63	5.95
		95	18.4	6.27	5.23
10 year (July 20, 2008)					
Time(min)	**Mg (mg/L)**	**Na (mg/L)**	**DOC (mg/L)**	**TDN (mg/L)**	**NO3 (mg/L)**
0	2.35	4.89	1.72	3.85	4.04
5	2.86	5.21	1.58	3.99	4.52
10	2.72	4.96	1.33	3.78	4.26
15	2.52	5.02	1.91	4.03	3.32
20	2.07	3.96	3.13	3.41	2.79
25	1.49	3.71	5.68	1.16	2.95
30	1.31	3.11	6.56	1.52	1.16
35	1.21	2.47	6.49	1.55	1.11
40	1.27	1.78	6.41	1.06	0.23
45	1.21	1.88	7.58	0.64	0.33
50	1.17	2.25	6.76	1.73	1.26
55	1.25	2.24	6.78	1.68	1.19

60	1.31	2.01	6.21	0.99	0.27
65	1.13	2.09	6.11	1.74	1.17
70	0.99	1.85	5.61	1.04	0.19
75	1.01	1.74	5.67	0.81	0.31
80	1.66	3.66	5.99	1.87	1.351
80	1.78	3.89	4.52	1.97	1.21
90	1.57	3.72	4.01	2.34	1.82
95	1.94	4.05	3.84	2.18	1.97

50 year (July 21, 2008)

	Rainfall (mm)	Time (min)	Discharge (L/min)	Ca (mg/L)	K (mg/L)
	0.3	0	22.4	5.67	1.78
	0.7	5	22.9	5.78	0.57
	0.9	10	23.3	5.12	1.92
	1.1	15	23.8	6.04	0.91
	1.2	20	24	5.63	1.21
	1.3	25	24.4	5.25	1.36
	1.2	30	24.8	5.08	0.87
	1.1	35	25.3	4.65	1.51
	1	40	25.9	4.29	2.31
	0.9	45	26.3	4.37	2.14
	0.6	50	26.6	4.24	3.74
	0.5	55	26.9	4.01	3.38
	0.4	60	26.8	4.23	2.98
	0.3	65	27.2	4.02	3.56
		70	27.5	4.07	2.82
		75	27.9	4.99	3.95
		80	28.1	4.98	3.39
		85	27.7	4.74	2.65
		90	27.5	4.67	2.46
		95	27.3	4.38	3.07

50 year (July 21, 2008)					
Time(min)	Mg (mg/L)	Na (mg/L)	DOC (mg/L)	TDN (mg/L)	NO3 (mg/L)
0	2.08	3.98	2.45	3.04	2.82
5	1.58	4.68	2.67	2.81	2.34
10	2.01	4.16	2.35	3.28	2.63
15	1.83	3.21	3.37	2.21	1.75
20	3.14	3.06	3.58	2.59	1.61
25	2.54	3.83	3.67	2.17	2.07
30	3.08	3.22	4.72	2.05	1.74
35	1.48	2.91	4.86	1.72	1.45
40	1.35	2.68	4.88	1.49	1.23
45	2.01	3.02	4.8	1.72	1.74
50	1.21	2.84	5.35	1.46	1.43
55	1.51	2.63	6.18	1.78	1.56
60	1.81	1.56	6.01	1.16	1.06
65	1.77	2.03	5.96	1.85	1.73
70	1.38	1.49	5.81	0.99	0.69
75	1.14	1.91	5.74	1.41	1.22
80	0.94	1.51	4.23	1.66	1.35
85	1.24	1.56	4.27	1.79	1.31
90	1.31	2.06	5.19	2.04	1.54
95	1.14	2.23	4.86	1.67	1.32

50 year (August 02, 2008)					
	Rainfall (mm)	Time (min)	Discharge (L/min)	Ca (mg/L)	K (mg/L)
	0.4	0	21.4	4.89	1.36
	0.8	5	21.9	4.56	1.13
	1.2	10	22.3	4.38	1.09
	1.4	15	22.8	5.47	1.32
	1.6	20	23.3	4.35	1.53
	1.8	25	23.7	3.71	2.65
	1.3	30	24.2	3.48	2.33
	1.2	35	24.7	3.26	1.88

	1	40	25.2	4.05	2.75
	0.9	45	25.6	3.48	3.14
	0.6	50	26.3	3.59	3.74
		55	26.9	3.42	3.61
		60	27.4	4.29	3.48
		65	27.7	3.77	4.12
		70	27.4	4.47	2.82
		75	27.1	4.32	3.67
		80	26.8	3.49	3.44
		85	26.4	4.52	3.24
50 year (August 02, 2008)					
Time(min)	**Mg (mg/L)**	**Na (mg/L)**	**DOC (mg/L)**	**TDN (mg/L)**	**NO3 (mg/L)**
0	2.63	3.18	2.51	3.58	3.14
5	2.47	3.73	2.85	3.94	3.23
10	1.89	3.53	2.79	3.73	2.95
15	2.87	3.02	3.18	4.02	3.06
20	2.13	2.62	3.98	2.61	1.47
25	1.95	2.81	4.68	2.27	2.15
30	2.13	2.55	4.81	1.95	1.64
35	2.35	3.28	4.79	2.69	2.36
40	1.63	2.57	4.85	1.45	1.27
45	2.03	2.48	4.95	2.13	1.82
50	1.48	2.04	5.46	1.79	1.61
55	1.38	2.98	5.34	1.38	1.13
60	1.46	2.35	5.87	1.45	1.34
65	1.23	1.96	6.23	1.52	1.31
70	1.18	1.76	5.67	1.71	1.33
75	1.14	2.15	5.74	2.11	1.87
80	1.22	1.81	4.85	2.32	1.87
85	1.49	2.25	4.32	2.42	2.05

Table C6: Data for chapter 3 Figure 3.2

50 yr (July 31, 2008)			
Discharge ($L\ min^{-1}$)	**K ($mg\ L^{-1}$)**	**DOC ($mg\ L^{-1}$)**	**Ca ($mg\ L^{-1}$)**
18.5	1.41	1.01	6.35
18.6	1.87	1.35	6.49
18.8	1.25	1.29	6.28
19.2	5.31	4.97	6.53
19.5	5.07	4.49	6.87
19.8	5.68	5.85	7.06
20.4	3.07	1.71	6.79
21.1	6.24	6.15	7.44
21.3	3.67	3.78	6.67
21.4	7.89	7.04	7.16
21.7	8.09	8.19	5.75
22.2	8.03	7.86	4.61
22.5	4.91	6.84	6.25
22.6	8.21	6.94	4.06
23.1	5.46	6.75	5.28
23.8	6.32	7.92	4.83
24.3	7.43	7.45	4.77
Discharge ($L\ min^{-1}$)	**Mg ($mg\ L^{-1}$)**	**Na ($mg\ L^{-1}$)**	**TDN ($mg\ L^{-1}$)**
18.5	2.54	5.24	4.42
18.6	2.44	5.74	4.19
18.8	2.67	5.19	4.53
19.2	2.38	4.98	4.59
19.5	2.31	4.65	4.27
19.8	2.49	4.79	4.63
20.4	2.35	5.55	4.62
21.1	2.12	5.12	4.85
21.3	2.41	5.31	4.09
21.4	2.01	4.48	5.64
21.7	1.82	4.15	4.53
22.2	1.95	4.05	3.82
22.5	2.17	4.96	3.78
22.6	1.73	3.81	3.43

23.1	1.91	4.25	3.17
23.8	1.69	4.11	3.02
24.3	1.55	4.09	3.23

Table C7: Data for chapter 3 Figure 3.3

50 yr storm (July 31, 2008)			
Discharge (L min^{-1})	**Ca (mg L^{-1})**	**K (mg L^{-1})**	**Mg (mg L^{-1})**
18.5	6.35	1.41	2.54
18.6	6.49	1.87	2.44
18.8	6.28	1.25	2.67
20.4	6.79	3.07	2.35
21.3	6.67	3.67	2.41
22.5	6.25	4.91	2.17
23.1	5.28	5.46	1.91
23.8	4.83	6.32	1.69
24.3	4.77	7.43	1.55
22.6	4.06	8.21	1.73
22.2	4.61	8.03	1.95
21.7	5.75	8.09	1.82
21.4	7.16	7.89	2.01
21.1	7.44	6.24	2.12
19.8	7.06	5.68	2.49
19.5	6.87	5.07	2.31
19.2	6.53	5.31	2.38
Discharge (L min^{-1})	**Na (mg L^{-1})**	**DOC (mg L^{-1})**	**TDN (mg L^{-1})**
18.5	5.24	1.01	4.42
18.6	5.74	1.35	4.19
18.8	5.19	1.29	4.53
20.4	5.55	1.71	4.62
21.3	5.31	3.78	4.09
22.5	4.96	6.84	3.78
23.1	4.25	6.75	3.17
23.8	4.11	7.92	3.02
24.3	4.09	7.45	3.23

22.6	3.81	6.94	3.43
22.2	4.05	7.86	3.82
21.7	4.15	8.19	4.53
21.4	4.48	7.04	5.64
21.1	5.12	6.15	4.85
19.8	4.79	5.85	4.63
19.5	4.65	4.49	4.27
19.2	4.98	4.97	4.59

Table C8: Data for chapter 3 Figure 3.4

Forest (August 1, 2008)					
Time (min)	**Ca – stream (mg/L)**	**DOC – stream (mg/L)**			
0	5.56	1.77			
5	6.39	1.84			
10	5.57	1.73			
15	6.4	1.99			
20	7.03	1.93			
25	6.35	2.12			
30	6.17	2.58			
35	6.33	3.01			
40	6.26	2.82			
45	5.63	3.62			
50	5.92	3.84			
55	5.98	3.64			
60	6.42	3.77			
65	5.38	4.13			
70	6.85	3.98			
75	5.58	4.01			
80	6.23	3.89			
85	5.74	4.15			
90	5.47	4.23			
95	6.43	3.69			
100	5.62	3.58			

Forest (August 1, 2008)					
Ca - groundwater	DOC - groundwater	Ca - soilwater	DOC - soilwater	Ca - overland	DOC - overland
(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
3.52	1.21	39.31	7.21	5.02	8.07
3.78	1.38	40.97	5.31	5.41	8.36
3.54	1.43	53.54	5.94	4.09	8.64
3.72	1.14	37.53	5.47	3.13	11.49
4.73	2.07	29.14	6.07	3.52	8.43
4.71	1.34	35.92	8.32	4.53	7.92
4.64	1.12	37.35	7.33	3.99	9.25
3.59	1.36	46.21	6.51	3.29	9.41
4.77	1.21	37.68	4.05	4.86	8.41
5.32	1.31	36.23	7.55	3.13	8.32
		32.36	8.86	4.32	10.9
		35.38	9.12	3.74	9.45
				4.41	8.43
				4.25	9.71
				4.36	9.65
				5.97	9.72
				3.98	8.03
				3.91	7.86
				4.67	8.32
				3.29	9.38
				4.04	8.27

5yr (July 31, 2008)					
Time (min)	Ca – stream (mg/L)	DOC stream (mg/L)			
0	5.51	2.91			
5	6.19	2.71			
10	5.42	3.01			
15	5.75	2.94			
20	6.01	3.65			
25	5.37	3.86			
30	4.83	3.59			
35	4.27	4.18			

40	4.14	4.73			
45	4.92	4.92			
50	4.77	5.21			
55	4.16	5.41			
60	4.35	4.88			
65	3.91	5.29			
70	4.85	5.54			
75	3.08	4.64			
5yr (July 31, 2008)					
Ca - groundwater (mg/L)	**DOC - groundwater (mg/L)**	**Ca - soilwater (mg/L)**	**DOC - soilwater (mg/L)**	**Ca - overland (mg/L)**	**DOC - overland (mg/L)**
1.93	1.83	34.76	9.81	3.01	12.65
1.59	1.34	30.83	10.06	2.96	14.93
1.58	1.42	34.72	10.44	1.98	15.34
1.67	1.57	33.06	9.46	3.77	15.26
1.55	1.39	30.99	11.52	2.94	16.23
1.69	1.35	30.29	11.14	2.82	13.94
1.48	1.34	31.37	9.38	2.87	11.72
1.61	1.78	29.29	11.03	2.36	12.93
2.48	1.01	33.98	8.09	3.25	14.34
2.72	1.29	31.37	10.28	2.92	13.73
				2.71	16.19
				3.09	13.41
				2.31	13.84
				2.23	10.83
				2.67	9.81
				3.09	15.55
10yr (July 20, 2008)					
Time (min)	**Ca stream (mg/L)**	**DOC stream (mg/L)**			
0	5.51	2.91			
5	6.19	2.71			
10	5.42	3.01			
15	5.75	2.94			

20	6.01	3.65			
25	5.37	3.86			
30	4.83	3.59			
35	4.27	4.18			
40	4.14	4.73			
45	4.92	4.92			
50	4.77	5.21			
55	4.16	5.41			
60	4.35	4.88			
65	3.91	5.29			
70	4.85	5.54			
75	3.08	4.64			
10yr (July 20, 2008)					
Ca - groundwater	**DOC - groundwater**	**Ca - soilwater**	**DOC - soilwater**	**Ca - overland**	**DOC - overland**
(mg/L)	**(mg/L)**	**(mg/L)**	**(mg/L)**	**(mg/L)**	**(mg/L)**
1.36	1.19	37.58	13.27	1.07	10.31
1.17	1.14	36.91	13.74	1.19	10.13
1.44	1.09	34.25	11.07	1.15	10.91
1.71	1.17	31.85	10.32	1.25	9.12
1.27	1.06	36.87	12.07	1.18	13.29
1.24	1.03	37.79	11.37	1.12	11.11
1.45	1.24	38.72	10.94	1.05	10.24
1.49	1.06	35.06	13.46	1.11	10.53
1.61	1.07	39.97	12.42	1.13	14.92
1.49	1.26	34.79	12.75	1.42	11.69
		39.85	10.92	1.04	11.42
				1.19	10.24
				1.11	10.22
				1.15	13.37
				1.04	11.07
				1.25	10.39

50yr (July 02, 2008)					
Time (min)	Ca – stream (mg/L)	DOC – stream (mg/L)			
0	6.81	3.89			
5	6.96	3.74			
10	6.02	3.65			
15	6.17	4.24			
20	5.74	4.56			
25	5.56	4.48			
30	5.66	5.06			
35	4.64	5.75			
40	4.58	5.42			
45	4.96	5.14			
50	5.71	5.33			
55	5.81	4.97			
60	4.92	5.48			
65	5.02	5.64			
70	5.84	5.66			
75	5.25	5.35			
50yr (July 02, 2008)					
Ca - groundwater	DOC - groundwater	Ca - soilwater	DOC - soilwater	Ca - overland	DOC - overland
(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
5.94	1.75	21.46	15.31	1.59	10.72
5.22	1.67	27.63	14.22	1.61	14.31
5.31	1.06	26.54	15.55	2.65	14.74
5.33	1.39	26.29	13.26	1.56	15.85
5.88	1.09	21.92	13.91	2.16	11.77
5.34	1.17	20.97	15.41	1.93	16.34
5.77	1.04	21.94	13.75	3.05	15.65
5.43	1.75	20.99	13.49	1.72	13.33
5.56	1.05	27.56	15.27	1.99	14.65
5.82	1.23	24.29	14.45	2	11.54
		21.99	13.74	2.07	13.08
		21.92	14.93	1.81	10.47
		26.32	15.37	2.42	12.07
				2.02	13.74
				1.39	12.94
				1.74	15.48

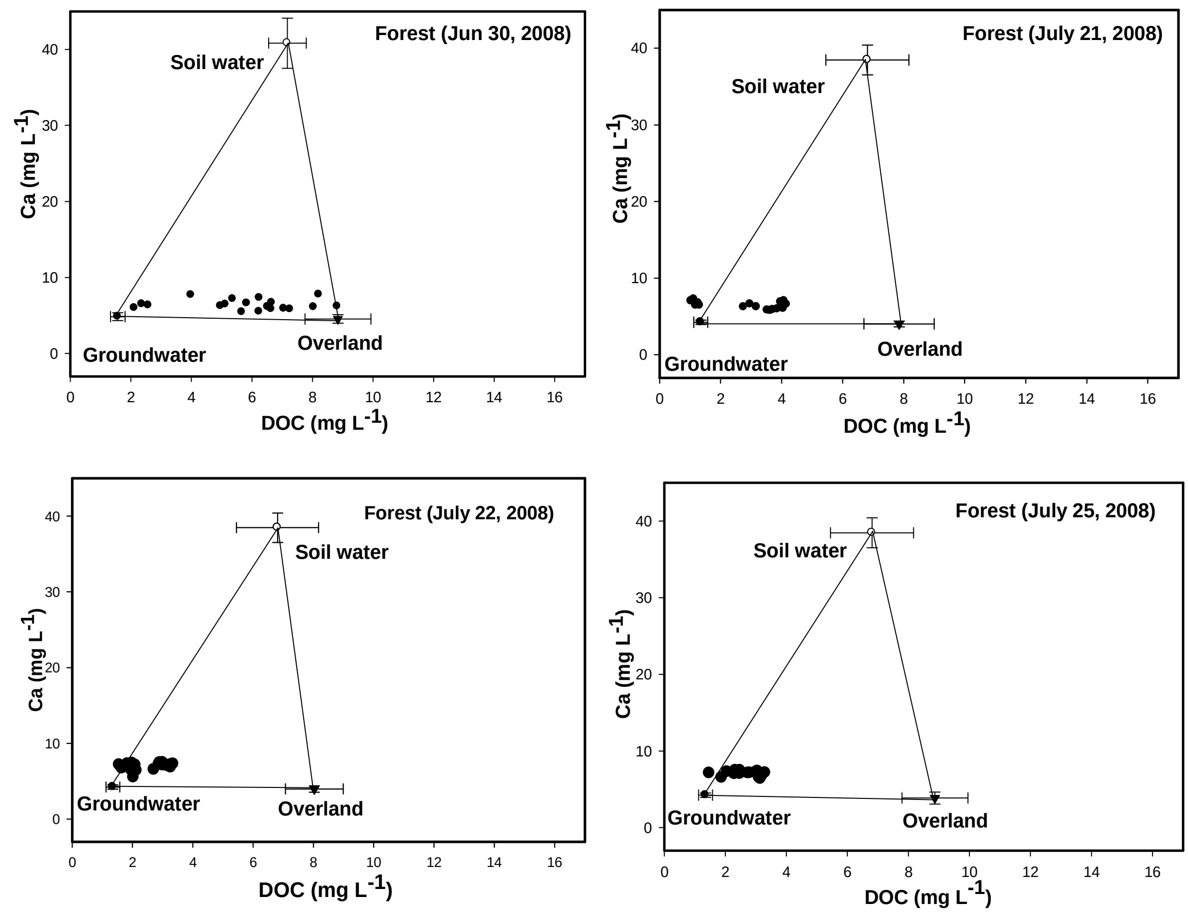

Figure C5: Mixing diagram showing DOC and Ca concentrations from stream water and end member members in various rainstorms in the forest watershed; contributions shown in Figure C9 and Table 3.2.

Table C9: Data for Figure C5.

Forest (June 30, 2008)					
Time (min)	Ca – stream (mg/L)	DOC – stream (mg/L)			
0	5.98	2.12			
5	6.32	2.58			
10	6.48	2.37			
15	7.69	3.99			
20	6.23	4.97			
25	5.43	5.67			
30	5.49	6.24			
35	6.43	5.13			
40	5.82	6.64			
45	7.75	8.21			
50	6.18	8.82			
55	6.09	8.04			
60	5.81	7.26			
65	5.88	7.06			
70	6.12	6.52			
75	6.67	6.66			
80	7.31	6.25			
85	7.15	5.37			
90	6.58	5.83			
Forest (June 30, 2008)					
Ca - groundwater (mg/L)	DOC - groundwater (mg/L)	Ca - soilwater (mg/L)	DOC - soilwater (mg/L)	Ca - overland (mg/L)	DOC - overland (mg/L)
4.581	1.538	40.971	8.315	3.672	8.357
5.035	1.393	43.744	7.345	4.098	8.641
5.321	1.854	39.537	6.773	5.134	11.49
5.654	1.787	42.954	7.169	5.159	8.432
5.352	1.784	35.927	6.513	4.528	7.917
4.981	1.572	37.916	7.563	3.986	9.252
5.276	1.431	43.216	7.879	5.258	9.412
4.879	1.431	41.685	6.424	4.862	8.409
4.905	1.601	36.235	6.599	5.529	8.343

4.648	1.813	36.833	6.875	3.904	10.938
4.285	1.928	42.382	7.456	4.231	9.452
5.158	1.218	42.383	6.462	4.324	8.428
3.815	1.047	46.687	7.901	5.159	9.742
4.027	1.608			4.528	9.643
4.716	1.618			3.986	9.192
				4.258	8.025
				4.303	8.586
				5.231	8.332
				4.809	7.389
				3.861	6.877
Forest (July 21, 2008)					
Time (min)	**Ca – stream (mg/L)**	**DOC stream (mg/L)**			
0	6.71	1.27			
5	6.98	1.04			
10	7.23	1.13			
15	6.41	1.19			
20	7.05	1.13			
25	6.42	1.32			
30	6.19	2.76			
35	6.56	2.97			
40	5.74	3.62			
45	5.86	3.72			
50	6.99	4.09			
55	5.77	3.54			
60	5.93	3.87			
65	6.85	3.98			
70	5.99	4.06			
75	6.64	4.01			
80	5.74	3.65			
85	6.53	4.17			
90	6.21	3.18			

Forest (July 21, 2008)					
Ca - groundwater	**DOC - groundwater**	**Ca - soilwater**	**DOC - soilwater**	**Ca - overland**	**DOC - overland**
(mg/L)	**(mg/L)**	**(mg/L)**	**(mg/L)**	**(mg/L)**	**(mg/L)**
4.312	1.208	39.313	6.213	4.342	6.532
4.378	1.384	40.974	5.312	4.192	7.212
4.354	1.432	39.743	5.946	3.875	6.872
4.592	1.139	37.532	5.473	4.425	7.359
3.823	1.368	40.943	6.071	3.875	8.983
3.931	1.336	35.922	8.324	4.154	8.274
4.064	1.121	39.349	6.328	4.231	10.237
4.159	1.364	36.211	6.509	3.923	8.982
4.377	1.206	39.683	4.048	3.631	7.894
4.632	1.313	36.227	7.987	4.431	7.984
4.285	1.928	40.357	8.858	3.763	9.764
3.958	1.218	39.379	8.123	3.436	9.056
3.845	1.047	37.326	6.624	3.654	7.876
4.067	1.608	40.608	6.655	3.765	9.264
4.716	1.618	35.949	8.373	3.876	6.575
		36.017	8.165	4.324	7.354
				3.768	6.236
				3.453	7.166
				4.546	7.326
				4.697	6.324
				4.345	7.649

Forest (July 22, 2008)					
Time (min)	**Ca stream (mg/L)**	**DOC stream (mg/L)**			
0	6.66	1.66			
5	7.12	1.57			
10	7.26	1.85			
15	6.87	1.91			
20	6.44	1.97			
25	7.09	2.11			
30	5.49	2.04			
35	7.33	2			

40	6.35	2.14			
45	7.08	2.02			
50	6.49	2.72			
55	7.07	3.13			
60	7.23	3.36			
65	6.97	3.17			
70	7.12	3.27			
75	7.09	3.01			
80	6.99	3.19			
85	7.41	2.92			
90	7.42	3.01			
95	7.21	2.89			
100	6.79	3.28			
Forest (July 22, 2008)					
Ca - groundwater	**DOC - groundwater**	**Ca - soilwater**	**DOC - soilwater**	**Ca - overland**	**DOC - overland**
(mg/L)	**(mg/L)**	**(mg/L)**	**(mg/L)**	**(mg/L)**	**(mg/L)**
4.312	1.208	39.313	6.213	3.873	9.323
4.378	1.384	40.974	5.312	3.291	7.612
4.354	1.432	39.743	5.946	4.037	7.432
4.592	1.139	37.532	5.473	3.763	9.943
3.823	1.368	40.943	6.071	4.421	8.305
3.931	1.336	35.922	8.324	3.768	8.674
4.064	1.121	39.349	6.328	3.879	8.325
4.159	1.364	36.211	6.509	4.653	8.186
4.377	1.206	39.683	4.048	4.526	8.087
4.632	1.313	36.227	7.987	3.876	8.325
4.285	1.928	40.357	8.858	3.764	7.536
3.958	1.218	39.379	8.123	3.291	6.236
3.845	1.047	37.326	6.624	3.932	7.345
4.067	1.608	40.608	6.655	3.587	7.476
4.716	1.618	35.949	8.373	3.781	6.143
		36.017	8.165	3.947	7.365
				4.826	7.315
				4.627	8.327
				3.765	9.549
				3.528	8.675
				4.241	8.459

Forest (July 25, 2008)					
Time (min)	Ca – stream (mg/L)	DOC – stream (mg/L)			
0	6.49	1.89			
5	7.07	1.48			
10	7.23	2.07			
15	6.97	2.31			
20	7.12	3.02			
25	7.09	2.81			
30	6.99	2.49			
35	7.41	2.49			
40	7.42	2.34			
45	7.09	2.32			
50	6.49	3.12			
55	7.33	3.07			
60	6.35	3.16			
65	7.08	2.75			
70	6.66	3.21			
75	7.12	3.31			
80	7.26	3.04			
Forest (July 25, 2008)					
Ca - groundwater	DOC - groundwater	Ca - soilwater	DOC - soilwater	Ca - overland	DOC - overland
(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
4.312	1.208	39.313	6.213	3.132	9.075
4.378	1.384	40.974	5.312	3.398	8.362
4.354	1.432	39.743	5.946	3.537	8.642
4.592	1.139	37.532	5.473	3.983	7.493
3.823	1.368	40.943	6.071	4.553	9.435
3.931	1.336	35.922	8.324	3.534	7.924
4.064	1.121	39.349	6.328	3.369	9.255
4.159	1.364	36.211	6.509	5.293	9.416
4.377	1.206	39.683	4.048	2.961	6.415
4.632	1.313	36.227	7.987	4.134	8.325
4.285	1.928	40.357	8.858	3.326	10.956
3.958	1.218	39.379	8.123	3.743	9.756
3.845	1.047	37.326	6.624	3.412	8.435

4.067	1.608	40.608	6.655	3.255	9.716
4.716	1.618	35.949	8.373	4.156	9.656
		36.017	8.165	5.927	9.925
				3.983	8.035

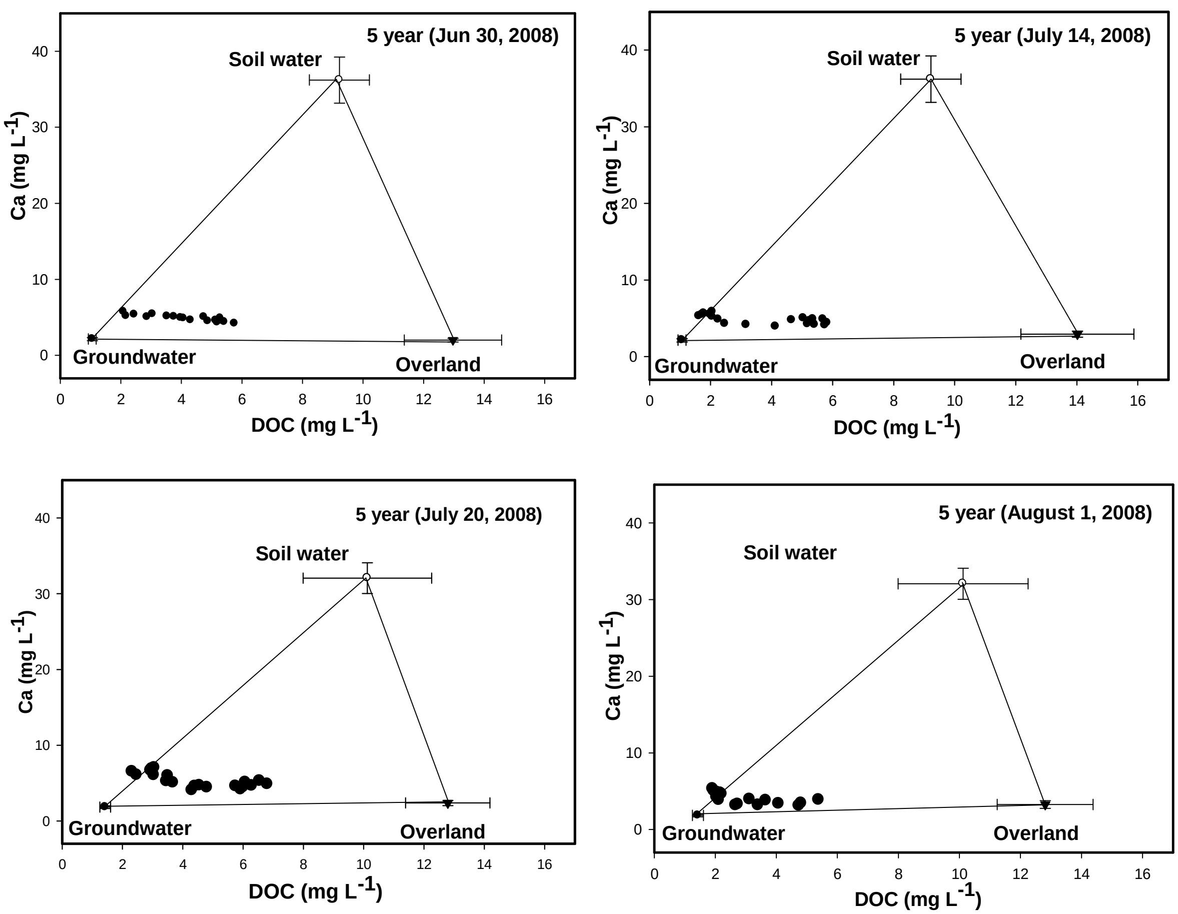

Figure C6: Mixing diagram showing DOC and Ca concentrations from stream water and end member members in various rainstorms in the 5 year old watershed; contributions shown in Figure C10 and Table 3.2.

Table C10: Data for Figure C6.

5yr (June 30, 2008)					
Time (min)	Ca – stream (mg/L)	DOC - Stream (mg/L)			
0	5.35	2.45			
5	5.74	2.09			
10	5.16	2.18			
15	5.04	2.87			
20	5.42	3.05			
25	5.07	3.76			
30	5.13	3.53			
35	4.87	4.07			
40	4.91	3.98			
45	4.62	4.31			
50	5.03	4.75			
55	4.88	5.29			
60	4.49	4.88			
65	4.57	5.14			
70	4.39	5.42			
75	4.17	5.76			
80	4.53	5.32			
85	4.31	5.19			
5yr (June 30, 2008)					
Ca - groundwater	DOC - groundwater	Ca - soilwater	DOC - soilwater	Ca - overland	DOC - overland
(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
2.014	0.951	34.763	9.813	2.082	13.054
1.985	0.897	35.832	10.062	2.121	14.643
1.961	1.123	34.725	7.542	1.954	11.532
2.102	1.025	33.766	9.463	1.453	13.274
2.292	1.262	38.991	9.224	1.898	14.653
1.845	1.041	37.292	8.746	2.212	11.859
1.797	0.989	32.373	9.384	2.035	12.532
1.823	1.108	29.593	11.032	2.195	10.757
2.231	1.129	34.981	8.091	1.796	9.732
2.428	1.348	37.876	8.253	1.908	14.438
2.626	0.953	39.598	8.052	2.102	14.106
2.145	0.877	38.892	10.215	1.859	12.624

2.198	1.012	39.842	10.013	1.764	12.722
2.324	1.089	38.473	9.241	1.982	11.764
2.287	0.986			1.859	15.857
2.211	1.231			2.201	14.543
				2.335	10.433
				1.784	12.864
				2.231	13.654
				2.501	14.433
5yr (July 14, 2008)					
Time (min)	**Ca – stream (mg/L)**	**DOC stream (mg/L)**			
0	5.62	1.78			
5	5.28	1.62			
10	5.43	1.72			
15	5.84	2.06			
20	5.51	1.98			
25	5.22	2.05			
30	4.83	2.25			
35	4.27	2.47			
40	4.14	3.17			
45	3.92	4.13			
50	4.77	4.66			
55	4.16	5.41			
60	4.35	5.38			
65	4.41	5.82			
70	4.85	5.69			
75	4.08	5.75			
80	4.24	5.18			
85	4.63	5.24			
90	4.87	5.36			
95	5.01	5.04			

5yr (July 14, 2008)					
Ca - groundwater	DOC - groundwater	Ca - soilwater	DOC - soilwater	Ca - overland	DOC - overland
(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
2.014	0.951	34.763	9.813	3.018	12.152
1.985	0.897	35.832	10.062	2.961	14.934
1.961	1.123	34.725	7.542	2.984	15.329
2.102	1.025	33.766	9.463	3.773	15.262
2.292	1.262	38.991	9.224	2.948	16.233
1.845	1.041	37.292	8.746	2.823	13.939
1.797	0.989	32.373	9.384	2.874	15.018
1.823	1.108	29.593	11.032	3.365	12.425
2.231	1.129	34.981	8.091	3.751	14.338
2.428	1.348	37.876	8.253	2.923	13.328
2.626	0.953	39.598	8.052	2.709	16.193
2.145	0.877	38.892	10.215	3.089	13.214
2.198	1.012	39.842	10.013	2.314	13.242
2.324	1.089	38.473	9.241	2.238	16.131
2.287	0.986			2.669	15.813
2.211	1.231			3.087	15.042
				2.729	11.523
				3.254	15.372
				2.519	10.123
				2.787	10.743

5yr (July 20, 2008)					
Time (min)	Ca stream (mg/L)	DOC stream (mg/L)			
0	6.6389	2.94			
5	6.482	2.328			
10	6.0543	2.472			
15	6.9984	3.06			
20	6.8556	2.98			
25	6.037	3.05			
30	5.9442	3.51			
35	5.2065	3.47			
40	5.0537	3.68			
45	4.028	4.31			

50	4.6681	4.56			
55	4.5568	4.41			
60	4.3973	4.81			
65	4.4217	6.01			
70	4.568	5.76			
75	4.1463	5.93			
80	5.0797	6.08			
85	5.2799	6.55			
90	4.6262	6.29			
95	4.8266	6.81			
5yr (July 20, 2008)					
Ca - groundwater (mg/L)	**DOC - groundwater (mg/L)**	**Ca - soilwater (mg/L)**	**DOC - soilwater (mg/L)**	**Ca - overland (mg/L)**	**DOC - overland (mg/L)**
1.591	1.461	35.836	10.063	2.876	13.982
1.984	1.551	31.724	9.546	2.135	10.233
1.938	1.328	33.069	8.463	2.419	11.731
1.652	1.699	30.997	10.251	2.287	15.673
1.892	1.254	29.196	13.743	1.962	12.522
1.687	1.441	32.375	11.385	2.701	12.482
1.669	1.478	30.394	9.276	1.872	12.543
1.681	1.681	34.981	9.092	2.318	12.184
1.724	1.369	32.853	9.285	2.328	15.643
1.923	1.508	31.527	10.458	2.718	11.982
1.706	1.305	33.891	11.108	1.798	12.652
1.945	1.405	28.876	10.052	2.241	13.661
1.998	1.304	30.491	9.235	2.398	13.701
2.194	1.826	32.831	9.776	2.285	12.104
2.048	1.141			2.629	13.008
1.694	1.205			2.419	12.027
				2.987	11.386
5 year (August 01, 2008)					
Time (min)	**Ca – stream (mg/L)**	**DOC – stream (mg/L)**			
0	4.62	2.21			
5	5.28	1.92			
10	4.73	2.17			
15	4.84	2.06			

20	5.01	1.96			
25	4.22	2.05			
30	3.83	2.12			
35	3.27	2.74			
40	3.14	2.67			
45	3.92	3.13			
50	3.77	3.66			
55	3.16	3.41			
60	3.35	4.08			
65	3.41	4.82			
70	3.85	5.39			
75	3.08	4.75			
5 year (August 01, 2008)					
Ca - groundwater	**DOC - groundwater**	**Ca - soilwater**	**DOC - soilwater**	**Ca - overland**	**DOC - overland**
(mg/L)	**(mg/L)**	**(mg/L)**	**(mg/L)**	**(mg/L)**	**(mg/L)**
1.591	1.461	35.836	10.063	3.363	12.992
1.984	1.551	31.724	9.546	3.915	13.341
1.938	1.328	33.069	8.463	3.773	15.262
1.652	1.699	30.997	10.251	3.944	15.942
1.892	1.254	29.196	13.743	3.826	12.941
1.687	1.441	32.375	11.385	2.801	12.723
1.669	1.478	30.394	9.276	2.963	12.405
1.681	1.681	34.981	9.092	3.657	12.349
1.724	1.369	32.853	9.285	2.924	12.731
1.923	1.508	31.527	10.458	3.109	11.194
1.706	1.305	33.891	11.108	3.697	13.287
1.945	1.405	28.876	10.052	2.363	14.846
1.998	1.304	30.491	9.235	2.757	11.834
2.194	1.826	32.831	9.776	2.924	13.881
2.048	1.141			3.709	10.523
1.694	1.205			2.944	11.227
				2.826	10.373

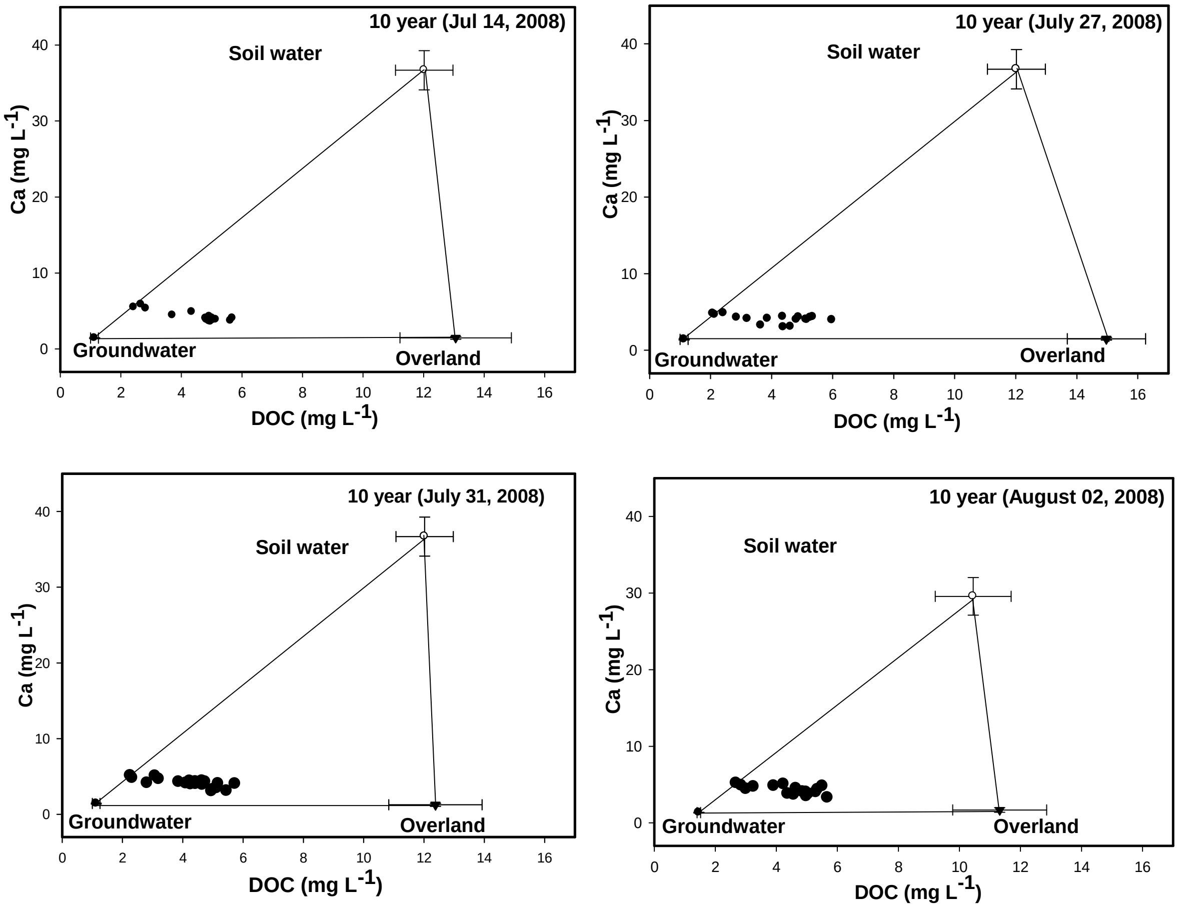

Figure C7: Mixing diagram showing DOC and Ca concentrations from stream water and end member members in various rainstorms in the 10 year old watershed; contributions shown in Figure C11 and Table 3.2).

Table C11: Data for Figure C7.

10yr (July 14, 2008)					
Time (min)	Ca – stream (mg/L)	DOC – Stream (mg/L)			
0	5.47	2.43			
5	5.84	2.67			
10	5.31	2.83			
15	4.42	3.71			
20	4.87	4.35			
25	4.03	5.02			
30	3.76	4.93			
35	3.64	4.92			
40	3.58	4.97			
45	3.86	5.14			
50	3.71	5.63			
55	3.81	5.07			
60	3.92	4.91			
65	4.02	5.69			
70	3.84	4.84			
75	4.25	4.93			
80	4.01	4.81			
10yr (July 14, 2008)					
Ca - groundwater	DOC - groundwater	Ca - soilwater	DOC - soilwater	Ca - overland	DOC - overland
(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
1.411	1.124	37.214	13.276	1.523	13.053
1.369	1.042	34.743	12.135	1.387	14.658
1.418	1.267	38.876	11.351	1.438	11.084
1.484	1.113	36.476	11.133	1.598	15.229
1.497	1.254	39.372	12.072	1.643	14.286
1.407	1.098	38.653	13.231	1.764	12.403
1.391	0.986	40.198	12.214	1.276	13.341
1.407	1.172	39.322	13.132	1.379	13.267
1.472	1.261	38.761	13.215	1.345	10.567
1.469	1.016	33.422	12.082	1.493	11.491
1.542	1.218	34.239	12.115	1.365	15.533
1.412	1.002	33.753	11.083	1.477	16.272
1.276	0.923	32.517	10.872	1.287	13.676

1.391	1.403	36.175	10.431	1.936	10.127
1.424	1.138			1.288	13.684
				1.437	10.498
				1.242	12.876
10yr (July 27, 2008)					
Time (min)	**Ca– stream (mg/L)**	**DOC - stream (mg/L)**			
0	4.78	2.08			
5	4.84	2.42			
10	4.63	2.14			
15	4.25	2.86			
20	4.08	3.21			
25	4.11	3.87			
30	3.23	3.65			
35	3.02	4.39			
40	3.07	4.62			
45	3.99	4.82			
50	3.98	5.16			
55	3.94	5.98			
60	4.35	5.35			
65	4.29	4.89			
70	4.37	4.37			
75	4.24	5.27			
80	4.01	5.13			
10yr (July 27, 2008)					
Ca - groundwater	**DOC - groundwater**	**Ca - soilwater**	**DOC - soilwater**	**Ca - overland**	**DOC - overland**
(mg/L)	**(mg/L)**	**(mg/L)**	**(mg/L)**	**(mg/L)**	**(mg/L)**
1.411	1.124	37.214	13.276	1.543	15.682
1.369	1.042	34.743	12.135	1.863	17.185
1.418	1.267	38.876	11.351	1.532	14.234
1.484	1.113	36.476	11.133	1.467	14.017
1.497	1.254	39.372	12.072	1.617	13.299
1.407	1.098	38.653	13.231	1.372	15.426
1.391	0.986	40.198	12.214	1.239	17.216

1.407	1.172	39.322	13.132	1.258	15.354
1.472	1.261	38.761	13.215	1.476	14.492
1.469	1.016	33.422	12.082	1.654	16.166
1.542	1.218	34.239	12.115	1.439	15.961
1.412	1.002	33.753	11.083	1.728	14.851
1.276	0.923	32.517	10.872	1.308	13.271
1.391	1.403	36.175	10.431	1.452	15.877
1.424	1.138			1.738	14.114
				1.383	13.108
				1.332	14.307
10yr (July 31, 2008)					
Time (min)	**Ca – stream (mg/L)**	**DOC – stream (mg/L)**			
0	5.08	2.27			
5	4.78	2.33			
10	4.12	2.82			
15	5.04	3.09			
20	4.63	3.21			
25	4.25	3.87			
30	4.08	4.11			
35	4.35	4.24			
40	4.29	4.43			
45	4.37	4.65			
50	4.24	4.75			
55	4.01	5.18			
60	3.23	5.01			
65	3.02	4.96			
70	3.07	5.46			
75	3.99	5.74			
80	3.98	4.43			
85	3.94	4.27			
90	3.42	5.13			
95	3.87	4.66			

10yr (July 31, 2008)					
Ca - groundwater	DOC - groundwater	Ca - soilwater	DOC - soilwater	Ca - overland	DOC - overland
(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
1.411	1.124	37.214	13.276	1.325	13.421
1.369	1.042	34.743	12.135	1.376	15.428
1.418	1.267	38.876	11.351	1.233	13.524
1.484	1.113	36.476	11.133	1.124	12.627
1.497	1.254	39.372	12.072	1.862	10.229
1.407	1.098	38.653	13.231	1.077	16.136
1.391	0.986	40.198	12.214	1.532	11.291
1.407	1.172	39.322	13.132	1.465	11.315
1.472	1.261	38.761	13.215	1.176	10.379
1.469	1.016	33.422	12.082	1.264	12.211
1.542	1.218	34.239	12.115	1.013	13.351
1.412	1.002	33.753	11.083	1.278	13.012
1.276	0.923	32.517	10.872	1.108	12.841
1.391	1.403	36.175	10.431	1.542	10.427
1.424	1.138			1.083	12.434
				1.103	11.228
				1.132	11.537
				1.029	11.256
				1.195	12.654
				1.321	12.325

10yr (August 02, 2008)					
Time (min)	Ca – stream (mg/L)	DOC – stream (mg/L)			
0	4.38	3.01			
5	4.85	2.86			
10	5.15	2.69			
15	4.68	3.26			
20	5.02	4.24			
25	4.79	3.92			
30	4.47	4.65			
35	4.23	4.67			
40	3.97	5.31			
45	3.25	5.68			

50	4.31	5.36			
55	4.76	5.52			
60	3.97	4.98			
65	3.75	5.06			
70	4.01	4.87			
75	3.44	4.99			
80	3.76	4.38			
85	3.65	4.58			
10yr (August 02, 2008)					
Ca - groundwater	**DOC - groundwater**	**Ca - soilwater**	**DOC - soilwater**	**Ca - overland**	**DOC - overland**
(mg/L)	**(mg/L)**	**(mg/L)**	**(mg/L)**	**(mg/L)**	**(mg/L)**
1.321	1.494	27.906	11.749	1.895	12.131
1.359	1.493	24.247	9.075	1.396	11.907
1.308	1.477	28.852	10.021	2.353	12.127
1.374	1.461	26.856	10.073	1.484	9.297
1.344	1.532	30.793	11.372	1.522	13.069
1.347	1.443	31.716	10.741	1.257	9.243
1.292	1.335	31.061	9.434	1.452	11.531
1.305	1.387	30.972	8.442	1.666	14.925
1.391	1.486	33.791	10.575	1.723	11.297
1.396	1.461	30.045	9.904	1.949	10.021
1.296	1.438	32.529	9.655	1.623	11.243
1.306	1.504	30.533	12.333	1.387	12.722
1.291	1.473	28.047	12.371	1.959	10.071
1.363	1.397	27.725	9.201	2.043	9.047
1.324	1.557	28.551	11.866	1.348	11.394
				1.806	13.328
				1.332	10.377
				1.829	10.145
				1.975	11.214

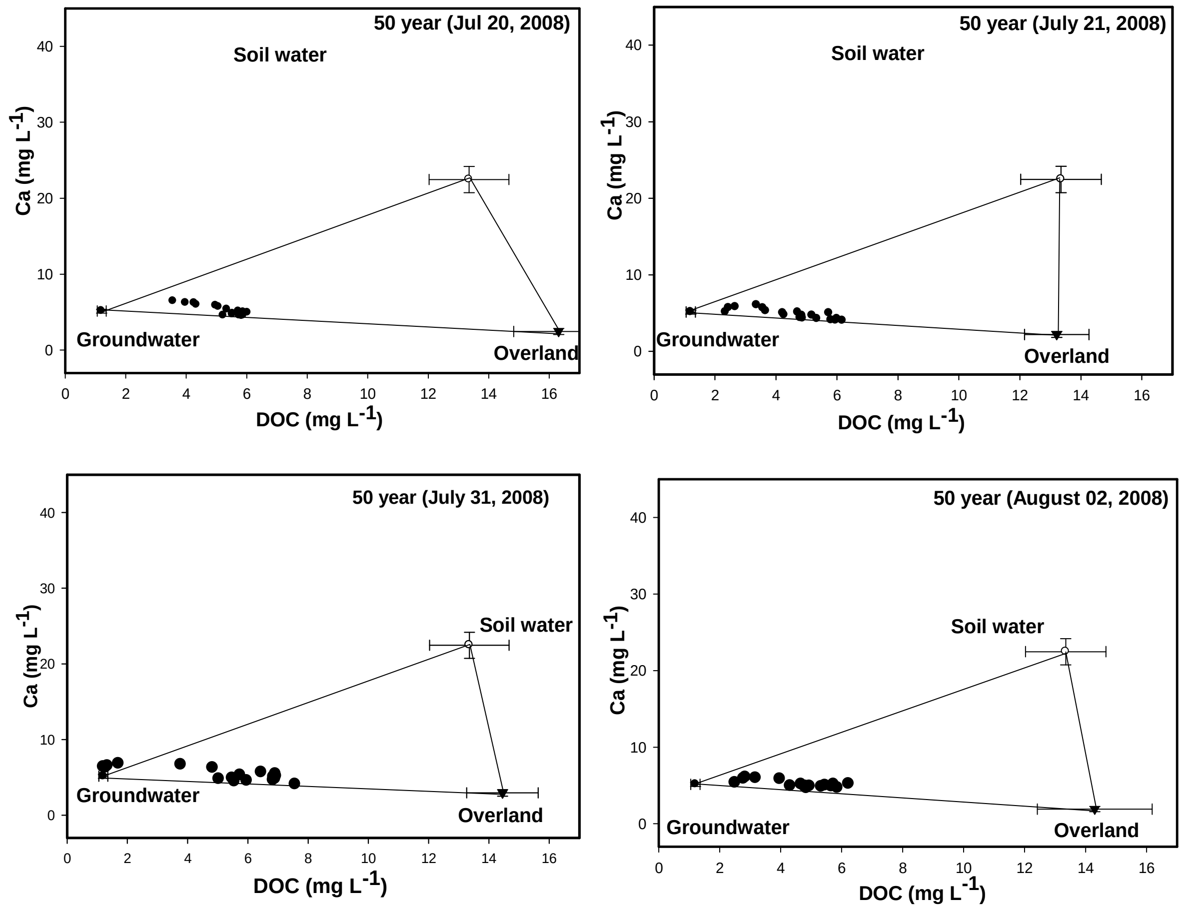

Figure C8: Mixing diagram showing DOC and Ca concentrations from stream water and end member members in various rainstorms in the 50 year old watershed; contributions shown in Figure C12 and Table 3.2.

Table C12: Data for Figure C8.

50yr (July 20, 2008)					
Time (min)	Ca – stream (mg/L)	DOC – stream (mg/L)			
0	5.96	4.34			
5	6.21	3.98			
10	6.43	3.57			
15	6.18	4.27			
20	5.85	4.98			
25	5.67	5.07			
30	5.34	5.35			
35	4.56	5.89			
40	4.69	5.53			
45	4.51	5.84			
50	4.78	5.54			
55	4.85	5.91			
60	4.92	6.03			
65	4.54	5.76			
70	4.98	5.89			
75	5.09	5.73			
80	4.54	5.23			
50yr (July 20, 2008)					
Ca - groundwater (mg/L)	DOC - groundwater (mg/L)	Ca - soilwater (mg/L)	DOC - soilwater (mg/L)	Ca - overland (mg/L)	DOC - overland (mg/L)
5.123	1.372	23.601	13.222	2.312	16.167
5.013	1.392	25.534	11.553	3.127	17.493
5.132	1.247	21.292	12.261	2.346	18.615
5.087	1.291	21.908	14.972	2.216	17.432
5.046	1.514	21.414	14.417	2.494	14.314
5.174	1.104	21.415	13.758	3.125	16.323
5.132	1.098	20.156	13.493	2.532	15.613
5.063	1.015	25.513	11.774	2.392	14.732
4.925	1.033	24.223	12.456	2.124	17.233
5.054	1.173	23.113	13.742	2.171	13.421
5.085	1.171	22.107	12.334	3.037	15.583
5.162	1.132	20.302	15.875	3.134	17.857
5.144	1.014	22.413	12.226	2.385	17.422

4.958	1.194	21.516	14.832	2.039	16.532
6.045	1.314			2.034	16.463
				2.141	17.881
				2.123	14.264

50yr (July 21, 2008)					
Time (min)	**Ca – stream (mg/L)**	**DOC - stream (mg/L)**			
0	5.67	2.45			
5	5.78	2.67			
10	5.12	2.35			
15	6.04	3.37			
20	5.63	3.58			
25	5.25	3.67			
30	5.08	4.72			
35	4.65	4.86			
40	4.29	4.88			
45	4.37	4.8			
50	4.24	5.35			
55	4.01	6.18			
60	4.23	6.01			
65	4.02	5.96			
70	4.07	5.81			
75	4.99	5.74			
80	4.98	4.23			
85	4.74	4.27			
90	4.67	5.19			
95	4.38	4.86			

50yr (July 21, 2008)					
Ca - groundwater	**DOC - groundwater**	**Ca - soilwater**	**DOC - soilwater**	**Ca - overland**	**DOC - overland**
(mg/L)	**(mg/L)**	**(mg/L)**	**(mg/L)**	**(mg/L)**	**(mg/L)**
5.123	1.372	23.601	13.222	2.313	13.131
5.013	1.392	25.534	11.553	2.027	13.479
5.132	1.247	21.292	12.261	2.206	13.052
5.087	1.291	21.908	14.972	1.863	15.021
5.046	1.514	21.414	14.417	2.034	13.241

5.174	1.104	21.415	13.758	2.025	13.162
5.132	1.098	20.156	13.493	3.163	13.413
5.063	1.015	25.513	11.774	2.322	14.102
4.925	1.033	24.223	12.456	2.024	14.316
5.054	1.173	23.113	13.742	2.613	14.068
5.085	1.171	22.107	12.334	2.357	11.272
5.162	1.132	20.302	15.875	2.177	14.153
5.144	1.014	22.413	12.226	3.065	12.381
4.958	1.194	21.516	14.832	1.839	13.042
6.045	1.314			2.094	12.343
				1.801	14.432
				2.143	11.892
				1.798	11.361
50yr (July 31, 2008)					
Time (min)	**Ca - stream (mg/L)**	**DOC - stream (mg/L)**			
0	6.35	1.21			
5	6.49	1.35			
10	6.28	1.29			
15	6.79	1.71			
20	6.67	3.78			
25	6.25	4.84			
30	5.28	5.75			
35	5.45	6.92			
40	5.66	6.45			
45	5.14	6.94			
50	5.03	6.86			
55	4.83	6.87			
60	4.77	6.91			
65	4.06	7.57			
70	4.61	6.85			
75	4.87	5.49			
80	4.53	5.97			
85	4.76	5.04			
90	4.43	5.56			

50yr (July 31, 2008)					
Ca - groundwater	DOC - groundwater	Ca - soilwater	DOC - soilwater	Ca - overland	DOC - overland
(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
5.123	1.372	23.601	13.222	2.107	12.942
5.013	1.392	25.534	11.553	2.735	13.483
5.132	1.247	21.292	12.261	2.632	11.782
5.087	1.291	21.908	14.972	2.862	12.714
5.046	1.514	21.414	14.417	1.934	14.986
5.174	1.104	21.415	13.758	2.584	15.094
5.132	1.098	20.156	13.493	2.452	14.497
5.063	1.015	25.513	11.774	3.238	14.449
4.925	1.033	24.223	12.456	2.978	16.132
5.054	1.173	23.113	13.742	3.371	14.523
5.085	1.171	22.107	12.334	3.269	16.725
5.162	1.132	20.302	15.875	3.377	14.944
5.144	1.014	22.413	12.226	3.585	13.935
4.958	1.194	21.516	14.832	2.839	15.441
6.045	1.314			3.436	13.743
				3.378	13.353
				2.943	15.162
				3.079	15.144
				3.165	14.732
				3.132	15.225

50yr (August 02, 2008)					
Time (min)	Ca – stream (mg/L)	DOC – stream (mg/L)			
0	5.32	2.51			
5	6.05	2.85			
10	5.85	2.79			
15	5.95	3.18			
20	5.82	3.98			
25	5.12	4.68			
30	4.88	4.81			
35	4.85	4.79			
40	4.63	4.85			
45	4.87	4.95			

50	4.99	5.46			
55	4.81	5.34			
60	4.67	5.87			
65	5.19	6.23			
70	4.86	5.67			
75	5.11	5.74			
80	4.79	4.85			
85	4.92	4.32			
50yr (August 02, 2008)					
Ca - groundwater	**DOC - groundwater**	**Ca - soilwater**	**DOC - soilwater**	**Ca - overland**	**DOC - overland**
(mg/L)	**(mg/L)**	**(mg/L)**	**(mg/L)**	**(mg/L)**	**(mg/L)**
5.123	1.372	23.601	13.222	1.911	14.311
5.013	1.392	25.534	11.553	2.257	14.749
5.132	1.247	21.292	12.261	2.466	14.854
5.087	1.291	21.908	14.972	1.86	18.774
5.046	1.514	21.414	14.417	1.934	12.341
5.174	1.104	21.415	13.758	2.255	16.652
5.132	1.098	20.156	13.493	1.726	16.313
5.063	1.015	25.513	11.774	1.992	14.652
4.925	1.033	24.223	12.456	1.224	12.536
5.054	1.173	23.113	13.742	2.171	12.081
5.085	1.171	22.107	12.334	2.027	13.472
5.162	1.132	20.302	15.875	1.537	16.175
5.144	1.014	22.413	12.226	1.585	13.941
4.958	1.194	21.516	14.832	1.439	12.942
6.045	1.314			2.094	13.483
				1.614	11.784
				1.941	12.712
				2.379	15.731

Table C13: Data for chapter 3 Figure 3.5

Forest storm (August 1, 2008)					
Time (min)	Rainfall (mm)	Stream discharge (L/min)	Ground water discharge (L/min)	Soil water discharge (L/min)	Overland flow discharge (L/min)
0	0.4	6.8	6.592	0.137	0.071
5	0.3	6.8	6.489	0.293	0.017
10	0.4	6.8	6.628	0.139	0.033
15	0.6	6.9	6.443	0.302	0.155
20	0.8	6.9	6.471	0.420	0.009
25	1.1	7.0	6.415	0.299	0.286
30	1.0	7.0	6.271	0.267	0.462
35	1.2	7.1	5.646	0.315	1.139
40	0.8	7.1	5.833	0.298	0.969
45	0.7	7.2	5.161	0.192	1.847
50	0.5	7.3	5.000	0.257	2.044
55	0.5	7.4	5.267	0.269	1.865
60	0.3	7.5	5.183	0.365	1.952
65	0.1	7.6	4.932	0.160	2.508
70	0.1	7.7	5.079	0.470	2.151
75		7.8	5.179	0.205	2.416
80		7.9	5.556	0.342	2.002
85		8.0	5.150	0.248	2.602
90		8.0	6.168	0.171	1.662
95		7.9	5.545	0.385	1.970
5 yr storm (July 31, 2008)					
Time (min)	Rainfall (mm)	Stream discharge (L/min)	Groundwater discharge (L/min)	Soil water discharge (L/min)	Overland flow discharge (L/min)
0	0.9	15.2	12.742	1.831	0.627
5	1.3	15.3	13.055	2.205	0.041
10	1.4	15.5	12.855	1.815	0.830
15	1.6	16.1	13.428	2.069	0.603
20	2.0	16.9	12.93	2.285	1.682
25	2.1	17.4	13.035	1.964	2.402
30	1.6	17.8	13.846	1.697	2.257
35	1.5	18.1	13.127	1.350	3.623

40	0.9	18.5	12.467	1.268	4.765
45	0.5	18.9	12.310	1.785	4.805
50		19.2	11.995	1.699	5.506
55		19.5	11.883	1.311	6.307
60		19.8	13.038	1.490	5.273
65		19.6	12.195	1.158	6.247
70		19.3	11.445	1.742	6.113
75		19.0	13.084	0.624	5.292
10 yr storm (July 20, 2008)					
Time (min)	Rainfall (mm)	Stream discharge (L/min)	Groundwater discharge (L/min)	Soil water discharge (L/min)	Overland flow discharge (L/min)
0	0.8	19.1	19.225	0	0
5	1.6	19.3	17.117	2.145	0.037
10	1.9	19.8	17.036	2.289	0.476
15	2.1	20.3	15.227	1.655	3.418
20	1.9	20.8	14.063	1.608	5.128
25	1.4	21.1	13.072	1.658	6.370
30	0.7	21.5	13.467	1.156	6.876
35	0.5	22.1	13.854	1.058	7.188
40	0.4	22.5	13.996	1.109	7.395
45	0.2	22.9	13.907	1.724	7.269
50		22.6	12.623	1.704	8.273
55		21.7	13.327	1.602	6.771
60		21.3	13.398	1.816	6.086
65		20.9	11.564	1.759	7.577
70		20.6	12.057	1.775	6.768
75		20.3	13.168	1.665	5.468
80		20.0	12.803	1.512	5.689
50 yr storm (July 02, 2008)					
Time (min)	Rainfall (mm)	Stream discharge (L/min)	Groundwater discharge (L/min)	Soil water discharge (L/min)	Overland flow discharge (L/min)
0	0.4	18.5	14.736	0	2.163
5	0.7	18.9	15.294	1.724	1.881
10	1.2	19.3	15.693	0.918	2.689

15	1.3	19.6	15.014	1.223	3.363
20	1.4	20.2	14.920	0.956	4.324
25	1.9	20.8	15.484	0.793	4.523
30	1.7	21.2	14.797	1.072	5.332
35	1.5	21.8	13.921	0.303	7.576
40	0.8	22.3	14.830	0.149	7.321
45	0.3	22.9	15.778	0.459	6.662
50		23.4	15.826	1.322	6.252
55		23.9	16.868	1.341	5.692
60		24.3	16.072	0.556	7.673
65		24.2	15.702	0.715	7.783
70		24.2	15.737	1.618	6.848
75		24.1	16.221	0.867	7.012

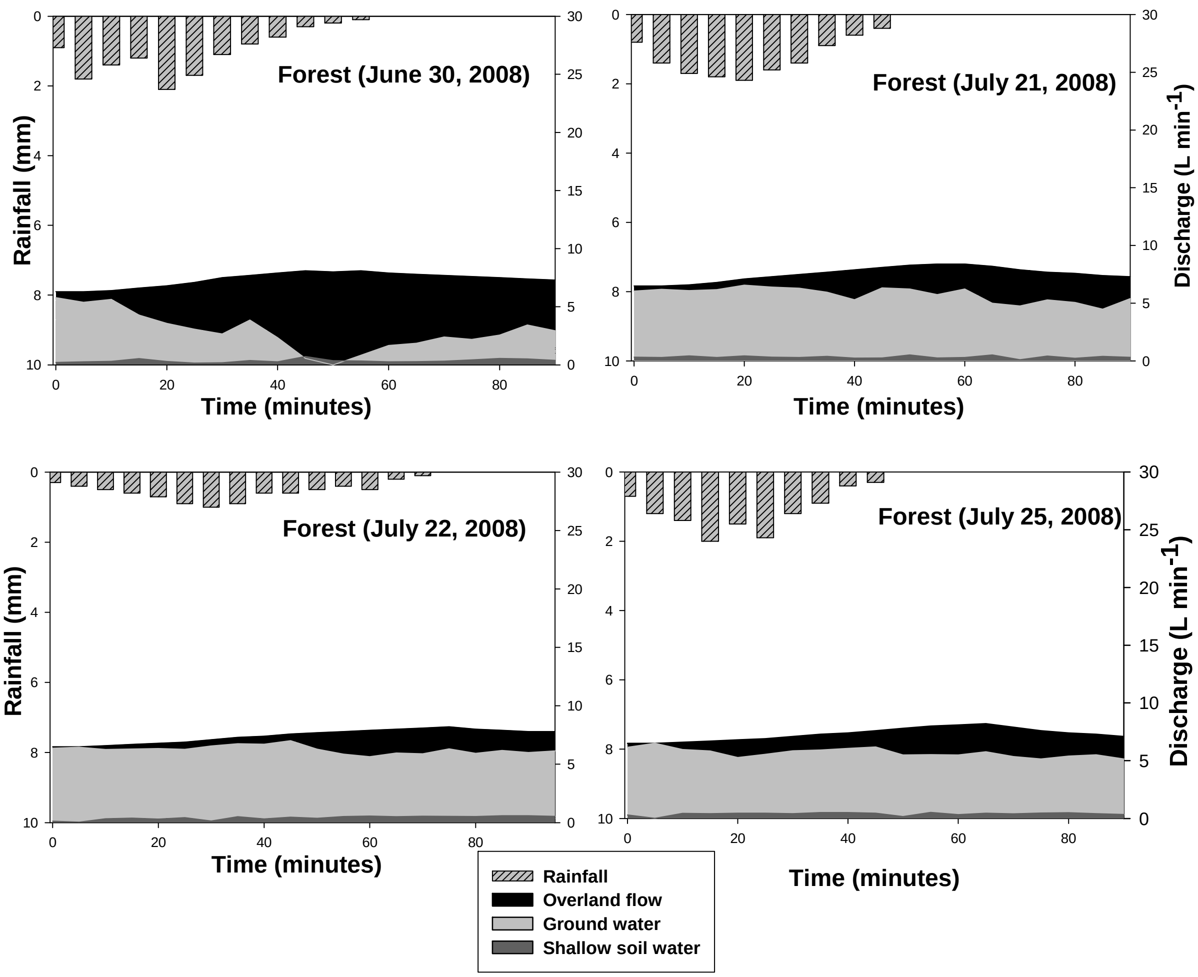

Figure C9: Estimated Event water contributions for rainstorms using EMMA, for the 4 remaining events in the forest (total contributions shown in Table 3.3).

Table C14: Data for Figure C9.

Forest (June 30, 2008)					
Time (min)	Rainfall (mm)	Stream discharge (L/min)	Groundwater discharge (L/min)	Soilwater discharge (L/min)	Overland discharge (L/min)
0	0.9	6.3	5.785	0.202	0.312
5	1.8	6.3	5.372	0.265	0.663
10	1.4	6.4	5.636	0.296	0.468
15	1.2	6.6	4.288	0.538	1.774
20	2.1	6.8	3.563	0.287	2.9
25	1.7	7.1	3.071	0.149	3.880
30	1.1	7.5	2.652	0.175	4.673
35	0.8	7.7	3.855	0.369	3.476
40	0.6	7.9	2.342	0.259	5.299
45	0.3	8.1	0.549	0.712	6.839
50	0.2	8	0	0.362	7.638
55	0.1	8.1	0.824	0.339	6.937
60		7.9	1.667	0.263	5.970
65		7.8	1.858	0.273	5.670
70		7.7	2.395	0.316	4.990
75		7.6	2.191	0.428	4.981
80		7.5	2.555	0.552	4.394
85		7.4	3.426	0.504	3.470
90		7.3	2.943	0.386	3.971
Forest (July 21, 2008)					
Time (min)	Rainfall (mm)	Stream discharge (L/min)	Groundwater discharge (L/min)	Soilwater discharge (L/min)	Overland discharge (L/min)
0	0.8	6.5	6.059	0.340	0.101
5	1.4	6.5	6.199	0.301	0
10	1.7	6.6	6.089	0.440	0.071
15	1.8	6.8	6.171	0.304	0.325
20	1.9	7.1	6.566	0.438	0.096
25	1.6	7.3	6.402	0.333	0.564
30	1.4	7.5	6.295	0.302	0.903
35	0.9	7.7	5.950	0.399	1.352
40	0.6	7.9	5.301	0.251	2.347

45	0.4	8.1	6.340	0.263	1.496
50		8.3	6.244	0.531	1.526
55		8.4	5.745	0.271	2.384
60		8.4	6.238	0.297	1.866
65		8.2	5.005	0.519	2.677
70		7.9	4.764	0.101	3.034
75		7.7	5.283	0.430	1.987
80		7.6	5.065	0.242	2.294
85		7.4	4.488	0.404	2.508
90		7.3	5.403	0.314	1.583

Forest (July 22, 2008)					
Time (min)	**Rainfall (mm)**	**Stream discharge (L/min)**	**Groundwater discharge (L/min)**	**Soilwater discharge (L/min)**	**Overland discharge (L/min)**
0	0.3	6.5	6.376	0.124	0
5	0.4	6.5	6.456	0.044	0
10	0.5	6.6	6.265	0.335	0
15	0.6	6.7	6.307	0.379	0.015
20	0.7	6.8	6.348	0.306	0.146
25	0.9	6.9	6.275	0.436	0.189
30	1	7.1	6.575	0.138	0.387
35	0.9	7.3	6.757	0.506	0.037
40	0.6	7.4	6.715	0.319	0.366
45	0.6	7.6	7.018	0.476	0.106
50	0.5	7.7	6.289	0.378	1.034
55	0.4	7.8	5.857	0.517	1.426
60	0.5	7.9	5.645	0.565	1.691
65	0.2	8	5.960	0.510	1.530
70	0.1	8.1	5.904	0.552	1.644
75		8.2	6.309	0.545	1.346
80		8	5.935	0.515	1.551
85		7.9	6.180	0.591	1.129
90		7.8	5.992	0.588	1.220
95		7.8	6.144	0.540	1.116

Forest (July 25, 2008)					
Time (min)	**Rainfall (mm)**	**Stream discharge (L/min)**	**Groundwater discharge (L/min)**	**Soilwater discharge (L/min)**	**Overland discharge (L/min)**
0	0.7	6.5	6.154	0.299	0.047
5	1.2	6.5	6.497	0.003	0
10	1.4	6.6	5.962	0.434	0.104
15	2	6.7	5.846	0.399	0.355
20	1.5	6.8	5.272	0.448	0.980
25	1.9	6.9	5.549	0.445	0.806
30	1.2	7.1	5.853	0.419	0.527
35	0.9	7.3	5.921	0.505	0.475
40	0.4	7.4	6.063	0.503	0.334
45	0.3	7.6	6.185	0.447	0.368
50		7.8	5.484	0.159	1.357
55		8	5.528	0.517	1.055
60		8.1	5.484	0.329	1.286
65		8.2	5.771	0.455	0.775
70		7.9	5.345	0.385	1.27
75		7.6	5.153	0.468	1.278
80		7.4	5.404	0.489	1.007
85		7.3	5.512	0.405	0.8833
90		7.1	5.146	0.334	1.32

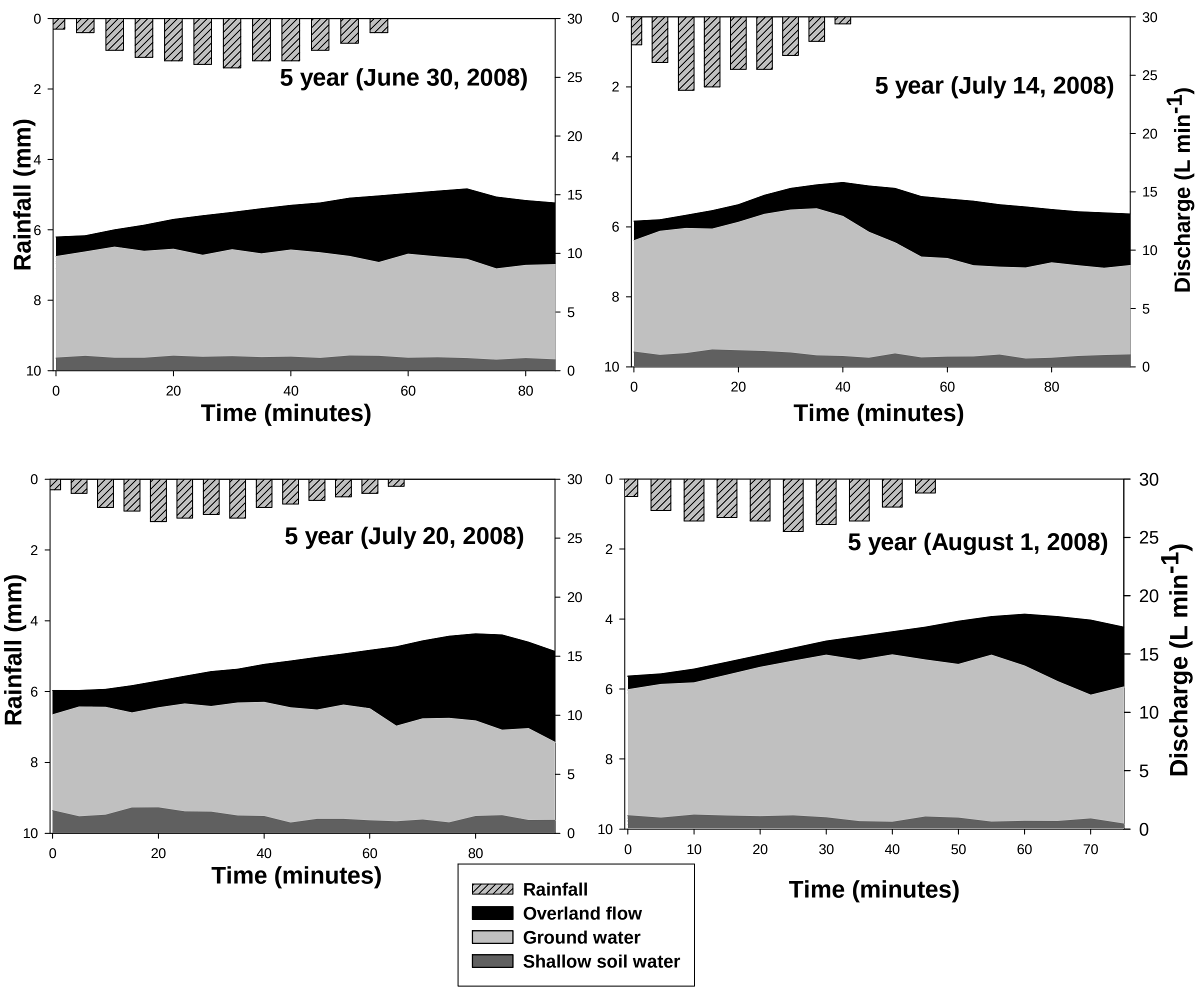

Figure C10: Estimated Event water contributions for rainstorms using EMMA, for the 4 remaining events in the 5 year old watershed (total contributions shown in Table 3.3).

Table C15: Data for Figure C10.

5 yr (June 30, 2008)					
Time (min)	Rainfall (mm)	Stream discharge (L/min)	Groundwater discharge (L/min)	Soilwater discharge (L/min)	Overland discharge (L/min)
0	0.3	11.4	9.731	1.076	0.593
5	0.4	11.5	10.123	1.216	0.161
10	0.9	12	10.537	1.065	0.398
15	1.1	12.4	10.182	1.060	1.158
20	1.2	12.9	10.352	1.247	1.301
25	1.3	13.2	9.848	1.144	2.209
30	1.4	13.5	10.325	1.192	1.983
35	1.2	13.8	9.961	1.116	2.723
40	1.2	14.1	10.279	1.157	2.664
45	0.9	14.3	10.067	1.053	3.180
50	0.7	14.7	9.749	1.261	3.690
55	0.4	14.9	9.226	1.215	4.459
60		15.1	9.924	1.057	4.119
65		15.3	9.710	1.108	4.482
70		15.5	9.498	1.043	4.960
75		14.8	8.676	0.902	5.222
80		14.5	8.988	1.034	4.478
85		14.3	9.050	0.927	4.323
5 yr (July 14, 2008)					
Time (min)	Rainfall (mm)	Stream discharge (L/min)	Groundwater discharge (L/min)	Soilwater discharge (L/min)	Overland discharge (L/min)
0	0.8	12.5	10.82	1.27	0.41
5	1.3	12.6	11.62	0.98	0
10	2.1	13	11.87	1.13	0
15	2	13.4	11.82	1.45	0.13
20	1.5	13.9	12.4	1.37	0.13
25	1.5	14.7	13.08	1.32	0.3
30	1.1	15.3	13.45	1.19	0.66
35	0.7	15.6	13.55	0.95	1.1
40	0.2	15.8	12.9	0.88	2.02
45		15.5	11.55	0.73	3.22

50		15.3	10.64	1.1	3.56
55		14.6	9.41	0.76	4.43
60		14.4	9.29	0.83	4.28
65		14.2	8.67	0.84	4.69
70		13.9	8.56	1	4.34
75		13.7	8.49	0.67	4.54
80		13.5	8.93	0.74	3.83
85		13.3	8.68	0.88	3.74
90		13.2	8.46	0.97	3.77
95		13.1	8.69	1.02	3.39
5 yr (July 20, 2008)					
Time (min)	**Rainfall (mm)**	**Stream discharge (L/min)**	**Groundwater discharge (L/min)**	**Soilwater discharge (L/min)**	**Overland discharge (L/min)**
0	0.3	12.1	10.038	1.915	0.147
5	0.4	12.1	10.709	1.391	0
10	0.8	12.2	10.682	1.518	0
15	0.9	12.5	10.203	2.125	0.172
20	1.2	12.9	10.635	2.135	0.130
25	1.1	13.3	10.965	1.816	0.519
30	1	13.7	10.746	1.787	1.167
35	1.1	13.9	11.03	1.459	1.411
40	0.8	14.3	11.098	1.406	1.797
45	0.7	14.6	10.629	0.855	3.116
50	0.6	14.9	10.445	1.182	3.273
55	0.5	15.2	10.870	1.161	3.169
60	0.4	15.5	10.554	1.059	3.887
65	0.2	15.8	9.075	0.974	5.752
70		16.3	9.705	1.113	5.482
75		16.7	9.745	0.877	6.078
80		16.9	9.517	1.422	5.961
85		16.8	8.735	1.481	6.584
90		16.2	8.877	1.085	6.238
95		15.4	7.705	1.089	6.606

5 yr (August 1, 2008)					
Time (min)	Rainfall (mm)	Stream discharge (L/min)	Groundwater discharge (L/min)	Soilwater discharge (L/min)	Overland discharge (L/min)
0	0.5	13.1	11.936	1.128	0.037
5	0.9	13.3	12.382	0.918	0
10	1.2	13.7	12.518	1.182	0
15	1.1	14.3	13.190	1.110	0
20	1.2	14.9	13.852	1.048	0
25	1.5	15.5	14.388	1.112	0
30	1.3	16.1	14.898	0.955	0.247
35	1.2	16.5	14.453	0.623	1.424
40	0.8	16.9	14.925	0.567	1.409
45	0.4	17.3	14.476	1.014	1.810
50		17.8	14.095	0.917	2.788
55		18.2	14.900	0.573	2.729
60		18.4	13.961	0.654	3.786
65		18.2	12.629	0.634	4.938
70		17.9	11.469	0.856	5.575
75		17.3	12.156	0.411	4.733

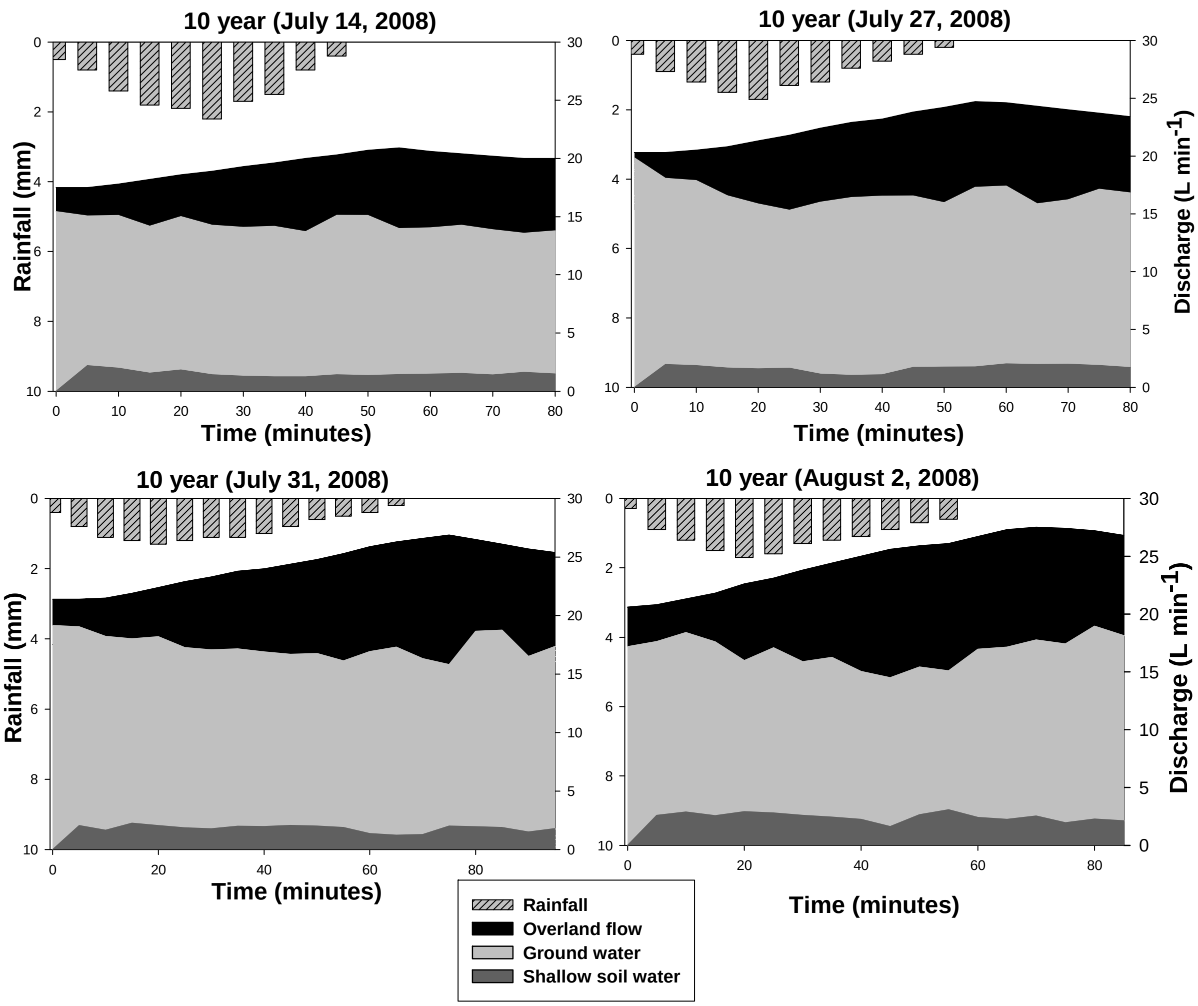

Figure C11: Estimated Event water contributions for rainstorms using EMMA, for the 4 remaining events in the 10 year old watershed (total contributions shown in Table 3.3).

Table C16: Data for Figure C11.

10 yr (July 14, 2008)					
Time (min)	Rainfall (mm)	Stream discharge (L/min)	Groundwater discharge (L/min)	Soilwater discharge (L/min)	Overland discharge (L/min)
0	0.5	17.5	15.419	0	0.071
5	0.8	17.5	15.054	2.193	0.252
10	1.4	17.8	15.105	1.964	0.731
15	1.8	18.2	14.172	1.551	2.477
20	1.9	18.6	15.011	1.821	1.766
25	2.2	18.9	14.256	1.402	3.241
30	1.7	19.3	14.080	1.285	3.935
35	1.5	19.6	14.161	1.238	4.201
40	0.8	20	13.712	1.231	5.058
45	0.4	20.3	15.122	1.409	3.770
50		20.7	15.105	1.349	4.246
55		20.9	13.971	1.423	5.507
60		20.6	14.035	1.466	5.099
65		20.4	14.262	1.509	4.629
70		20.2	13.884	1.392	4.925
75		20	13.574	1.610	4.816
80		20	13.786	1.474	4.740
10 yr (July 27, 2008)					
Time (min)	Rainfall (mm)	Stream discharge (L/min)	Groundwater discharge (L/min)	Soilwater discharge (L/min)	Overland discharge (L/min)
0	0.4	20.3	19.843	0	0
5	0.9	20.3	18.076	1.968	0.256
10	1.2	20.5	17.881	1.864	0.755
15	1.5	20.8	16.568	1.664	2.568
20	1.7	21.3	15.850	1.599	3.852
25	1.3	21.8	15.320	1.653	4.827
30	1.2	22.4	16.007	1.139	5.254
35	0.8	22.9	16.410	1.028	5.462
40	0.6	23.2	16.534	1.074	5.592
45	0.4	23.8	16.537	1.723	5.540
50	0.2	24.2	15.960	1.744	6.497

55		24.7	17.295	1.754	5.652
60		24.6	17.412	2.033	5.154
65		24.3	15.875	1.965	6.461
70		24	16.222	1.996	5.782
75		23.7	17.133	1.886	4.681
80		23.4	16.814	1.709	4.878
10 yr (July 31, 2008)					
Time (min)	**Rainfall (mm)**	**Stream discharge (L/min)**	**Groundwater discharge (L/min)**	**Soilwater discharge (L/min)**	**Overland discharge (L/min)**
0	0.4	21.4	19.160	0	0.019
5	0.8	21.4	19.052	2.040	0.308
10	1.1	21.5	18.217	1.653	1.629
15	1.2	21.9	18.012	2.255	1.633
20	1.3	22.4	18.193	2.049	2.159
25	1.2	22.9	17.263	1.855	3.782
30	1.1	23.3	17.071	1.777	4.451
35	1.1	23.8	17.157	1.998	4.645
40	1	24	16.897	1.976	5.127
45	0.8	24.4	16.699	2.066	5.634
50	0.6	24.8	16.756	2.010	6.034
55	0.5	25.3	16.132	1.891	7.278
60	0.4	25.9	16.924	1.363	7.613
65	0.2	26.3	17.307	1.228	7.765
70		26.6	16.321	1.285	8.994
75		26.9	15.813	2.001	9.086
80		26.5	18.664	1.950	5.886
85		26.1	18.755	1.890	5.456
90		25.7	16.515	1.492	7.693
95		25.4	17.373	1.793	6.235

10yr (August 2, 2008)					
Time (min)	**Rainfall (mm)**	**Stream discharge (L/min)**	**Groundwater discharge (L/min)**	**Soilwater discharge (L/min)**	**Overland discharge (L/min)**
0	0.3	20.6	17.167	0	1.224
5	0.9	20.8	17.619	2.585	0.596
10	1.2	21.3	18.389	2.881	0.030
15	1.5	21.8	17.594	2.566	1.640
20	1.7	22.6	15.972	2.907	3.722
25	1.6	23.1	17.091	2.790	3.219
30	1.3	23.8	15.872	2.58	5.348
35	1.2	24.4	16.242	2.435	5.724
40	1.1	25	15.041	2.242	7.718
45	0.9	25.6	14.500	1.623	9.477
50	0.7	25.9	15.423	2.636	7.841
55	0.6	26.1	15.082	3.072	7.947
60		26.7	16.956	2.405	7.339
65		27.3	17.135	2.241	7.924
70		27.5	17.767	2.520	7.213
75		27.4	17.419	1.948	8.034
80		27.2	18.945	2.266	5.989
85		26.8	18.133	2.121	6.547

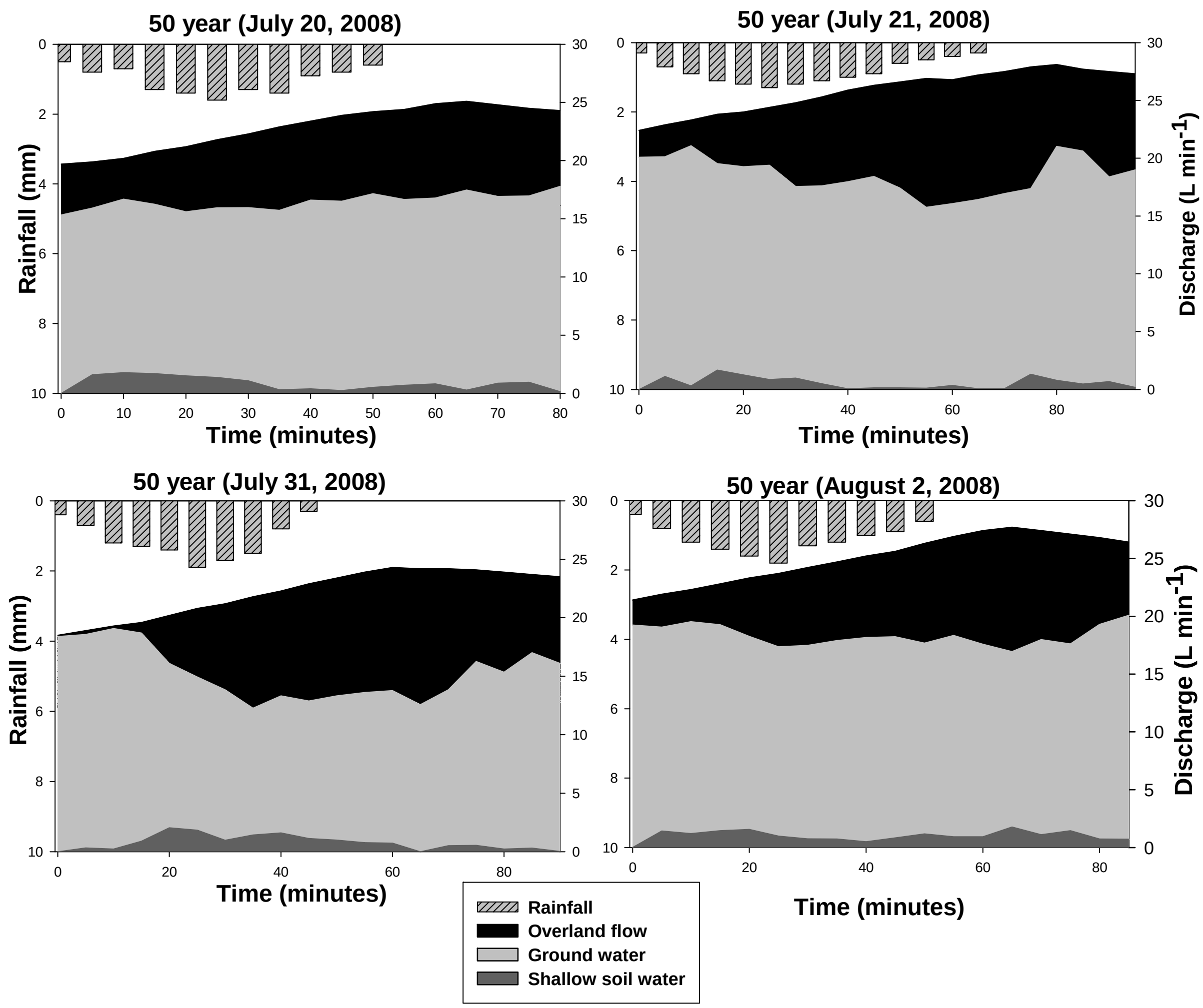

Figure C12: Estimated event water contributions for rainstorms using EMMA, for the 4 remaining events in the 50 year old watershed (total contributions shown in Table 3.3).

Table C17: Data for Figure C12.

50 yr (July 20, 2008)					
Time (min)	**Rainfall (mm)**	**Stream discharge (L/min)**	**Groundwater discharge (L/min)**	**Soilwater discharge (L/min)**	**Overland discharge (L/min)**
0	0.5	19.7	15.333	0	2.973
5	0.8	19.9	15.926	1.598	2.376
10	0.7	20.2	16.684	1.775	1.741
15	1.3	20.8	16.242	1.694	2.864
20	1.4	21.2	15.602	1.505	4.094
25	1.6	21.8	15.949	1.364	4.487
30	1.3	22.3	15.965	1.075	5.261
35	1.4	22.9	15.733	0.300	6.867
40	0.9	23.4	16.619	0.385	6.396
45	0.8	23.9	16.514	0.241	7.146
50	0.6	24.2	17.149	0.513	6.539
55		24.4	16.660	0.687	7.054
60		24.9	16.780	0.818	7.302
65		25.1	17.472	0.273	7.355
70		24.8	16.934	0.859	7.007
75		24.5	16.969	0.951	6.580
80		24.3	17.790	0.147	6.363
50 yr (July 21, 2008)					
Time (min)	**Rainfall (mm)**	**Stream discharge (L/min)**	**Groundwater discharge (L/min)**	**Soilwater discharge (L/min)**	**Overland discharge (L/min)**
0	0.3	22.4	20.086	0	1.393
5	0.7	22.9	20.117	1.126	1.657
10	0.9	23.3	21.079	0.298	1.922
15	1.1	23.8	19.526	1.676	2.598
20	1.2	24	19.265	1.266	3.469
25	1.3	24.4	19.398	0.856	4.146
30	1.2	24.8	17.549	0.976	6.276
35	1.1	25.3	17.602	0.502	7.197
40	1	25.9	17.971	0.060	7.869
45	0.9	26.3	18.424	0.140	7.736
50	0.6	26.6	17.416	0.147	9.037

55	0.5	26.9	15.752	0.112	11.036
60	0.4	26.8	16.076	0.347	10.377
65	0.3	27.2	16.426	0.055	10.720
70		27.5	16.951	0.073	10.476
75		27.9	17.374	1.316	9.209
80		28.1	21.027	0.801	6.272
85		27.7	20.632	0.476	6.593
90		27.5	18.378	0.682	8.441
95		27.3	18.989	0.178	8.133
50 yr (July 31, 2008)					
Time (min)	**Rainfall (mm)**	**Stream discharge (L/min)**	**Groundwater discharge (L/min)**	**Soilwater discharge (L/min)**	**Overland discharge (L/min)**
0	0.4	18.5	18.390	0	0
5	0.7	18.9	18.574	0.326	0
10	1.2	19.3	19.073	0.227	0
15	1.3	19.6	18.700	0.900	0
20	1.4	20.2	16.097	2.045	2.058
25	1.9	20.8	14.933	1.842	4.025
30	1.7	21.2	13.839	0.978	6.383
35	1.5	21.8	12.271	1.416	8.113
40	0.8	22.3	13.331	1.601	7.368
45	0.3	22.9	12.886	1.124	8.890
50		23.4	13.321	0.999	9.079
55		23.9	13.608	0.776	9.516
60		24.3	13.768	0.721	9.810
65		24.2	12.569	0	11.665
70		24.2	13.839	0.506	9.856
75		24.1	16.252	0.548	7.301
80		23.9	15.342	0.222	8.437
85		23.7	17.018	0.316	6.666
90		23.5	16.102	0.013	7.885

50yr (August 2, 2008)					
Time (min)	**Rainfall (mm)**	**Stream discharge (L/min)**	**Groundwater discharge (L/min)**	**Soilwater discharge (L/min)**	**Overland discharge (L/min)**
0	0.4	21.4	19.228	0	1.644
5	0.8	21.9	19.046	1.419	1.437
10	1.2	22.3	19.512	1.209	1.580
15	1.4	22.8	19.254	1.456	2.090
20	1.6	23.3	18.248	1.565	3.487
25	1.8	23.7	17.339	0.977	5.385
30	1.3	24.2	17.482	0.750	5.968
35	1.2	24.7	17.884	0.723	6.093
40	1	25.2	18.149	0.483	6.568
45	0.9	25.6	18.218	0.824	6.558
50	0.6	26.3	17.668	1.165	7.467
55		26.9	18.338	0.914	7.648
60		27.4	17.571	0.918	8.911
65		27.7	16.942	1.758	8.999
70		27.4	17.976	1.108	8.316
75		27.1	17.608	1.452	8.040
80		26.8	19.286	0.725	6.789
85		26.4	20.067	0.713	5.620

Table C18: Data for chapter 3 Table 3.2

Forest flowpaths						
	DOC (mg/L)	K (mg/L)	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	TDN (mg/L)
Overland	8.07	4.09	5.02	0.97	1.21	2.13
Overland	8.36	5.23	5.41	0.92	1.38	2.01
Overland	8.64	2.41	4.09	1.02	1.17	1.68
Overland	11.49	5.02	5.13	1.5	2.62	1.79
Overland	8.43	4.64	5.52	0.79	1.35	1.87
Overland	7.92	2.96	4.53	1.15	0.89	1.84
Overland	9.25	3.35	3.39	0.65	2.03	1.81
Overland	9.41	3.43	5.29	0.74	1.48	1.01
Overland	6.41	4.47	4.86	0.83	1.36	1.27
Overland	8.32	6.25	6.13	1.09	2.01	1.95
Overland	10.9	2.74	4.32	1.11	1.46	1.71
Overland	9.45	4.01	5.74	1.06	0.96	1.68
Overland	8.43	3.02	4.41	1.03	1.05	1.81
Overland	9.71	5.86	6.25	0.67	1.26	2.24
Overland	9.65	3.98	4.16	0.56	1.14	1.84
Overland	9.92	4.43	5.97	0.82	2.03	1.67
Overland	8.03	3.64	3.98	0.66	1.15	1.58
Overland	7.86	4.96	4.81	0.52	1.08	2.13
Overland	8.32	2.35	4.67	0.83	1.14	1.32
Overland	5.38	3.61	3.29	0.55	1.21	0.81
Overland	8.27	3.79	4.04	0.76	2.63	1.61
Overland	8.91	4.89	4.15	0.35	1.53	2.01
Overland	6.83	3.51	4.12	0.47	1.24	2.15
Overland	11.9	4.69	3.39	0.67	1.02	1.88
Overland	9.45	3.09	5.18	0.85	1.19	1.84
Overland	8.43	5.07	4.86	0.59	0.85	2.29
Overland	9.74	3.19	5.13	0.98	1.23	2.01
Overland	9.54	4.14	4.31	1.15	1.39	1.87
Overland	11.19	4.52	4.23	0.73	1.49	1.75
Overland	6.95	2.75	3.76	1.09	1.28	2.66
Overland	8.79	5.83	4.29	0.98	1.19	1.61
Overland	11.32	3.24	3.13	1.02	1.64	1.72
Overland	8.79	4.96	4.19	1.07	1.03	2.12
Overland	9.96	2.41	3.53	1.23	2.02	2.16

Overland	9.31	5.72	3.76	0.79	1.39	2.23
Soilwater	7.21	4.97	39.31	10.17	0.68	9.72
Soilwater	5.31	4.24	40.97	10.81	0.41	7.94
Soilwater	5.94	3.16	53.74	13.99	0.63	8.14
Soilwater	5.47	4.03	37.53	7.12	0.52	7.04
Soilwater	6.07	4.41	29.94	8.23	0.39	8.05
Soilwater	8.32	3.35	35.92	9.56	0.34	8.76
Soilwater	7.33	3.09	37.35	5.16	0.29	6.51
Soilwater	6.51	5.71	46.21	13.91	0.81	7.63
Soilwater	4.05	4.08	37.68	6.04	0.28	11.1
Soilwater	7.99	3.16	36.23	12.67	0.73	10.52
Soilwater	8.86	4.18	32.36	10.83	0.32	10.91
Soilwater	9.12	4.46	35.38	5.01	0.36	11.74
Soilwater	9.62	5.01	37.33	6.12	0.49	12.93
Soilwater	7.65	4.29	33.61	6.71	0.35	8.78
Soilwater	9.37	3.24	31.95	11.53	0.38	7.46
Soilwater	8.16	5.02	46.02	9.41	0.49	6.85
Soilwater	8.18	3.99	37.74	9.73	0.35	9.47
Soilwater	9.48	3.47	37.08	7.15	0.45	10.42
Soilwater	7.29	4.23	47.33	9.11	0.56	9.84
Soilwater	7.49	3.52	40.72	7.79	0.42	7.46
Groundwater	1.21	0.32	4.52	2.81	3.93	1.34
Groundwater	1.38	0.41	3.78	1.06	2.38	0.81
Groundwater	1.43	0.23	5.54	2.47	3.81	1.28
Groundwater	1.14	0.35	5.72	2.41	4.07	0.97
Groundwater	2.37	0.48	4.73	1.88	2.92	1.09
Groundwater	1.34	0.29	4.71	2.94	3.89	0.83
Groundwater	1.12	0.49	4.64	2.02	3.55	0.96
Groundwater	1.36	0.37	5.59	1.95	3.42	0.79
Groundwater	1.21	0.46	4.77	2.53	3.41	0.88
Groundwater	1.31	0.63	5.32	2.39	4.16	0.92
Groundwater	1.93	0.53	4.85	2.19	2.77	0.78
Groundwater	2.25	0.32	4.58	1.23	4.12	0.82
Groundwater	1.05	0.26	3.84	1.36	2.77	1.03
Groundwater	1.64	0.22	4.67	2.15	3.82	1.15
Groundwater	1.75	0.49	5.71	1.87	4.36	1.08
Groundwater	2.11	0.37	4.73	2.19	3.55	1.29
Groundwater	1.65	0.46	5.71	2.23	3.72	1.17
Groundwater	2.49	0.43	5.24	1.82	3.91	1.12

Groundwater	1.63	0.25	5.59	1.65	4.16	0.98
Groundwater	1.32	0.32	4.43	2.51	3.77	1.18
5 yr flowpaths						
	DOC (mg/L)	**K (mg/L)**	**Ca (mg/L)**	**Mg (mg/L)**	**Na (mg/L)**	**TDN (mg/L)**
Overland	12.15	6.56	3.01	1.12	1.46	2.82
Overland	14.93	4.05	2.96	1.03	1.05	2.36
Overland	15.34	4.69	1.98	0.84	1.51	2.39
Overland	15.26	5.96	3.77	1.06	1.79	2.03
Overland	16.23	6.33	2.94	0.93	2.15	2.75
Overland	13.94	3.62	2.82	0.86	1.14	3.32
Overland	11.72	6.97	2.87	0.71	1.61	2.18
Overland	12.43	4.12	2.36	0.79	1.72	2.12
Overland	14.34	7.69	3.75	1.19	1.92	2.23
Overland	13.73	5.32	2.92	0.72	1.02	2.31
Overland	16.19	8.15	2.71	0.95	1.05	1.45
Overland	13.41	4.61	3.09	0.76	1.79	2.32
Overland	13.84	4.64	2.31	0.81	1.01	2.74
Overland	10.83	3.96	2.23	0.92	1.32	3.36
Overland	9.81	4.35	1.67	1.21	1.27	2.22
Overland	15.55	7.42	3.09	1.15	0.96	2.97
Overland	11.52	5.47	2.13	1.04	1.09	2.62
Overland	15.37	6.25	2.25	1.22	1.02	2.57
Overland	10.12	5.73	2.52	0.84	1.17	2.51
Overland	10.74	4.67	2.39	1.01	1.02	2.41
Overland	11.93	3.91	2.26	1.21	1.35	3.15
Overland	10.38	5.23	2.86	0.94	2.01	2.42
Overland	12.42	5.47	2.52	0.85	1.39	2.27
Overland	13.58	6.44	3.31	0.78	1.43	2.59
Overland	14.05	4.64	1.93	1.14	1.05	2.74
Overland	17.78	3.76	2.32	0.97	1.56	1.92
Overland	13.32	4.35	2.19	1.14	2.24	2.83
Overland	15.38	6.42	2.03	0.81	1.31	2.62
Overland	14.87	5.47	1.85	0.77	1.62	2.08
Overland	13.49	4.41	1.52	0.96	1.36	2.51
Overland	18.32	5.19	2.34	0.81	1.24	1.87
Overland	10.29	5.13	4.52	0.89	1.03	1.85
Overland	11.45	6.53	2.39	1.02	1.45	2.54
Overland	9.42	5.51	5.05	1.15	0.91	2.31

Overland	10.74	6.33	4.81	0.73	1.01	2.75
Soilwater	9.81	5.81	34.76	7.13	0.65	8.24
Soilwater	10.06	4.09	35.83	9.03	0.58	6.31
Soilwater	7.54	3.87	34.72	7.53	0.47	6.08
Soilwater	9.46	7.19	33.06	6.52	0.67	5.12
Soilwater	11.52	6.24	38.99	6.83	0.87	8.19
Soilwater	8.74	5.59	37.29	7.14	1.26	7.43
Soilwater	9.38	4.24	32.37	6.41	1.02	9.91
Soilwater	11.03	4.88	29.29	5.21	0.58	6.51
Soilwater	8.09	4.64	34.98	6.32	0.78	8.33
Soilwater	10.28	5.32	37.87	8.13	1.18	6.35
Soilwater	8.75	4.41	39.19	6.81	0.42	5.66
Soilwater	10.21	3.97	38.89	7.63	0.51	6.31
Soilwater	10.01	4.07	39.84	5.73	0.57	5.62
Soilwater	9.24	4.04	33.49	6.63	0.62	7.96
Soilwater	9.71	3.83	40.83	8.06	0.69	8.59
Soilwater	8.81	4.32	37.94	6.28	1.03	7.91
Soilwater	10.63	3.59	36.55	7.54	0.68	6.18
Soilwater	8.92	3.29	37.95	5.53	0.53	6.42
Soilwater	9.01	4.49	35.58	6.74	0.46	7.15
Soilwater	12.24	4.53	34.78	7.25	0.68	8.57
Groundwater	1.83	0.62	2.43	1.73	4.31	1.52
Groundwater	1.54	0.44	2.59	1.26	3.88	1.43
Groundwater	1.42	0.51	2.28	1.19	4.12	1.37
Groundwater	1.57	0.49	2.17	1.97	4.35	1.34
Groundwater	1.69	0.57	2.05	1.47	3.93	1.39
Groundwater	1.75	0.53	2.39	1.36	4.12	1.33
Groundwater	1.84	0.47	2.18	1.46	3.98	1.31
Groundwater	1.78	0.58	2.11	1.39	3.89	1.31
Groundwater	1.71	0.43	2.48	1.12	4.11	1.37
Groundwater	1.69	0.48	2.72	1.54	3.96	1.43
Groundwater	1.52	0.57	2.5	1.51	3.75	1.32
Groundwater	1.45	0.42	1.77	1.42	3.95	1.28
Groundwater	1.57	0.71	1.94	1.52	3.69	1.34
Groundwater	1.74	0.46	1.99	1.46	3.98	1.25
Groundwater	1.37	0.44	1.79	1.43	4.12	1.18
Groundwater	1.46	0.61	1.74	1.45	4.03	1.53
Groundwater	1.98	0.51	2.56	1.39	4.09	1.43
Groundwater	1.78	0.45	1.97	1.79	3.97	1.29

Groundwater	1.69	0.51	2.54	1.49	3.95	1.15
Groundwater	1.88	0.49	1.61	1.69	4.05	1.07
10 yr flowpaths						
	DOC (mg/L)	**K (mg/L)**	**Ca (mg/L)**	**Mg (mg/L)**	**Na (mg/L)**	**TDN (mg/L)**
Overland	16.31	4.47	1.67	0.73	1.23	4.21
Overland	14.13	5.25	1.39	0.46	1.36	3.87
Overland	15.91	4.89	1.55	0.79	1.12	3.34
Overland	16.12	4.66	1.65	0.46	1.17	3.96
Overland	13.29	6.84	1.48	0.51	1.29	3.75
Overland	13.11	4.78	2.12	0.62	1.19	4.53
Overland	15.24	4.59	1.75	0.51	1.32	5.41
Overland	14.53	5.99	1.41	0.87	1.02	3.37
Overland	14.92	5.41	1.63	0.53	0.96	3.16
Overland	14.29	4.31	1.42	0.77	0.89	3.72
Overland	11.02	5.91	1.64	0.55	0.78	4.05
Overland	15.24	5.87	1.39	0.59	1.37	3.42
Overland	13.22	4.66	1.61	0.61	0.65	3.67
Overland	13.97	5.45	1.45	0.52	0.98	3.83
Overland	14.07	5.91	1.34	0.68	1.19	3.23
Overland	16.39	6.41	1.55	0.83	0.84	4.12
Overland	14.32	3.17	1.51	0.95	0.86	4.04
Overland	15.37	5.93	1.12	0.59	0.98	3.86
Overland	16.15	5.16	1.48	0.64	0.91	3.69
Overland	15.21	5.39	1.35	0.67	2.46	4.19
Overland	14.55	4.55	2.26	0.57	1.06	3.29
Overland	15.53	3.83	1.39	0.85	1.17	3.39
Overland	15.32	5.53	1.65	0.71	0.97	4.52
Overland	13.33	4.54	1.48	0.58	1.04	4.33
Overland	13.62	4.46	1.77	0.74	1.15	4.14
Overland	14.74	5.91	1.39	0.67	1.07	4.87
Overland	13.51	5.26	1.24	0.72	1.13	3.94
Overland	13.21	3.68	1.62	0.59	1.28	3.16
Overland	15.08	4.46	1.58	0.88	1.27	3.48
Overland	11.15	5.43	1.16	0.65	0.95	3.59
Overland	13.62	5.04	1.04	0.78	0.98	3.77
Overland	15.29	4.16	1.35	0.63	0.91	3.65
Overland	14.75	4.93	1.81	0.76	0.84	4.61
Overland	14.07	5.26	1.33	0.65	0.83	5.43
Overland	15.61	4.39	1.71	0.81	0.72	4.48

Soilwater	13.27	4.67	37.58	7.42	0.65	13.48
Soilwater	15.74	3.71	36.91	6.61	0.44	16.23
Soilwater	11.07	4.51	34.25	7.96	0.69	14.83
Soilwater	10.32	3.58	31.85	8.77	0.58	11.36
Soilwater	12.07	3.49	36.87	6.38	0.49	10.79
Soilwater	11.37	3.92	37.79	9.85	0.76	13.41
Soilwater	14.74	3.19	38.72	10.19	0.61	10.73
Soilwater	13.46	4.72	35.06	6.44	0.63	15.79
Soilwater	13.42	2.95	39.97	9.25	0.58	13.65
Soilwater	12.75	3.46	40.79	9.31	0.82	12.88
Soilwater	10.92	3.48	39.85	12.88	0.56	10.82
Soilwater	14.65	4.32	36.92	11.76	0.64	11.34
Soilwater	13.83	3.87	34.53	10.73	0.39	12.18
Soilwater	12.37	4.06	32.05	9.31	0.57	11.75
Soilwater	11.21	3.95	30.06	8.74	0.62	10.13
Soilwater	10.86	4.47	34.55	9.53	0.52	14.57
Soilwater	12.81	4.84	33.88	9.96	0.44	13.24
Soilwater	13.46	3.58	32.19	6.26	0.63	13.75
Soilwater	9.85	4.73	35.85	8.87	0.65	13.94
Soilwater	10.31	3.71	34.13	9.43	0.59	10.82
Groundwater	1.29	0.56	1.76	1.89	5.52	5.98
Groundwater	1.34	0.61	1.87	1.75	5.39	6.07
Groundwater	1.39	0.67	1.84	1.78	5.32	5.95
Groundwater	1.77	0.63	1.71	1.72	5.22	5.92
Groundwater	1.86	0.64	1.97	1.74	5.05	5.95
Groundwater	1.43	0.85	1.94	1.71	5.51	5.84
Groundwater	1.24	0.61	1.45	1.68	5.15	5.81
Groundwater	1.56	0.72	1.69	1.65	5.32	6.28
Groundwater	1.87	0.69	1.61	1.69	5.27	5.71
Groundwater	1.26	0.53	1.49	1.68	5.38	5.69
Groundwater	1.61	0.62	1.59	1.69	5.76	5.76
Groundwater	1.23	0.69	1.89	1.66	5.37	5.43
Groundwater	1.24	0.97	1.61	1.65	5.39	5.79
Groundwater	1.57	0.62	1.69	1.67	5.43	5.51
Groundwater	1.48	0.57	1.56	1.71	5.41	5.84
Groundwater	1.35	0.63	1.72	1.73	5.85	5.97
Groundwater	1.24	0.62	1.82	1.71	5.36	5.94
Groundwater	1.23	0.66	1.65	1.72	5.74	5.98
Groundwater	1.34	0.64	1.74	1.72	5.67	6.19

Groundwater	1.36	0.54	1.64	1.74	5.53	5.61
50 yr flowpaths						
	DOC (mg/L)	**K (mg/L)**	**Ca (mg/L)**	**Mg (mg/L)**	**Na (mg/L)**	**TDN (mg/L)**
Overland	16.72	7.87	2.59	0.92	0.89	4.31
Overland	14.31	7.51	1.61	1.07	1.34	5.3
Overland	14.74	9.66	2.95	0.76	1.37	5.97
Overland	15.85	8.61	2.56	1.24	0.65	5.21
Overland	18.77	9.63	2.86	0.42	0.98	4.61
Overland	16.34	7.91	3.93	0.96	0.99	4.64
Overland	16.65	6.87	3.95	0.85	0.98	3.71
Overland	16.33	7.91	1.72	0.79	0.91	4.16
Overland	14.65	6.76	2.99	0.82	1.31	4.13
Overland	18.54	7.37	3.02	0.84	1.06	3.44
Overland	15.08	8.19	2.87	1.12	1.04	5.84
Overland	16.47	6.53	1.31	0.74	0.97	3.09
Overland	15.07	5.98	2.42	0.83	1.04	4.14
Overland	13.94	6.34	3.02	0.74	1.05	4.55
Overland	12.94	8.47	2.39	0.97	0.83	5.43
Overland	15.48	8.53	3.34	0.88	0.98	5.14
Overland	17.78	9.56	1.25	0.75	0.91	4.97
Overland	16.71	9.72	2.33	1.16	1.24	4.67
Overland	15.73	7.55	3.41	0.32	1.07	4.23
Overland	16.35	8.15	2.34	0.78	1.13	4.39
Overland	12.58	6.59	1.36	0.57	1.28	5.19
Overland	14.69	7.41	2.35	1.15	1.27	4.89
Overland	15.38	6.59	2.34	0.93	0.95	4.59
Overland	16.31	7.54	2.36	0.82	1.13	5.75
Overland	11.87	6.77	1.43	0.96	1.09	4.27
Overland	16.27	6.43	2.37	0.95	0.84	5.03
Overland	14.63	8.68	2.02	1.22	0.96	3.36
Overland	15.35	6.76	1.97	0.67	1.23	5.03
Overland	15.44	7.02	2.16	0.78	1.26	3.54
Overland	16.74	5.83	2.18	0.86	1.12	5.21
Overland	12.74	9.85	2.12	0.76	1.47	3.62
Overland	11.08	8.98	2.08	0.45	1.29	3.81
Overland	10.96	7.48	2.29	0.71	1.19	7.35
Overland	11.16	6.23	2.19	0.65	1.32	5.92
Overland	12.13	6.55	2.35	0.75	1.02	4.47
Soilwater	15.31	3.58	21.46	8.35	1.03	12.53

Soilwater	14.22	2.35	27.6	6.64	1.19	10.65
Soilwater	10.55	3.92	26.54	8.93	0.96	11.98
Soilwater	13.26	3.21	26.29	10.26	0.89	13.45
Soilwater	12.9	3.13	21.9	9.18	0.78	10.74
Soilwater	9.41	2.41	28.97	5.67	0.83	10.59
Soilwater	12.75	3.83	19.44	9.49	0.67	10.25
Soilwater	13.49	4.66	29.21	10.79	1.02	11.36
Soilwater	15.77	3.75	27.51	7.48	1.08	9.77
Soilwater	14.45	5.62	24.23	4.16	0.89	12.53
Soilwater	13.74	2.93	19.89	7.44	1.27	15.05
Soilwater	14.23	2.12	21.92	8.36	0.95	16.49
Soilwater	15.37	4.17	26.32	7.31	1.05	12.95
Soilwater	10.62	2.28	27.41	7.43	0.98	10.36
Soilwater	14.92	2.38	21.01	11.75	0.69	10.61
Soilwater	13.86	4.45	24.72	6.91	1.05	9.43
Soilwater	10.48	3.19	22.62	2.35	1.14	11.34
Soilwater	14.52	4.31	21.39	7.54	0.76	16.07
Soilwater	16.44	2.26	20.61	9.32	0.84	11.42
Soilwater	12.74	3.86	25.65	7.29	0.76	9.434
Groundwater	1.75	1.12	5.24	2.32	5.4	5.43
Groundwater	1.67	1.15	5.22	2.29	5.55	5.45
Groundwater	1.92	1.19	5.31	2.23	5.44	5.51
Groundwater	1.87	1.16	5.33	2.32	5.56	5.49
Groundwater	1.89	1.29	5.38	2.17	5.59	5.59
Groundwater	1.87	1.21	5.34	2.25	5.68	5.42
Groundwater	1.94	1.25	5.47	2.31	5.73	5.43
Groundwater	1.75	1.36	5.43	2.23	5.78	5.56
Groundwater	1.85	1.38	5.56	2.32	5.81	5.68
Groundwater	1.83	1.31	5.52	2.28	5.72	5.67
Groundwater	1.67	1.28	5.45	2.24	5.83	5.71
Groundwater	1.89	1.23	5.35	2.25	5.96	5.66
Groundwater	1.87	1.36	5.39	2.14	6.08	5.93
Groundwater	1.79	1.31	5.41	2.21	5.95	5.87
Groundwater	1.72	1.23	5.59	2.34	6.05	5.78
Groundwater	1.74	1.19	5.44	2.26	5.93	5.84
Groundwater	1.89	1.24	5.37	2.22	6.17	5.48
Groundwater	1.64	1.31	5.33	2.14	5.76	5.43
Groundwater	1.96	1.29	5.28	2.01	5.92	5.38
Groundwater	1.98	1.23	5.26	2.07	5.97	5.93

Overland flow						
	DOC (mg/L)	**K (mg/L)**	**Ca (mg/L)**	**Mg (mg/L)**	**Na (mg/L)**	**TDN (mg/L)**
Forest	8.07	4.09	5.02	0.97	1.21	2.13
Forest	8.36	5.23	5.41	0.92	1.38	2.01
Forest	8.64	2.41	4.09	1.02	1.17	1.68
Forest	11.49	5.02	5.13	1.5	2.62	1.79
Forest	8.43	4.64	5.52	0.79	1.35	1.87
Forest	7.92	2.96	4.53	1.15	0.89	1.84
Forest	9.25	3.35	3.39	0.65	2.03	1.81
Forest	9.41	3.43	5.29	0.74	1.48	1.01
Forest	6.41	4.47	4.86	0.83	1.36	1.27
Forest	8.32	6.25	6.13	1.09	2.01	1.95
Forest	10.9	2.74	4.32	1.11	1.46	1.71
Forest	9.45	4.01	5.74	1.06	0.96	1.68
Forest	8.43	3.02	4.41	1.03	1.05	1.81
Forest	9.71	5.86	6.25	0.67	1.26	2.24
Forest	9.65	3.98	4.16	0.56	1.14	1.84
Forest	9.92	4.43	5.97	0.82	2.03	1.67
Forest	8.03	3.64	3.98	0.66	1.15	1.58
Forest	7.86	4.96	4.81	0.52	1.08	2.13
Forest	8.32	2.35	4.67	0.83	1.14	1.32
Forest	5.38	3.61	3.29	0.55	1.21	0.81
Forest	8.27	3.79	4.04	0.76	2.63	1.61
Forest	8.91	4.89	4.15	0.35	1.53	2.01
Forest	6.83	3.51	4.12	0.47	1.24	2.15
Forest	11.9	4.69	3.39	0.67	1.02	1.88
Forest	9.45	3.09	5.18	0.85	1.19	1.84
Forest	8.43	5.07	4.86	0.59	0.85	2.29
Forest	9.74	3.19	5.13	0.98	1.23	2.01
Forest	9.54	4.14	4.31	1.15	1.39	1.87
Forest	11.19	4.52	4.23	0.73	1.49	1.75
Forest	6.95	2.75	3.76	1.09	1.28	2.66
Forest	8.79	5.83	4.29	0.98	1.19	1.61
Forest	11.32	3.24	3.13	1.02	1.64	1.72
Forest	8.79	4.96	4.19	1.07	1.03	2.12
Forest	9.96	2.41	3.53	1.23	2.02	2.16
Forest	9.31	5.72	3.76	0.79	1.39	2.23
5year	12.15	6.56	3.01	1.12	1.46	2.82
5year	14.93	4.05	2.96	1.03	1.05	2.36

5year	15.34	4.69	1.98	0.84	1.51	2.39
5year	15.26	5.96	3.77	1.06	1.79	2.03
5year	16.23	6.33	2.94	0.93	2.15	2.75
5year	13.94	3.62	2.82	0.86	1.14	3.32
5year	11.72	6.97	2.87	0.71	1.61	2.18
5year	12.43	4.12	2.36	0.79	1.72	2.12
5year	14.34	7.69	3.75	1.19	1.92	2.23
5year	13.73	5.32	2.92	0.72	1.02	2.31
5year	16.19	8.15	2.71	0.95	1.05	1.45
5year	13.41	4.61	3.09	0.76	1.79	2.32
5year	13.84	4.64	2.31	0.81	1.01	2.74
5year	10.83	3.96	2.23	0.92	1.32	3.36
5year	9.81	4.35	1.67	1.21	1.27	2.22
5year	15.55	7.42	3.09	1.15	0.96	2.97
5year	11.52	5.47	2.13	1.04	1.09	2.62
5year	15.37	6.25	2.25	1.22	1.02	2.57
5year	10.12	5.73	2.52	0.84	1.17	2.51
5year	10.74	4.67	2.39	1.01	1.02	2.41
5year	11.93	3.91	2.26	1.21	1.35	3.15
5year	10.38	5.23	2.86	0.94	2.01	2.42
5year	12.42	5.47	2.52	0.85	1.39	2.27
5year	13.58	6.44	3.31	0.78	1.43	2.59
5year	14.05	4.64	1.93	1.14	1.05	2.74
5year	17.78	3.76	2.32	0.97	1.56	1.92
5year	13.32	4.35	2.19	1.14	2.24	2.83
5year	15.38	6.42	2.03	0.81	1.31	2.62
5year	14.87	5.47	1.85	0.77	1.62	2.08
5year	13.49	4.41	1.52	0.96	1.36	2.51
5year	18.32	5.19	2.34	0.81	1.24	1.87
5year	10.29	5.13	4.52	0.89	1.03	1.85
5year	11.45	6.53	2.39	1.02	1.45	2.54
5year	9.42	5.51	5.05	1.15	0.91	2.31
5year	10.74	6.33	4.81	0.73	1.01	2.75
10year	16.31	4.47	1.67	0.73	1.23	4.21
10year	14.13	5.25	1.39	0.46	1.36	3.87
10year	15.91	4.89	1.55	0.79	1.12	3.34
10year	16.12	4.66	1.65	0.46	1.17	3.96
10year	13.29	6.84	1.48	0.51	1.29	3.75
10year	13.11	4.78	2.12	0.62	1.19	4.53

10year	15.24	4.59	1.75	0.51	1.32	5.41
10year	14.53	5.99	1.41	0.87	1.02	3.37
10year	14.92	5.41	1.63	0.53	0.96	3.16
10year	14.29	4.31	1.42	0.77	0.89	3.72
10year	11.02	5.91	1.64	0.55	0.78	4.05
10year	15.24	5.87	1.39	0.59	1.37	3.42
10year	13.22	4.66	1.61	0.61	0.65	3.67
10year	13.97	5.45	1.45	0.52	0.98	3.83
10year	14.07	5.91	1.34	0.68	1.19	3.23
10year	16.39	6.41	1.55	0.83	0.84	4.12
10year	14.32	3.17	1.51	0.95	0.86	4.04
10year	15.37	5.93	1.12	0.59	0.98	3.86
10year	16.15	5.16	1.48	0.64	0.91	3.69
10year	15.21	5.39	1.35	0.67	2.46	4.19
10year	14.55	4.55	2.26	0.57	1.06	3.29
10year	15.53	3.83	1.39	0.85	1.17	3.39
10year	15.32	5.53	1.65	0.71	0.97	4.52
10year	13.33	4.54	1.48	0.58	1.04	4.33
10year	13.62	4.46	1.77	0.74	1.15	4.14
10year	14.74	5.91	1.39	0.67	1.07	4.87
10year	13.51	5.26	1.24	0.72	1.13	3.94
10year	13.21	3.68	1.62	0.59	1.28	3.16
10year	15.08	4.46	1.58	0.88	1.27	3.48
10year	11.15	5.43	1.16	0.65	0.95	3.59
10year	13.62	5.04	1.04	0.78	0.98	3.77
10year	15.29	4.16	1.35	0.63	0.91	3.65
10year	14.75	4.93	1.81	0.76	0.84	4.61
10year	14.07	5.26	1.33	0.65	0.83	5.43
10year	15.61	4.39	1.71	0.81	0.72	4.48
50year	16.72	7.87	2.59	0.92	0.89	4.31
50year	14.31	7.51	1.61	1.07	1.34	5.3
50year	14.74	9.66	2.95	0.76	1.37	5.97
50year	15.85	8.61	2.56	1.24	0.65	5.21
50year	18.77	9.63	2.86	0.42	0.98	4.61
50year	16.34	7.91	3.93	0.96	0.99	4.64
50year	16.65	6.87	3.95	0.85	0.98	3.71
50year	16.33	7.91	1.72	0.79	0.91	4.16
50year	14.65	6.76	2.99	0.82	1.31	4.13
50year	18.54	7.37	3.02	0.84	1.06	3.44

50year	15.08	8.19	2.87	1.12	1.04	5.84
50year	16.47	6.53	1.31	0.74	0.97	3.09
50year	15.07	5.98	2.42	0.83	1.04	4.14
50year	13.94	6.34	3.02	0.74	1.05	4.55
50year	12.94	8.47	2.39	0.97	0.83	5.43
50year	15.48	8.53	3.34	0.88	0.98	5.14
50year	17.78	9.56	1.25	0.75	0.91	4.97
50year	16.71	9.72	2.33	1.16	1.24	4.67
50year	15.73	7.55	3.41	0.32	1.07	4.23
50year	16.35	8.15	2.34	0.78	1.13	4.39
50year	12.58	6.59	1.36	0.57	1.28	5.19
50year	14.69	7.41	2.35	1.15	1.27	4.89
50year	15.38	6.59	2.34	0.93	0.95	4.59
50year	16.31	7.54	2.36	0.82	1.13	5.75
50year	11.87	6.77	1.43	0.96	1.09	4.27
50year	16.27	6.43	2.37	0.95	0.84	5.03
50year	14.63	8.68	2.02	1.22	0.96	3.36
50year	15.35	6.76	1.97	0.67	1.23	5.03
50year	15.44	7.02	2.16	0.78	1.26	3.54
50year	16.74	5.83	2.18	0.86	1.12	5.21
50year	12.74	9.85	2.12	0.76	1.47	3.62
50year	11.08	8.98	2.08	0.45	1.29	3.81
50year	10.96	7.48	2.29	0.71	1.19	7.35
50year	11.16	6.23	2.19	0.65	1.32	5.92
50year	12.13	6.55	2.35	0.75	1.02	4.47
Soil water						
	DOC (mg/L)	**K (mg/L)**	**Ca (mg/L)**	**Mg (mg/L)**	**Na (mg/L)**	**TDN (mg/L)**
forest	7.21	4.97	39.31	10.17	0.68	9.72
forest	5.31	4.24	40.97	10.81	0.41	7.94
forest	5.94	3.16	53.74	13.99	0.63	8.14
forest	5.47	4.03	37.53	7.12	0.52	7.04
forest	6.07	4.41	29.94	8.23	0.39	8.05
forest	8.32	3.35	35.92	9.56	0.34	8.76
forest	7.33	3.09	37.35	5.16	0.29	6.51
forest	6.51	5.71	46.21	13.91	0.81	7.63
forest	4.05	4.08	37.68	6.04	0.28	11.1
forest	7.99	3.16	36.23	12.67	0.73	10.52
forest	8.86	4.18	32.36	10.83	0.32	10.91
forest	9.12	4.46	35.38	5.01	0.36	11.74

forest	9.62	5.01	37.33	6.12	0.49	12.93
forest	7.65	4.29	33.61	6.71	0.35	8.78
forest	9.37	3.24	31.95	11.53	0.38	7.46
forest	8.16	5.02	46.02	9.41	0.49	6.85
forest	8.18	3.99	37.74	9.73	0.35	9.47
forest	9.48	3.47	37.08	7.15	0.45	10.42
forest	7.29	4.23	47.33	9.11	0.56	9.84
forest	7.49	3.52	40.72	7.79	0.42	7.46
5year	9.81	5.81	34.76	7.13	0.65	8.24
5year	10.06	4.09	35.83	9.03	0.58	6.31
5year	7.54	3.87	34.72	7.53	0.47	6.08
5year	9.46	7.19	33.06	6.52	0.67	5.12
5year	11.52	6.24	38.99	6.83	0.87	8.19
5year	8.74	5.59	37.29	7.14	1.26	7.43
5year	9.38	4.24	32.37	6.41	1.02	9.91
5year	11.03	4.88	29.29	5.21	0.58	6.51
5year	8.09	4.64	34.98	6.32	0.78	8.33
5year	10.28	5.32	37.87	8.13	1.18	6.35
5year	8.75	4.41	39.19	6.81	0.42	5.66
5year	10.21	3.97	38.89	7.63	0.51	6.31
5year	10.01	4.07	39.84	5.73	0.57	5.62
5year	9.24	4.04	33.49	6.63	0.62	7.96
5year	9.71	3.83	40.83	8.06	0.69	8.59
5year	8.81	4.32	37.94	6.28	1.03	7.91
5year	10.63	3.59	36.55	7.54	0.68	6.18
5year	8.92	3.29	37.95	5.53	0.53	6.42
5year	9.01	4.49	35.58	6.74	0.46	7.15
5year	12.24	4.53	34.78	7.25	0.68	8.57
10year	13.27	4.67	37.58	7.42	0.65	13.48
10year	15.74	3.71	36.91	6.61	0.44	16.23
10year	11.07	4.51	34.25	7.96	0.69	14.83
10year	10.32	3.58	31.85	8.77	0.58	11.36
10year	12.07	3.49	36.87	6.38	0.49	10.79
10year	11.37	3.92	37.79	9.85	0.76	13.41
10year	14.74	3.19	38.72	10.19	0.61	10.73
10year	13.46	4.72	35.06	6.44	0.63	15.79
10year	13.42	2.95	39.97	9.25	0.58	13.65
10year	12.75	3.46	40.79	9.31	0.82	12.88
10year	10.92	3.48	39.85	12.88	0.56	10.82

10year	14.65	4.32	36.92	11.76	0.64	11.34
10year	13.83	3.87	34.53	10.73	0.39	12.18
10year	12.37	4.06	32.05	9.31	0.57	11.75
10year	11.21	3.95	30.06	8.74	0.62	10.13
10year	10.86	4.47	34.55	9.53	0.52	14.57
10year	12.81	4.84	33.88	9.96	0.44	13.24
10year	13.46	3.58	32.19	6.26	0.63	13.75
10year	9.85	4.73	35.85	8.87	0.65	13.94
10year	10.31	3.71	34.13	9.43	0.59	10.82
50year	15.31	3.58	21.46	8.35	1.03	12.53
50year	14.22	2.35	27.6	6.64	1.19	10.65
50year	10.55	3.92	26.54	8.93	0.96	11.98
50year	13.26	3.21	26.29	10.26	0.89	13.45
50year	12.9	3.13	21.9	9.18	0.78	10.74
50year	9.41	2.41	28.97	5.67	0.83	10.59
50year	12.75	3.83	19.44	9.49	0.67	10.25
50year	13.49	4.66	29.21	10.79	1.02	11.36
50year	15.77	3.75	27.51	7.48	1.08	9.77
50year	14.45	5.62	24.23	4.16	0.89	12.53
50year	13.74	2.93	19.89	7.44	1.27	15.05
50year	14.23	2.12	21.92	8.36	0.95	16.49
50year	15.37	4.17	26.32	7.31	1.05	12.95
50year	10.62	2.28	27.41	7.43	0.98	10.36
50year	14.92	2.38	21.01	11.75	0.69	10.61
50year	13.86	4.45	24.72	6.91	1.05	9.43
50year	10.48	3.19	22.62	2.35	1.14	11.34
50year	14.52	4.31	21.39	7.54	0.76	16.07
50year	16.44	2.26	20.61	9.32	0.84	11.42
50year	12.74	3.86	25.65	7.29	0.76	9.434
Ground water						
	DOC (mg/L)	**K (mg/L)**	**Ca (mg/L)**	**Mg (mg/L)**	**Na (mg/L)**	**TDN (mg/L)**
forest	1.21	0.32	4.52	2.81	3.93	1.34
forest	1.38	0.41	3.78	1.06	2.38	0.81
forest	1.43	0.23	5.54	2.47	3.81	1.28
forest	1.14	0.35	5.72	2.41	4.07	0.97
forest	2.37	0.48	4.73	1.88	2.92	1.09
forest	1.34	0.29	4.71	2.94	3.89	0.83
forest	1.12	0.49	4.64	2.02	3.55	0.96
forest	1.36	0.37	5.59	1.95	3.42	0.79

forest	1.21	0.46	4.77	2.53	3.41	0.88
forest	1.31	0.63	5.32	2.39	4.16	0.92
forest	1.93	0.53	4.85	2.19	2.77	0.78
forest	2.25	0.32	4.58	1.23	4.12	0.82
forest	1.05	0.26	3.84	1.36	2.77	1.03
forest	1.64	0.22	4.67	2.15	3.82	1.15
forest	1.75	0.49	5.71	1.87	4.36	1.08
forest	2.11	0.37	4.73	2.19	3.55	1.29
forest	1.65	0.46	5.71	2.23	3.72	1.17
forest	2.49	0.43	5.24	1.82	3.91	1.12
forest	1.63	0.25	5.59	1.65	4.16	0.98
forest	1.32	0.32	4.43	2.51	3.77	1.18
5year	1.83	0.62	2.43	1.73	4.31	1.52
5year	1.54	0.44	2.59	1.26	3.88	1.43
5year	1.42	0.51	2.28	1.19	4.12	1.37
5year	1.57	0.49	2.17	1.97	4.35	1.34
5year	1.69	0.57	2.05	1.47	3.93	1.39
5year	1.75	0.53	2.39	1.36	4.12	1.33
5year	1.84	0.47	2.18	1.46	3.98	1.31
5year	1.78	0.58	2.11	1.39	3.89	1.31
5year	1.71	0.43	2.48	1.12	4.11	1.37
5year	1.69	0.48	2.72	1.54	3.96	1.43
5year	1.52	0.57	2.5	1.51	3.75	1.32
5year	1.45	0.42	1.77	1.42	3.95	1.28
5year	1.57	0.71	1.94	1.52	3.69	1.34
5year	1.74	0.46	1.99	1.46	3.98	1.25
5year	1.37	0.44	1.79	1.43	4.12	1.18
5year	1.46	0.61	1.74	1.45	4.03	1.53
5year	1.98	0.51	2.56	1.39	4.09	1.43
5year	1.78	0.45	1.97	1.79	3.97	1.29
5year	1.69	0.51	2.54	1.49	3.95	1.15
5year	1.88	0.49	1.61	1.69	4.05	1.07
10year	1.29	0.56	1.76	1.89	5.52	5.98
10year	1.34	0.61	1.87	1.75	5.39	6.07
10year	1.39	0.67	1.84	1.78	5.32	5.95
10year	1.77	0.63	1.71	1.72	5.22	5.92
10year	1.86	0.64	1.97	1.74	5.05	5.95
10year	1.43	0.85	1.94	1.71	5.51	5.84
10year	1.24	0.61	1.45	1.68	5.15	5.81

10year	1.56	0.72	1.69	1.65	5.32	6.28
10year	1.87	0.69	1.61	1.69	5.27	5.71
10year	1.26	0.53	1.49	1.68	5.38	5.69
10year	1.61	0.62	1.59	1.69	5.76	5.76
10year	1.23	0.69	1.89	1.66	5.37	5.43
10year	1.24	0.97	1.61	1.65	5.39	5.79
10year	1.57	0.62	1.69	1.67	5.43	5.51
10year	1.48	0.57	1.56	1.71	5.41	5.84
10year	1.35	0.63	1.72	1.73	5.85	5.97
10year	1.24	0.62	1.82	1.71	5.36	5.94
10year	1.23	0.66	1.65	1.72	5.74	5.98
10year	1.34	0.64	1.74	1.72	5.67	6.19
10year	1.36	0.54	1.64	1.74	5.53	5.61
50year	1.75	1.12	5.24	2.32	5.4	5.43
50year	1.67	1.15	5.22	2.29	5.55	5.45
50year	1.92	1.19	5.31	2.23	5.44	5.51
50year	1.87	1.16	5.33	2.32	5.56	5.49
50year	1.89	1.29	5.38	2.17	5.59	5.59
50year	1.87	1.21	5.34	2.25	5.68	5.42
50year	1.94	1.25	5.47	2.31	5.73	5.43
50year	1.75	1.36	5.43	2.23	5.78	5.56
50year	1.85	1.38	5.56	2.32	5.81	5.68
50year	1.83	1.31	5.52	2.28	5.72	5.67
50year	1.67	1.28	5.45	2.24	5.83	5.71
50year	1.89	1.23	5.35	2.25	5.96	5.66
50year	1.87	1.36	5.39	2.14	6.08	5.93
50year	1.79	1.31	5.41	2.21	5.95	5.87
50year	1.72	1.23	5.59	2.34	6.05	5.78
50year	1.74	1.19	5.44	2.26	5.93	5.84
50year	1.89	1.24	5.37	2.22	6.17	5.48
50year	1.64	1.31	5.33	2.14	5.76	5.43
50year	1.96	1.29	5.28	2.01	5.92	5.38
50year	1.98	1.23	5.26	2.07	5.97	5.93

Table C19: Data for chapter 3 Table 3.3

	Ground water (%)	Soil water (%)	Overland flow (%)
forest	76.54	4.52	18.93
forest	84.32	5.63	10.05
forest	83.31	5.73	10.96
forest	78.40	3.77	17.83
5yr	75.83	7.10	17.06
5yr	83.22	5.71	11.07
5yr	69.33	9.56	21.11
5yr	71.00	8.09	20.99
5yr	71.11	9.19	19.70
10yr	74.64	7.36	17.99
10yr	67.24	7.32	25.44
10yr	76.19	7.41	16.40
10yr	71.59	7.56	20.85
10yr	68.11	9.92	21.97
50yr	70.62	4.47	24.91
50yr	72.19	4.01	23.80
50yr	71.63	2.32	26.05
50yr	68.62	3.45	27.70
50yr	73.11	4.15	22.74