OXYGEN-18 IN SURFACE AND SOIL WATERS IN A DRYLAND AGRICULTURAL SETTING, EASTERN WASHINGTON: FLOW PROCESSES AND MEAN RESIDENCE TIMES AT VARIOUS WATERSHED SCALES

By

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To the faculty of Washington State University:

The members of the committee appointed to examine the thesis of ANGELA JASNA GOODWIN find it satisfactory and recommend that it be accepted.

Chair

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Abstract

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Understanding the hydrologic processes and residence time involved in water transport can be applied to fertilizer and pesticide management and watershed responses to global climate changes. Measurements of oxygen-18 ($\delta^{18}O$) and electrical conductivity (EC) were used to investigate hydrological processes in the Missouri Flat Creek watershed, located north of Pullman, Washington. The watershed of study covers approximately 5700 hectares of agricultural land. The $\delta^{18}O$ of precipitation, surface water, soil water, and outflow of a tile-drained field were investigated over a 3-5 year period. Precipitation shows seasonal variation with enriched $\delta^{18}O$ values in dry months and depleted values in wet months. Surface and soil water show seasonal $\delta^{18}O$ variations and seem to respond to precipitation signatures during the same water year. Tile-drain outflow shows a steadier trend in $\delta^{18}O$ compared to precipitation, surface, and soil waters. EC decreased with an increase in discharge. $\delta^{18}O$ and EC responded approximately 1-2 months after the soil profile wetted up and discharge increased, indicating approximately 1-2 months residence time for vertical flow. Surface waters and tile-drain water show depleted $\delta^{18}O$ waters in the wet months for 2000-2001, 2001-2002, and 2003-2004 water years and enriched waters in 2002-2003 and 2004-2005, whereas EC showed decreasing concentrations in the wet months for all 5 water years. EC and $\delta^{18}O$ indicates new water contributes to flow each wet season, but in some years the $\delta^{18}O$ signature of the new water is undistinguishable from older water already in the system. A lumped-parameter model was used to estimate water mean residence times (MRTs) at four locations in the watershed. The model uses a convolution integral with $\delta^{18}O$ input precipitation signatures and response functions that describe subsurface mixing processes. MRT obtained for a 12 ha tile-drained field is 6-7 months. MRTs obtained for surface waters for a 660 ha, 4700 ha, and 5700 ha are 5-6 months, 4-6 months, and 4-7 months, respectively. MRTs confirm that the locations' waters originated as precipitation within a water year. The mixing processes modeled are practically indistinguishable for each surface water location indicating a complex watershed with a combination of mixing processes or processes not modeled.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF APPENDICES

1. INTRODUCTION

Oxygen-18 (^{18}O) is a conservative stable isotope and has been used as a tracer in many studies to understand groundwater sources and movements (Gat, 1971; Clark and Fritz, 1997); recharge processes (Larson et al., 2000; Welker, 2000); subsurface processes (Harvey, 2001; Barnes and Allison, 1988); geochemical reactions (Clark and Fritz, 1997; Duffy and Cusumano, 1998); and water residence times (Maloszewski and Zuber, 1998; Maloszewski et al., 1992; Lindstrom and Rhode, 1992; Soulsby et al., 2000). It is important to understand the processes and residence time involved in the transport of water because these insights can be applied to fertilizer and pesticide management, contaminant transport studies, and watershed responses to climate changes.

The hydrogeology and hydrochemistry of the Missouri Flat Creek Watershed (MFC) has been extensively studied over the past 5 years (Simmons, 2003; Suzuki, 2005; Wannamaker, 2005). Simmons (2003) used electrical conductivity (EC) and silica to construct a hydrograph separation and estimate pesticide mass discharge rates in surface waters at MFC. The surface waters in the study area are comprised of varying amounts of overland flow, soil water, and groundwater. Results showed that soil water and groundwater flow contribute more to total flow in drier years than overland flow. Simmons concluded that overland flow is the most important flowpath contributing to pesticide mass discharge and a tile-drained field shows a reduction in overland flow.

Suzuki (2005) examined strontium isotopes to evaluate sources of strontium (Sr) and calcium (Ca) loss in runoff water at MFC. Sr and Ca concentrations and $^{87}Sr/^{86}Sr$ were measured from the water samples of precipitation, a tile-drained field, surface waters, and soil waters. Suzuki concluded that more than 54% of Sr was from basalt and volcanic ash source, and 46% from a crust source. The loss of Ca in runoff was 0.008-0.013% of the total Ca in the bulk soil.

Wannamaker (2005) examined nitrate and EC in MFC to determine edge of field occurrence and loss of nitrate and proposed two conceptual models to explain the nitrate behavior in a tile-drained field. The four stage nitrate-mobilization/uptake model proposed describes the nitrate path through the subsurface. The hydrologic model proposed depth-variable lateral flow contributions to discharge with a variable chemical profile. Results showed nitrate loss to tile drainage occurred during the wet part of the year when there is an increase in soil hydraulic conductivity, which mobilizes the nitrate from the soil to the tile drainage outflow.

In this study, ^{18}O is investigated to further study flow processes by quantifying water residence times. ^{18}O in meteoric water has a characteristic isotopic signature due to isotope fractionation during evaporation from the ocean and subsequent condensation into rainfall. Precipitation has seasonal variations in its isotope signature and after entering a subsurface system, the signatures are transformed by flow processes via combining the water particles of different residence times along flow paths. The result is that the isotopic signature of the precipitation is different than the signature of the surface and soil waters. Therefore, the precipitation isotope signature can be traced through the soil to estimate and examine water residence times and flow processes.

EC is an environmental tracer that has been used to determine the flow paths of runoff components, which is commonly used in hydrograph separations (Matsubayashi et al., 1993; Laudon and Slaymaker, 1997; Simmons, 2003). EC is dependent on the length of time along a flow path where water reacts with encountered mineral material. Therefore, EC can estimate relative residence times; the longer the water is in contact with the soil the larger the EC value (Laudon and Slaymaker, 1997).

Several models of water mixing in the subsurface (exponential flow, exponential-piston flow, or dispersion flow) have been used to estimate the mean residence time (MRT) in the watershed. Different models including two-component mixing models, multi-parameter response function models, water balance models, and direct simulation models have been used in previous studies to estimate residence times (Lindstrom and Rodhe, 1992; Soulsby et al., 2000; McGuire et al., 2002). Maloszewski and Zuber (1996) define a lumped-parameter modeling approach using $\delta^{18}O$ precipitation isotopic signatures and response functions to estimate MRTs. The models are used to estimated MRTs by matching the output of the simulated models to the observed $\delta^{18}O$ values of the watershed and adjusting the MRT parameter, i.e. inverse modeling.

The goal of this study was to examine the behavior of stable oxygen isotopes in precipitation, surface water, and soil water over 3-5 water years in MFC to understand water flow dynamics and residence times in this agricultural setting. The specific objectives were to: 1) characterize the temporal variations in $\delta^{18}O$ values in precipitation, surface water, and soil water; 2) compare and contrast $\delta^{18}O$ and EC signatures and define flow paths; and 3) estimate the MRTs using a lumped-parameter model at four locations within the watershed.

2. BACKGROUND AND METHODS

2.1 Site Description

Missouri Flat Creek Watershed (MFC) is a 5700 hectare (ha) semi-arid agricultural watershed located north-northeast of Pullman, Washington at N 46°45’40” latitude and W 117°10’00” longitude (Figure 1). The area comprises undulating loess hills and swales overlaying basalt. The primary watershed drainage is by ephemeral and perennial streams with soil types consisting of mostly silt-loam Mollisols (Donaldson, 1980). The annual precipitation for 2000-2004 water years ranges from 336 to 472 mm/year and averages 421 mm/year (Figure 2a). The water year begins in October and the wettest months are October through May, totaling more than 60% of the annual precipitation. The monthly average air temperatures for 2000-2005 water years ranges from -3 to 23°C (Figure 2b).

2.2 Sampling Locations

There are six sampling stations located at MFC. The Cunningham Research Farm (CRF), managed by the United States Department of Agriculture (USDA), is located at the northern part of the MFC watershed and has three sampling stations: ES-6, ES-106, and TD-12 (Figure 3). The ES-6 and ES-106 are ephemeral streams that drain 6 ha and 106 ha, respectively, and only flow during the height of the wet season. The TD-12 is from a tile-drained field that covers approximately 12 ha, which is an estimate since there are no records from when the tile drain was installed (Simmons, 2003). The tile drain (shallow groundwater) is a 10 cm diameter perforated plastic pipe buried approximately 1 meter below the land surface and flows continually except for August, which is the driest month. All three drainage areas converge into a roadside ditch just outside of the CRF. The other three sampling stations located in the MFC watershed are MFC-660, which covers an area of 660 ha and is across the road from the TD-12 station, MFC-4700 and MFC-5700 that cover an area of 4700 ha and 5700 ha, respectively (Figure 1). MFC-4700 and MFC-5700 are on the main stem of MFC that drains part of Moscow Mountain (1518 m elevation).

Lysimeters were installed at ES-6 and TD-12 at varying depths starting at about 20 cm below surface so cultivation will not destroy the equipment (Wannamaker, 2005). Shallow, middle, and deep lysimeters were installed approximately 20 cm, 45 cm, and 90 cm below land surface. The lysimeters consist of three different types: suction ceramic, stainless steel, and pan (TD-12 only). The ceramic and stainless steel lysimeters extract water from the soil via suction and the pan catches the freely draining water from the soil. Time domain reflectometers (TDR) were also installed at 4 varying depths (25-85 cm) at the TD-12 location to measure the volumetric soil water content.

2.3 Water Discharge and Precipitation Measurement

Water discharges at the ES-6 and TD-12 locations were measured manually with a beaker and a stopwatch. ES-106 was measured using a flume and stilling well which records the head continuously using a Global Water pressure transducer and datalogger. MFC-660, MFC-4700, and MFC-5700 were all equipped with Global Water pressure transducers and dataloggers that continuously record pressure head every hour (Simmons, 2003). Rain was measured using a tipping bucket connected to a data logger. Some $\delta^{18}O$

enrichment was found during analysis that could be partly due to delayed sample collection where evaporation occurs in the field sample bottle for samples collected in the 2002-2003 water year (addressed in 3.1).

2.4 Sample Collection and Analysis

Field collection methods for water samples were designed to be consistent with United States Geological Survey (USGS) sampling methods (Shelton, 1994). All of the surface sampling locations and the tile drain location were collected as grab samples on a bi-monthly basis. More frequent sampling occurred during times of increased precipitation or high levels of runoff. Field samples were collected in Nalgene® plastic bottles that have been through an inorganic wash conforming to USGS guidelines (Shelton, 1994). The inorganic wash procedure was: 1) rinse in tap water to remove excess dirt, 2) 10% Liquinox bath for 24 hours, 3) rinse 3 times with tap water, 4) 10% hydrochloric (HCl) bath for 24 hours, 5) rinse 4 times with deionized water, 6) rinse 1 time with nanopure water, 7) air dry, 8) cap bottles with lids or with Teflon tape, and 9) store in bags or drawers.

Precipitation was collected using a 1000 mL bottle connected to the bottom of a tipping bucket at TD-12. The lysimeters were sampled once a month for as long as they produced water. To collect water from the lysimeters, the suction ceramic and stainless steel cup had a vacuum of 50 cbar applied for approximately 24 hours in order for the water to move into the lysimeter cup (Wannamaker, 2005). After 24 hours all the lysimeter water samples were hand pumped into pre-washed 250 mL Nalgene® bottles and subsequently were analyzed for electrical conductivity (EC), oxygen-18 ($\delta^{18}O$), and nitrate N (NO_3-N).

Directly from the field, EC was measured in the laboratory using an Orion ® temperature compensated probe. The standard was 1413 µS/cm at 25°C and the probe response was measured using nanopure water (measured less than 1 µS/cm). The probe was rinsed twice after each sample with nanopure water. Simmons (2003) and Wannamaker (2005) describe in detail the two correction factors applied to raw EC data. The first correction adjusts for differences in true and observed EC values due to the meter calibration. The second correction adjusts for the effect of nitrate on the EC value of the field sample. The laboratory containers and equipment were cleaned by rinsing them once in deionized water, 2 times in nanopure water, and air dried.

Samples for oxygen-18 and nitrate analysis were filtered using a 0.45-µm Whatman ® Cellulose Nitrate Membrane Filter and placed in a 30 mL plastic scintillation vial. Samples for oxygen-18 analysis were stored in a dark cupboard at room temperature. Samples for nitrate were stored frozen until analysis. Oxygen-18 was analyzed using a Delta S Mass Spectrometer Continuous Flow Gas Bench in the Geology Department at Washington State University (WSU). The analytical uncertainty is $\pm$ 0.28‰ and the method uncertainty for the samples is $\pm$ 0.58‰. See Appendix A for analytical and method uncertainties. Nitrate samples were thawed the day before being analyzed at the USDA laboratory at WSU and used a continuous flow analyzer. Electrical conductivity was then corrected for nitrate using methods in Wannamaker (2005).

2.5 Oxygen-18

Oxygen-18 is a stable isotope and measured as a ratio of $^{18}O/^{16}O$ relative to a standard. The natural abundance of the oxygen isotopes are: 99.76% for ^{16}O, 0.04% for ^{17}O, and 0.20% for ^{18}O (Clark and Fritz, 1997). The heavy isotope values are expressed using a delta (δ) notation in per mil (‰), which is defined as (Craig, 1961):

$$\delta^{18}O_{sample} = \left(\frac{(^{18}O/^{16}O)_{sample}}{(^{18}O/^{16}O)_{standard}} - 1 \right) * 1000 \qquad (1)$$

The typical standard used for isotope ratios in water is VSMOW (Vienna Standard Mean Ocean Water) obtained by the IAEA (International Atomic Energy Agency) who prepares the standard from distilled ocean water and has an assigned value of 0‰. GISP (Greenland Ice Sheet Program) is a standard that is used when waters are depleted in ^{18}O with a value of -25.25‰. SLAP (Standard Light Antarctic Precipitation) is another standard that is used when waters are extremely depleted in ^{18}O with a value of -55.5‰ (Clark and Fritz, 1997). Appendix B shows the standards used in this study.

The variations in isotope content in meteoric waters are related to the isotopic fractionation that occurs during evaporation, condensation, and freezing. During fractionation, ^{18}O isotopes preferentially remain in the liquid during evaporation, partition first into the liquid during condensation, and partition first into the solid during freezing (Araguas-Araguas et al., 2000).

The controls on precipitation isotope ratios of ^{18}O are environmental. As clouds containing water vapor move across the continent the water vapor condenses in the form of precipitation, and a process called rain out occurs where isotopes fractionate in the atmosphere and the heavy isotopes are removed first in the precipitation (Gat, 1996). Water vapor that evaporated from the ocean is isotopically depleted compared to oceanic water, producing negative precipitation $\delta^{18}O$ values. Specific effects that control $\delta^{18}O$ values in precipitation are the: altitude effect, where precipitation produces lower $\delta^{18}O$ values at higher altitudes; the continental effect, where precipitation produces lower $\delta^{18}O$ values toward continental interiors; the latitude effect, where precipitation produces lower $\delta^{18}O$ values at higher latitudes; and the temperature effect, where precipitation produces lower $\delta^{18}O$ values at colder temperatures (Alley and Cuffey, 2001). Since the tipping bucket for the precipitation of the study area is stationary, the continental and latitude effects would only affect precipitation via the location from where the storm tracks originated.

There have been many studies on the relationship between climate temperature and $\delta^{18}O$. Joussaume and Jouzel (1993) reported 0.26-0.69‰ shift in precipitation $\delta^{18}O$ per 1°C shift for North America. Rozanski et al. (1992) reported a global 0.6‰ shift in precipitation $\delta^{18}O$ per 1°C shift. Welker (2000) reported 0.55‰ and 0.46‰ per 1°C for Colorado and Nebraska, respectively, and suggested the results are slightly below the global average due to the large air temperature variations between winter and summer.

Sklash and Farvolden (1979) used terms "old" and "new" water to differentiate between subsurface water and incoming new water such that water present in the watershed is distinguished from water in a rainwater event. Many studies have used this terminology, for example Hooper and Shoemaker (1986) at a New Hampshire site completed a hydrograph separation using isotopes and chemical tracers. The hydrograph was separated into subsurface flow (old water) and event water (new water). Hooper and Shoemaker found that most of the flow (60-75%) in the study area was old water, even during water input events.

2.6 Model Theory

Lumped-parameter flow models were developed in chemical engineering and can be used to interpret environmental tracer data in aquifers and catchment systems. These models assume a one-dimensional system that describes the relation of a conservative tracer ($\delta^{18}O$) output to the input tracer by the convolution integral (Maloszewski and Zuber, 1996):

$$\delta(t) = \int_{-\infty}^{t} \delta_{in}(t')g(t-t')dt' \tag{2}$$

where $\delta(t)$ is the output $\delta^{18}O$ value, $\delta_{in}(t')$ is the input $\delta^{18}O$ value, t is the calendar time, t′ is a dummy variable of integration, and g(t-t′) is the response (or weighting) function of the residence time for different mixing models. The response functions are subsurface mixing models that represent water flow processes in the system. The models described by Maloszewski and Zuber (1982, 1996) and modified by McGuire et al. (2002) include:

Exponential Model (EM)

$$g(t) = \frac{1}{\tau}\exp\left(\frac{-t}{\tau}\right) \tag{3}$$

Exponential-Piston Flow Model (EPM)

$$\begin{aligned} g(t) &= \frac{\eta}{\tau}\exp\left(-\frac{\eta t}{\tau}+\eta-1\right) \quad for\ t \geq \tau\left(1-\frac{1}{\eta}\right) \\ g(t) &= 0 \qquad\qquad\qquad\qquad for\ t < \tau\left(1-\frac{1}{\eta}\right) \end{aligned} \tag{4}$$

Dispersion Model (DM)

$$g(t) = \left(\frac{4\pi D_p t}{\tau}\right)^{-1/2} t^{-1}\exp\left[-\left(1-\frac{t}{\tau}\right)^2\left(\frac{\tau}{4D_p t}\right)\right] \tag{5}$$

where g(t) is the response function of the model, τ is the mean residence time of the system, D_p is the dispersion parameter, and η equals the total volume of water divided by the exponential (mixed) flow volume (Maloszewski and Zuber, 1982 and 1996).

The EM has one parameter (τ) and is mathematically equivalent to the good mixing model that is used in some lake and industrial vessel investigations (Maloszewski and Zuber, 1996). The model assumes complete mixing takes place at the sampling site, i.e. spring, stream, or sampling well (Maloszewski and Zuber, 1996). EM is a mathematically-valid model as long as $\tau \neq 0$, otherwise the response function is undefined.

EPM has two parameters (τ and η) and is a model that consists of the exponential distribution and the piston flow distribution of mean residence times, i.e. a well-mixed system in parallel with a piston flow system. The η parameter determines how much of the water flow is due to exponential or piston flow. The model is equal to the EM when $\eta=1$ and the model approaches piston flow when $\eta \rightarrow \infty$ (Maloszewski and Zuber, 1982 and 1996). Maloszewski and Zuber (1996) stated that in their experience EPM works well for η values slightly larger than 1.

DM has two parameters (τ and D_p) and the dispersion parameter is $D_p = D/vx = 1/Pe$, where D is the dispersion coefficient, v is the groundwater velocity, x is the distance from source, and Pe is the Peclet number (Maloszewski and Zuber, 1996). Kreft and Zuber (1978) give a description of several different variations of the dispersion equation solutions with different initial and boundary conditions. Another version of the dispersion equation would be used if the isotope data from lysimeters were used in the model since the lysimeter data show depth profiles and not an average of $\delta^{18}O$ values, i.e. stream outflows.

2.7 Input Function

The input function in equation (2) is determined from the volume-weighted $\delta^{18}O$ of the precipitation that falls on the watershed. The input function, $\delta_{in}(t')$, is defined as (Maloszewski and Zuber, 1996):

$$\delta_{in}(t') = \delta_{GW} + \frac{N\alpha_i P_i\left(\delta_i - \delta_{GW}\right)}{\sum_{i=1}^{N} \alpha_i P_i} \tag{6}$$

where δ_{GW} is the average $\delta^{18}O$ of the groundwater, N is the number of months the precipitation is used for the models, α_i is the monthly infiltration coefficient, δ_i is the monthly isotope composition (‰), and P_i is the monthly precipitation (mm).

For the purpose of this study, α_i is redefined as monthly recharge factor:

$$\alpha_i = \frac{Q_{i-2}}{P_i} \tag{7}$$

where Q_{i-2} is the monthly discharge rate at TD-12 and shifted back 2 months. The recharge factor is a fraction that shows the amount of precipitation that becomes recharge, i.e. α=0 when recharge does not occur and α=1 when all precipitation is recharge (McGuire et al., 2002). Appendix D shows that the discharge lags the precipitation about 2 months at the beginning of the water year, which equation 7 corrects, so a representative fraction of precipitation for each month can be applied to the input function. The discharge does not lag the precipitation at the end of the water year, but equation 7 is still used for simplification. This will cause some fitting errors with the models.

3. RESULTS

3.1 δ^{18}O in Precipitation

Data for δ^{18}O in precipitation begins in April 2002 and ends in March 2005. The precipitation was monthly volume-weighted using the following equation:

$$\delta^{18}O_{sample} = \frac{\sum_{i=sample}^{month} \delta^{18}O_i P_i}{\sum_{i=sample}^{month} P_i} \quad (8)$$

The volume-weighted precipitation (Figure 2a) shows a seasonal trend with the lighter δ^{18}O coinciding with the wetter months and the heavier δ^{18}O coinciding with the drier months. This is reasonable because of the temperature effect: temperatures are higher in the dry months causing enrichment as the water vapor condenses into precipitation and lower in the wet months causing depletion in the precipitation (Figure 2b and Appendix C). The seasonal variations could also be caused by the locations where storm tracks originated, which are due to the continental and latitude effects. Summers of 2003 and 2004 show the most enriched precipitation samples. December 2003 and January 2004 show the most depleted precipitation samples due to the extreme cold weather during those months (Appendix C).

Section 2.4 stated that some enrichment could be caused by delayed sample collection in 2002-2003. This delay apparently did not have an overall major affect on the precipitation δ^{18}O values because the enrichment pattern and values in the dry months are consistent in the following years (Figure 2ab).

3.2 $\delta^{18}O$ in Surface Waters and Soil Waters

Figure 4 shows the isotopic signatures for all the surface waters and tile drain with the discharge of MFC-660 for reference to watershed flow patterns. The surface waters and tile drain show similar $\delta^{18}O$ patterns compared to the precipitation with troughs of light values during the cold, wet months and peaks during the warm, dry months. TD-12 exhibits a dampened response and steadier trend in $\delta^{18}O$ compared to the other stations, which exhibit more pronounced seasonal variations in $\delta^{18}O$ and follow the precipitation signature (Figure 2). The larger scales (MFC-4700 and MFC-5700) show larger seasonal variations in $\delta^{18}O$ and heavier values during the dry season than the smaller scales (TD-12 and MFC-660). The 2000-2001, 2001-2002, and 2003-2004 water years exhibit depleted $\delta^{18}O$ values in the wet season, whereas 2002-2003 and 2004-2005 water years do not. All of the stations show a sharp decrease in $\delta^{18}O$ in January-February 2004. ES-6 and ES-106 have fewer data points due to the lack of water for sampling during the dry months.

Results in Figure 5 show the average $\delta^{18}O$ of the lysimeters, $\delta^{18}O$ of tile drain outflow, and discharge at TD-12 location. The tile-drained field exhibits a relatively steady trend of $\delta^{18}O$ from the outflow that ranges from approximately -13.5 to -16‰. The plotted lysimeter values are an average of all the lysimeters (suction ceramic, stainless steel, and pan) for each depth (shallow, middle, and deep) on a given day. The lysimeters show a different trend each year (Figure 5). In 2000-2001 water year, the shallow lysimeters show heavy $\delta^{18}O$ values in the beginning of the wet season and light $\delta^{18}O$ values at the end, whereas the deep lysimeters are steady then increase rapidly at the end. In 2001-2002, the lysimeters produce more water for a longer time than any of the other years. The shallow and middle lysimeters show a "U"-shape in the data with the lowest part of the "U" having lighter $\delta^{18}O$ values, which suggest temperature effects (addressed in 4.1 below). The deep lysimeters are more inconsistent than the previous year and heavier than the shallow and middle lysimeters. Lysimeters were not sampled in the 2002-2003 water year. The 2003-2004 water year shows a sharp decrease in $\delta^{18}O$ starting in late January for lysimeters and tile drain outflow due to extremely cold weather. The rapid $\delta^{18}O$ response to the cold weather indicates some instances of shorter residence times in the wet season that could be due to subsurface flow processes such as macropore flow. The deep lysimeters are heavier than the shallow and middle lysimeters and are close to the $\delta^{18}O$ values of the tile drain outflow. In 2004-2005, the lysimeters show the last three quarters of the "U"-shape and the deep lysimeters follow the tile drain outflow.

The 2000-2001 and 2004-2005 lysimeter data show heavy values during the wet season. The 2001-2002 data show heavy values in the deep lysimeters, but the shallow and middle lysimeters decrease in March. The 2003-2004 lysimeters show relatively depleted values during the wet season.

ES-6 is dry most of the year and flows during February to April each water year except in 2004-2005 (Figure 6). The lysimeter data at that location show a "U"-shape trend for each water year. In the 2000-2001 water year the deep lysimeters are isotopically heavier and the shallow lysimeters are isotopically lighter. The 2003-2004 deep lysimeters are relatively stable compared to the shallow and middle lysimeters. The sharp decrease in $\delta^{18}O$ in late January to February 2004 is seen in the stream outflow and the shallow and middle lysimeters. Comparison of Figures 5 and 6 shows that surface runoff from the latter location, which is not tile-drained, is more isotopically variable than runoff from the tile drain.

3.3 Electrical Conductivity

EC shows a strong seasonal trend with increased values in the dry months and decreased values in the wet months (Figure 7). The highest EC values occur from June to November and the lowest values occur in December to May in all four water years. The increase in EC values coincides with the decrease in water discharge and the decrease in values coincides with the increase in discharge throughout the watershed (Figure 7). EC exhibits relatively high values for MFC-4700 and MFC-5700 during low flow. The 2003-2004 water year exhibits a sharp trough that indicates shorter residence times and could be more evidence for macropore flow (section 3.2).

EC measured from the TD-12 outflow decreases when the soil volumetric water content (VWC) and the flow volume increase (Figure 8a). The increases in EC levels occur when the VWC and the flow discharge decrease. The lowest EC value is in late January 2004, where the VWC is high and the discharge peaks for that water year (Figure 8a).

4. DISCUSSION

4.1 δ^{18}O and Temperature

Temperature is a major factor that controls the partitioning of δ^{18}O in precipitation. Precipitation data show depletion in the colder years (Figure 2a). Precipitation for 2002-2003 and 2004-2005 exhibit a volume-weighted average (for wet season) of -12.8‰ and -12.3‰, respectively. The 2003-2004 precipitation data exhibits a volume-weighted average of -14.8‰, which is 2‰ and 2.5‰ different from the 2002-2003 and 2004-2005 values, respectively. There is no δ^{18}O precipitation data in 2000 through 2002.

The surface waters and tile drain have a combination of newer precipitation water and older water already in the system. If discussing just the temperature effect, then the relationship between temperature and δ^{18}O is explored further in Figure 4 where the δ^{18}O values of surface waters drop below -15.1‰ in the wet season for 3 water years (2000-2001, 2001-2002, and 2003-2004), but not in the other 2 water years (2002-2003 and 2004-2005). The average winter temperatures for the former 3 water years are ~3 to 7°C lower than the latter 2 water years (Figure 2b and Appendix C) causing lower δ^{18}O values in the former years. The global relationship between temperature and δ^{18}O of 0.6‰ per °C (section 2.5) would predict a ~2-4‰ shift in δ^{18}O values, which is in the observed range of the difference between the warm and cold water years. This year-to-year concordance of temperature and δ^{18}O in runoff, as well as in precipitation, indicates that a substantial fraction of flow in the surface waters originated as precipitation within the same water year.

Temperature also appears to affect $\delta^{18}O$ of soil waters. In Figures 5 and 6, lysimeters exhibit "U"-shape trends in some water years. The beginning of the "U" exhibits heavier values due to enriched precipitation during the warmer months. Also, possibly contributing to this enrichment is soil water that was remnant from the previous water year that had undergone some evaporation during the dry months. An increase in discharge corresponds to the beginning of the lysimeter sampling because the soil water profile wets up (Figure 8a). The "old" water is sampled first, which has an enriched $\delta^{18}O$ value. As the "new" and non-evaporated water comes in, the lysimeter $\delta^{18}O$ reflect more depleted waters. The end of the "U" once again reflects the enriched precipitation in the drier months. Macropore flow was suggested in Section 3.2 as a mechanism for why all the water stations' $\delta^{18}O$ decrease sharply (indicating "new" water coming into system) in 2003-2004. However, the "U"-shape trend in the shallow and middle lysimeters in 2001-2002 do not seem to indicate macropore flow.

4.2 $\delta^{18}O$ and EC

In 2002-2003 and 2004-2005 water years, the EC data (Figure 7) show shallower troughs than the rest of the water years, whereas the $\delta^{18}O$ data (Figure 4) for those years exhibit no troughs. EC is dependent on length and time along a flow path. Since EC does decrease, then "new" water is coming into the system each wet season, but this "new" water is not distinguishable by the catchment-output $\delta^{18}O$ signature in some seasons.

Simmons (2003) stated that there is an observable difference between tracer levels (EC and silica) at small and large watershed scales due to the influence of varying proportions of flowpath contributions to total stream flow. The difference in EC levels was also attributed to the groundwater origins, where groundwater of smaller watersheds was derived from loess and groundwater of larger watershed scales was suppose to be derived from basaltic lava flows. Figure 4 and 7 show an increase in both $\delta^{18}O$ and EC, respectively, for large scale watersheds during dry months. The difference between large and small EC levels Simmons (2003) described, as well as the $\delta^{18}O$ enrichments observed here, maybe due to evaporation. The larger watershed scales (MFC-4700 and MFC-5700) have large, exposed water surfaces and the smaller scales (TD-12 and MFC-660) are enclosed or covered by vegetation. Larson et al. (2000) determined the most enriched $\delta^{18}O$ value for groundwater basin wide (including loess, basalt, and other sediments) was -12.6‰. The $\delta^{18}O$ values of surface water for the large watersheds in the dry months are substantially greater than -12.6‰. This indicates that flow at the large watershed scales do not originate from deeper groundwater and probably have the same flow pathways as the smaller scales.

EC and $\delta^{18}O$ respond to water coming into the system within 1-2 months after the soil profile wets up and discharge increases in 2002-2003 and 2004-2005 (Figure 8ab). This implies a short residence time of approximately 1-2 months for transport of shallow-low-EC water to the tile drain by vertical flow during the wet seasons of these two water years.

EC gradually decreases with an increase in flow during 2000-2001, 2001-2002, 2002-2003, and 2004-2005 (Figure 8b). In 2001-2002, the $\delta^{18}O$ and EC decrease with increasing discharge, but the main $\delta^{18}O$ trough lags approximately 1 month behind the EC trough (Figure 8b). The inconsistency could be due to discharge fluctuations. In

2002-2003 the second discharge peak corresponds to an increase in EC and $\delta^{18}O$ (Figure 8b). The increase in $\delta^{18}O$ is due to the heavy winter precipitation.

4.3 Models

Models are used to quantitatively estimate a mean residence time from when water (precipitation) enters the system to when it leaves (sampling location outflow). The discharge $\delta^{18}O$ records for MFC-5700, MFC-4700, MFC-660, and TD-12 were modeled from April 2002 to March 2005, which is the interval of available precipitation data used in the input function (equation 2). The sampling location $\delta^{18}O$ outputs (observed) were volume-weighted by month (using equation 8 with discharge instead of precipitation amount) to compare to the model's monthly outputs (simulated). See Appendix D for model methodology. A goodness of fit statistic was calculated in the following least-square method (Maloszewski and Zuber, 1996):

$$\sum = \frac{\left[\sum_{i=1}^{n}\left(O_i - X_i\right)^2\right]^{1/2}}{n} \qquad (9)$$

where O_i is the observed $\delta^{18}O$ values and X_i is the modeled $\delta^{18}O$ values.

The simulated results do not perfectly match the observed outputs (Figures 9-12). Each location has more than one simulated result that matches some parts of the observed output values. The simulated outputs that match the peak and trough of the observed outputs and had a minimum least square statistic were considered the best fit. Table 1 shows a best-fit model first and a poor-fit model second for each mixing model. The double asterisks represent the best-fit models for the sampling location.

Sample Location	Mixing Model	Parameters			Goodness of Fit (Σ)	Best-Fit Dates
		τ (mo.)	η	Dp		
MFC-5700 (Figure 9)	EM*	4			0.22	Feb-04 to Oct-04
	EM	1			0.91	
	EPM	6	1.3		0.21	
	EPM	4	1.3		0.58	
	DM**	7		0.8	0.18	Apr-02 to Jan-04
	DM	2		0.8	0.49	
MFC-4700 (Figure 10)	EM**	6			0.21	Feb-04 to Oct-04
	EM	2			0.50	
	EPM	6	1.3		0.24	
	EPM	4	1.3		0.57	
	DM*	4		0.8	0.25	Apr-02 to Jan-04
	DM	2		0.8	0.53	
MFC-660 (Figure 11)	EM*	6			0.22	Feb-04 to Jul-04
	EM	2			0.56	
	EPM	5	1.4		0.21	
	EPM	4	1.4		0.35	
	DM**	5		0.8	0.19	Apr-02 to Nov-03
	DM	2		0.8	0.60	
TD-12 (Figure 12)	EM	6			0.29	
	EM	1			1.10	
	EPM**	7	1.3		0.19	Apr-02 to Dec-03
	EPM	4	1.3		0.45	
	DM*	6		0.8	0.23	Jan-04 to Apr-04
	DM	2		0.8	0.67	

Table 1: The table shows the best-fit model first and the poor-fit model second for each mixing model with their parameters and goodness of fit statistics.
** Best-fit model
* Second best-fit model

DM an EM simulations of MFC-5700, MFC-4700, and MFC-660 produced results that match the observed output values. TD-12 output values were the hardest to match to the simulated values. The model's simulated peak and trough predicted an amplification of the actual peak and trough. Models simulated with MRTs larger than 7 months showed some dampening in model results, but shifted the model's overall values to higher values and the model's simulated peaks and troughs were delayed 1-2 months past the actual peak in 2003 and trough in 2004 (not shown). Some of the fitting problems are possibly due to the method of estimating the recharge factor (see section 2.7 and Appendix D). Since most of the models did not match the observed values of TD-12, perhaps there is other subsurface mixing occurring that is not described in the modeling.

4.4 Model Predicted Mean Residence Times

The mean residence times (τ or MRT) of each model are the average residence time over the entire data set from April 2002 to March 2005 including the dry and wet seasons. The best-fit models were used to estimate the MRT. MFC-5700 exhibited a τ of 4-7 months, MFC-4700 exhibited a τ of 4-6 months, MFC-660 exhibited a τ of 5-6 months, and TD-12 exhibited a τ of 6-7 months.

The main difference between the model results is the MRT since the flow types are practically indistinguishable for each surface water location. TD-12 showed a longer MRT compared to MFC-660, which seems counter intuitive since TD-12 drains a much smaller area. TD-12 has a longer MRT since it is a tile-drained field and shallow groundwater, apparently taking at least 1-2 months for vertical flow to reach the tile drain outlet during the wet season (section 4.2), whereas MFC-660 has more of a surface component. Since MFC-4700 and MFC-5700 have larger drainage areas, they show longer MRTs compared to MFC-660.

TD-12 model results for EPM and DM are practically indistinguishable, but EM results show a poor fit to the observed data. The best-fit model is EPM with η=1.3, where 77% (1/η) of the total flow volume that was exponential flow and 23% (1-1/η) of the total flow volume that was piston flow. The EPM was modeled many times with different η values, but the larger values (>1.4) showed extreme amplitudes and did not match the observed output. The second best-fit model is DM with Dp=0.8. Maloszewski et al. (1992) calculated large values of Dp (~0.6) for obtaining best-fit stream flow models in an alpine catchment. Larger Dp values indicate a more heterogeneous hydrologic system with relatively high variation in flow path length throughout the watershed (McGuire et al., 2002). The DM was modeled using Dp values greater than 1.0, which shifted the overall simulated values higher and the tail-end of the peaks and troughs had a gradual slope (not shown).

The trough in 2004-2005 water year at MFC-5700 and MFC-4700 did not match any of the model results, which predicted higher $\delta^{18}O$ values (Figure 9 and 10). This could be attributed to the precipitation for the water year, which had a seasonal volume-weighted average higher than the previous two water years (Figure 2). The input function should have accounted for this, but there might be some fitting errors due to the method of estimating the recharge factor (see section 2.7). Another reason for heavier predicted values is that the flow was very low during this water year (Figure 4). EPM with a τ of 6 months shows the best match for MFC-5700 and MFC-4700 in 2004-2005.

Models never give definite answers in their results, but some of the interpretations from models can aid in understanding the hydrogeology of the watershed. Most of the models seem to have some response functions (EM, EPM, and DM) fit better during one water year and a different response function fit better the other water year. For example, MFC-5700 output data matches the DM with τ=7 and Dp=0.8 during the 2002-2003 water year, and the output data matches the EM with τ=4 during 2003-2004 water year. Perhaps the system at each station is more complex and has a combination of mixing processes or other processes not modeled.

5. CONCLUSIONS

Precipitation has seasonal $\delta^{18}O$ variations with the depleted values in the wet months (~-17‰) and the enriched values in the dry months (~-8‰). Temperature is a major factor that controls partitioning of $\delta^{18}O$ in precipitation and evaporation in the surface and soil waters. The precipitation isotope signatures appear in the sampling location's outflow during a given water year.

Like precipitation, the surface waters show seasonal variations with depleted values in the wet months and enriched values in the dry months. All locations show a sharp decrease in $\delta^{18}O$ in late January to February 2004 due to extreme cold weather. The rapid response in lysimeters in TD-12 during the cold weather suggests small residence times with the "new" water (depleted snowmelt) coming into system via macropore flow. The 2002-2003 and 2004-2005 water years do not dip below -15.1‰ in the wet season, but the EC for those years do decrease. This suggests that "new" water is coming into the system each wet season, but in some years the $\delta^{18}O$ signature of the "new" water is undistinguishable. EC and $\delta^{18}O$ respond approximately 1-2 months after the soil water profile wets up and discharge increased, which implies a short wet-season residence time of 1-2 months for vertical flow at TD-12.

Mean residence times were estimated at four locations (MFC-5700, MFC-4700, MFC-660, and TD-12) using a lumped-parameter approach. The general model uses a convolution integral of an input function and a response function. The input function uses $\delta^{18}O$ precipitation values weighted by the amount coming into the system. The response functions depicts the type of subsurface mixing, e.g. exponential (good mixing), exponential-piston (partial mixing), and dispersion flow. The models output is compared to the four location's volume-weighted $\delta^{18}O$ output.

The types of subsurface mixing are practically indistinguishable for each surface water location indicating a complex system that has a combination of subsurface mixing processes. MFC-5700 exhibited a mean residence time, τ, of 4-7 months. MFC-4700 exhibited a τ of 4-6 months. MFC-660 exhibited a τ of 5-6 months. TD-12 exhibited a τ of 6-7 months. These results confirm that much of the sampling locations' outflows originated as precipitation within a given water year.

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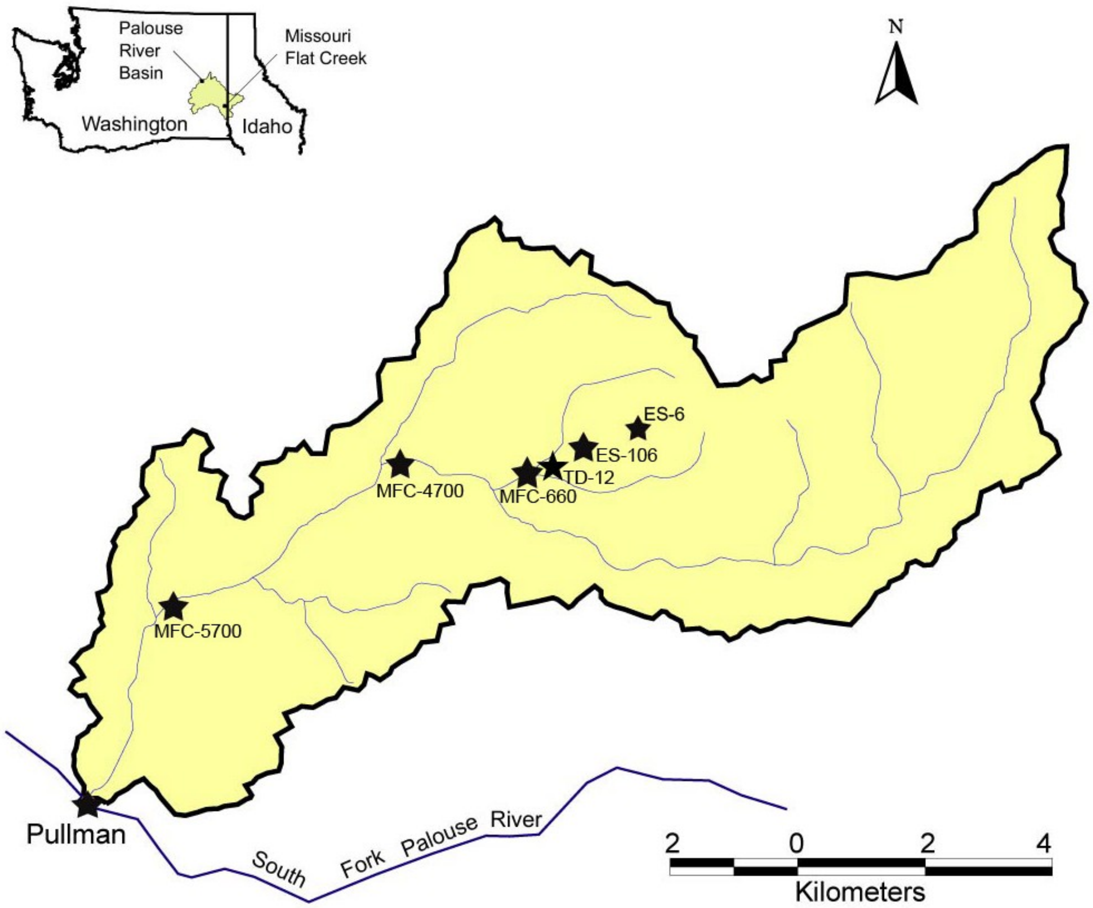

Figure 1: Missouri Flat Creek Watershed map. Six sampling locations (stars) are located in the watershed where the name designators indicate type of location and size of watershed drainage in hectares. ES, TD, and MFC indicate ephemeral stream, tile drain, and Missouri Flat Creek sampling locations, respectively.

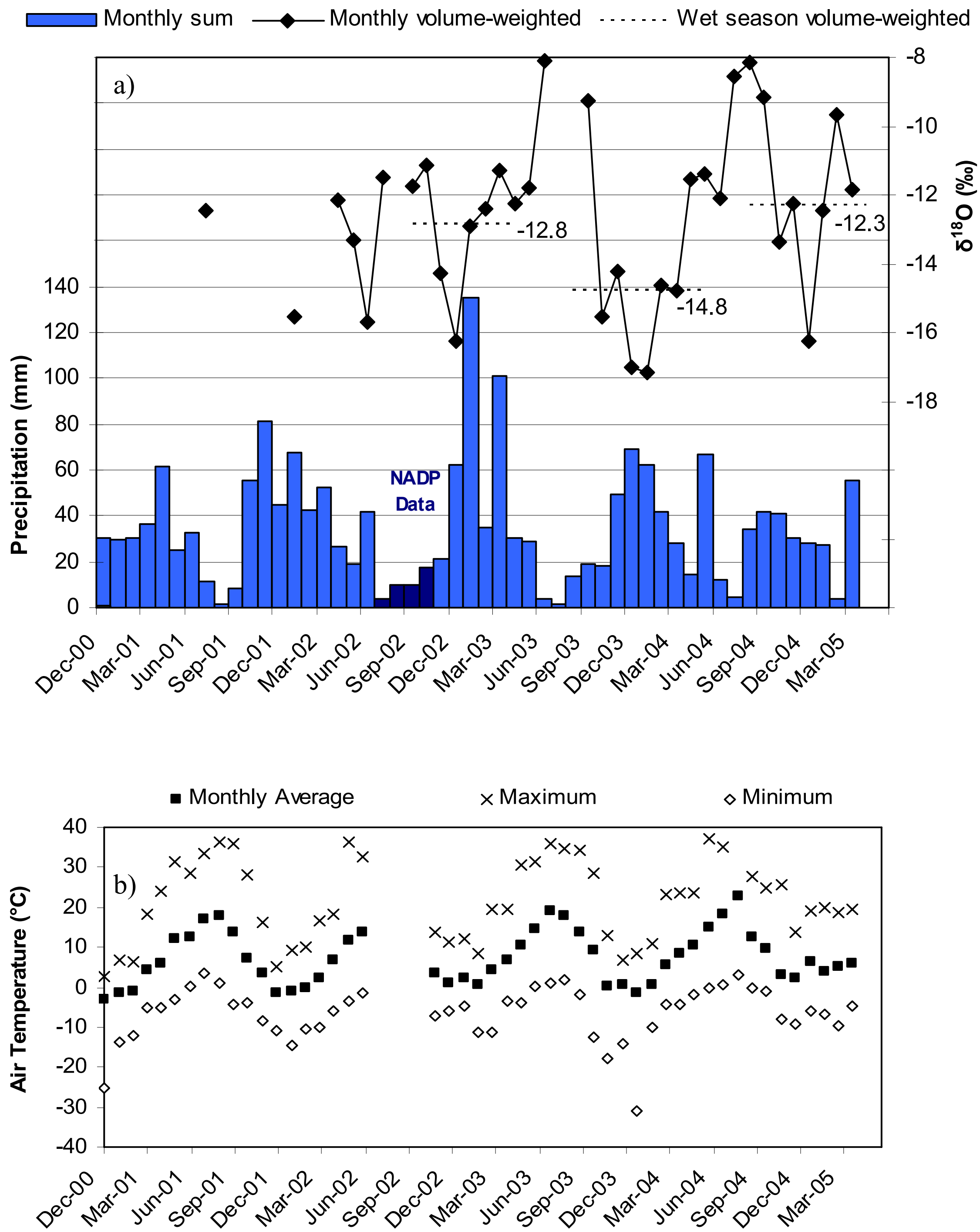

Figure 2: a) $\delta^{18}O$ and precipitation of Cunningham Research Farm (CRF). Precipitation measurements were taken every two hours using a tipping bucket and data logger. Precipitation $\delta^{18}O$ values are monthly volume-weighted (see text). NADP (National Atmospheric Deposition Program) data was used during May to September 2002 due to data logger malfunction (Appendix C). b) Monthly averages and absolute maximums and minimums of air temperatures from datalogger attached to tipping bucket (Appendix C).

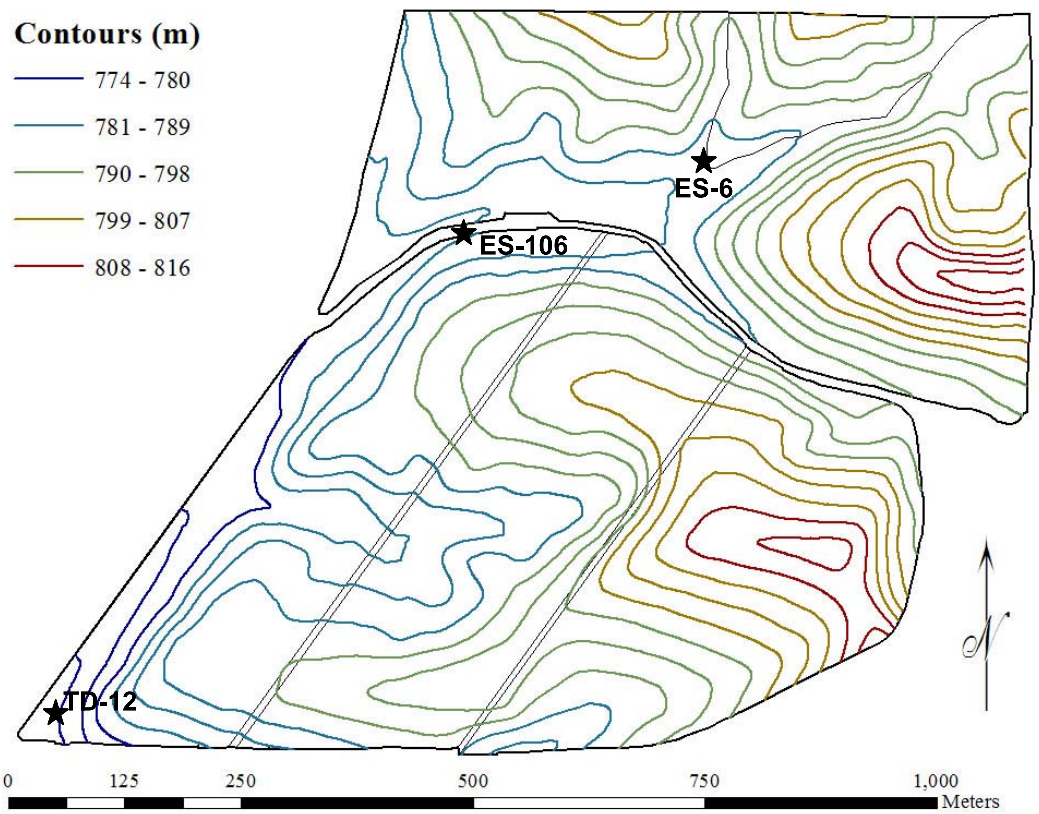

Figure 3: Topographic map of Cunningham Research Farm (CRF). Three sampling stations (stars) are located on CRF. The parallel gray lines are crop rotation boundaries.

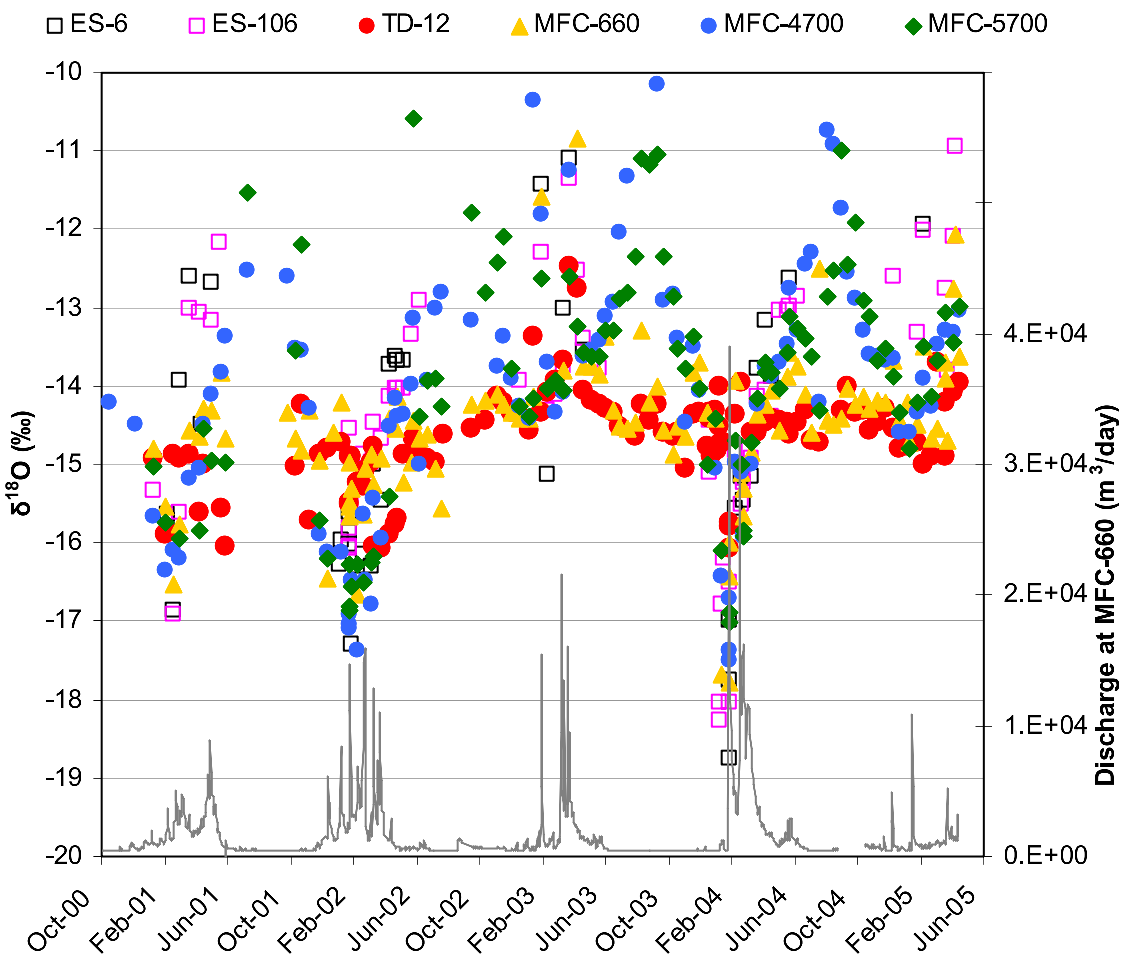

Figure 4: $\delta^{18}O$ for surface waters and tile drain. Surface waters and tile drain show troughs for wet months in 2000-2001, 2001-2002, and 2003-2004 and peaks for the wet months in 2002-2003 and 2004-2005.

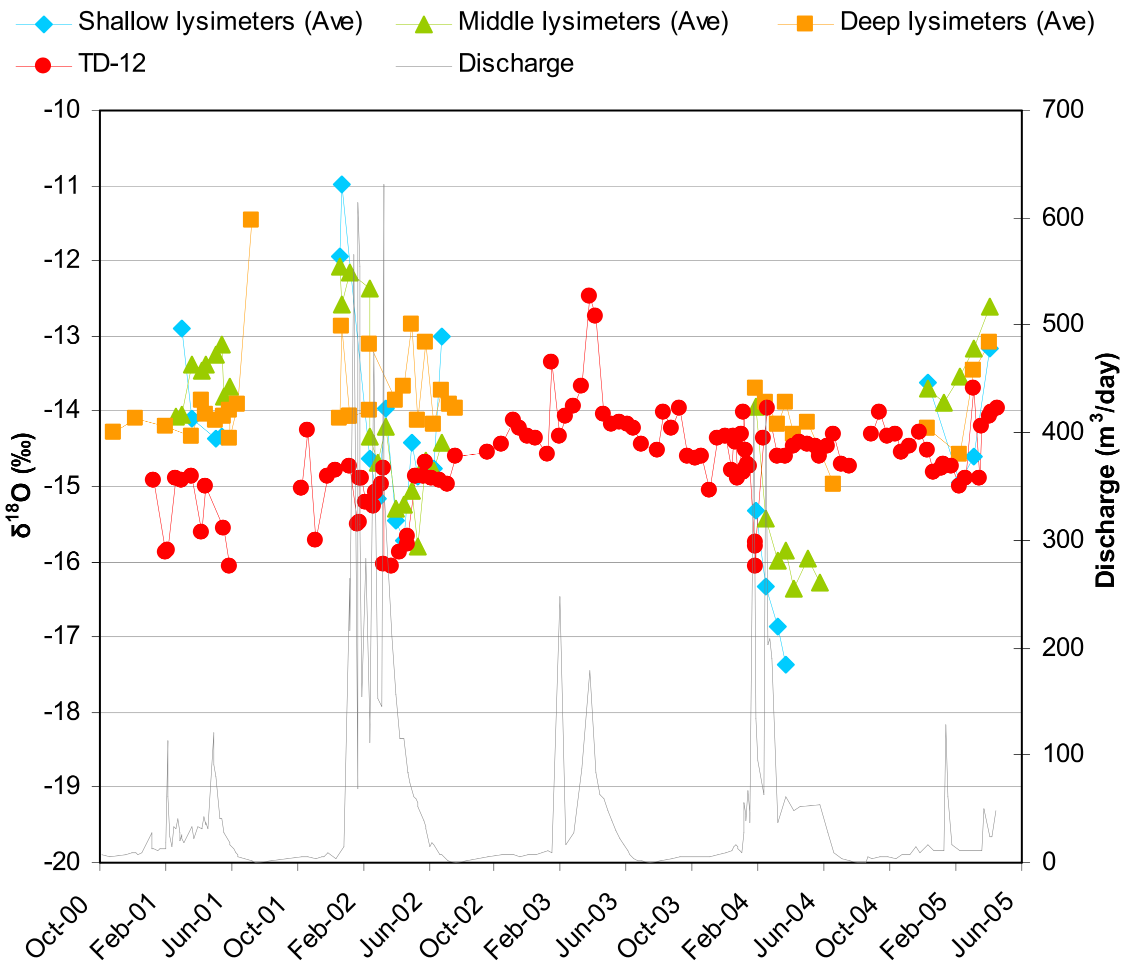

Figure 5: $\delta^{18}O$ and hydrograph for TD-12. The lysimeters are averaged for shallow (~20 cm), middle (~45 cm), and deep (~90 cm) depths (Appendix G). Lysimeters were sampled periodically in 2000-2002 and once a month in 2003-2005 for as long as they produced water. Discharge measurements were taken using a beaker and a stopwatch.

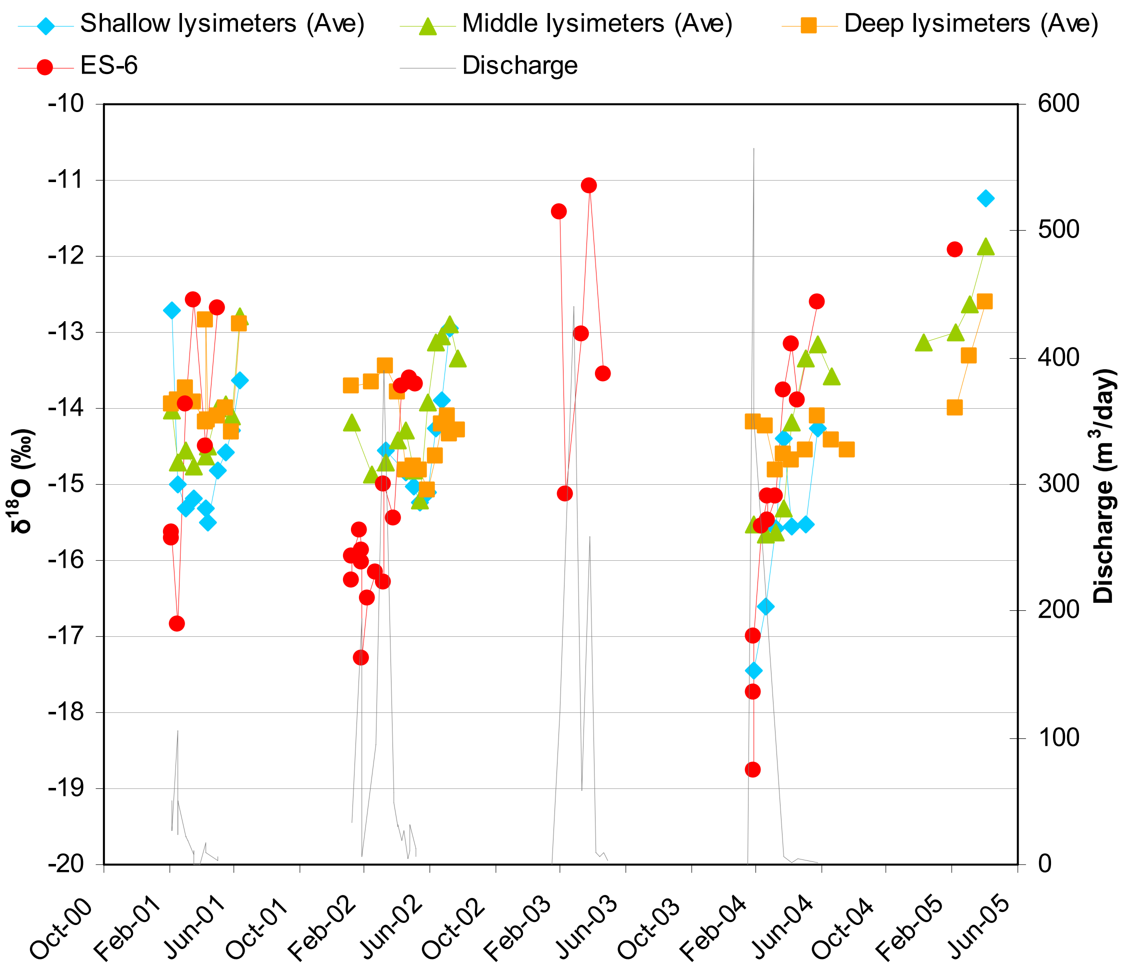

Figure 6: $\delta^{18}O$ and hydrograph for ES-6. The lysimeters are averaged for shallow (~20 cm), middle (~45 cm), and deep (~90 cm) depths (Appendix G). Lysimeters were sampled periodically in 2000-2002 and once a month in 2003-2005 for as long as they produced water. Discharge measurements were taken using a beaker and a stopwatch.

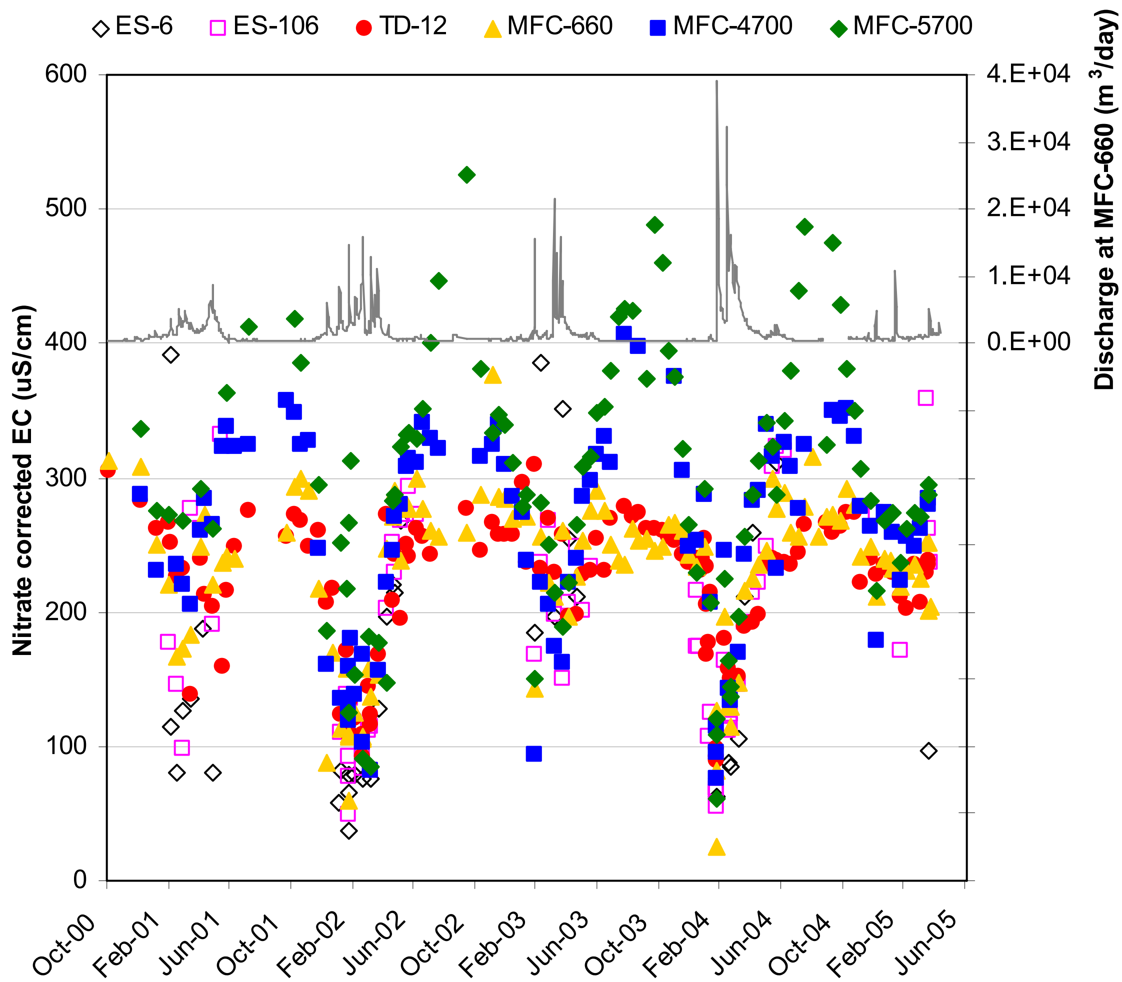

Figure 7: EC for surface waters and tile drain.

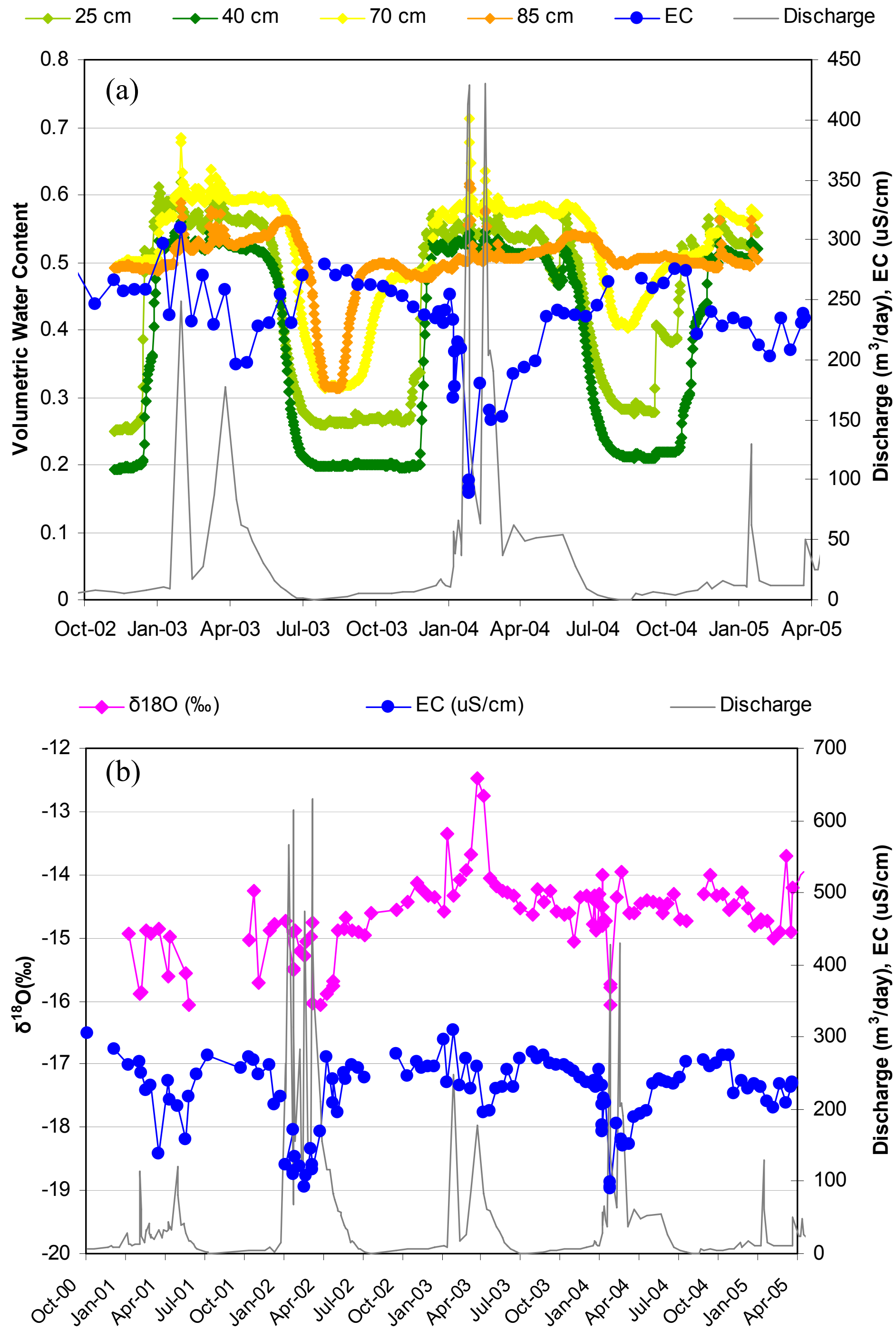

Figure 8: TD-12 (a) VWC, EC, and discharge, (b) $\delta^{18}O$, EC, and discharge. (a) VWC at four different depths show the profile wetting from the bottom upwards (85 cm to 70 cm) and from the top downwards (25 cm to 40 cm). Discharge peaks about a month after the VWC of the shallow soil water peaks. (b) $\delta^{18}O$ and EC are measured from the TD-12 outflow and EC is usually dependant on discharge rates.

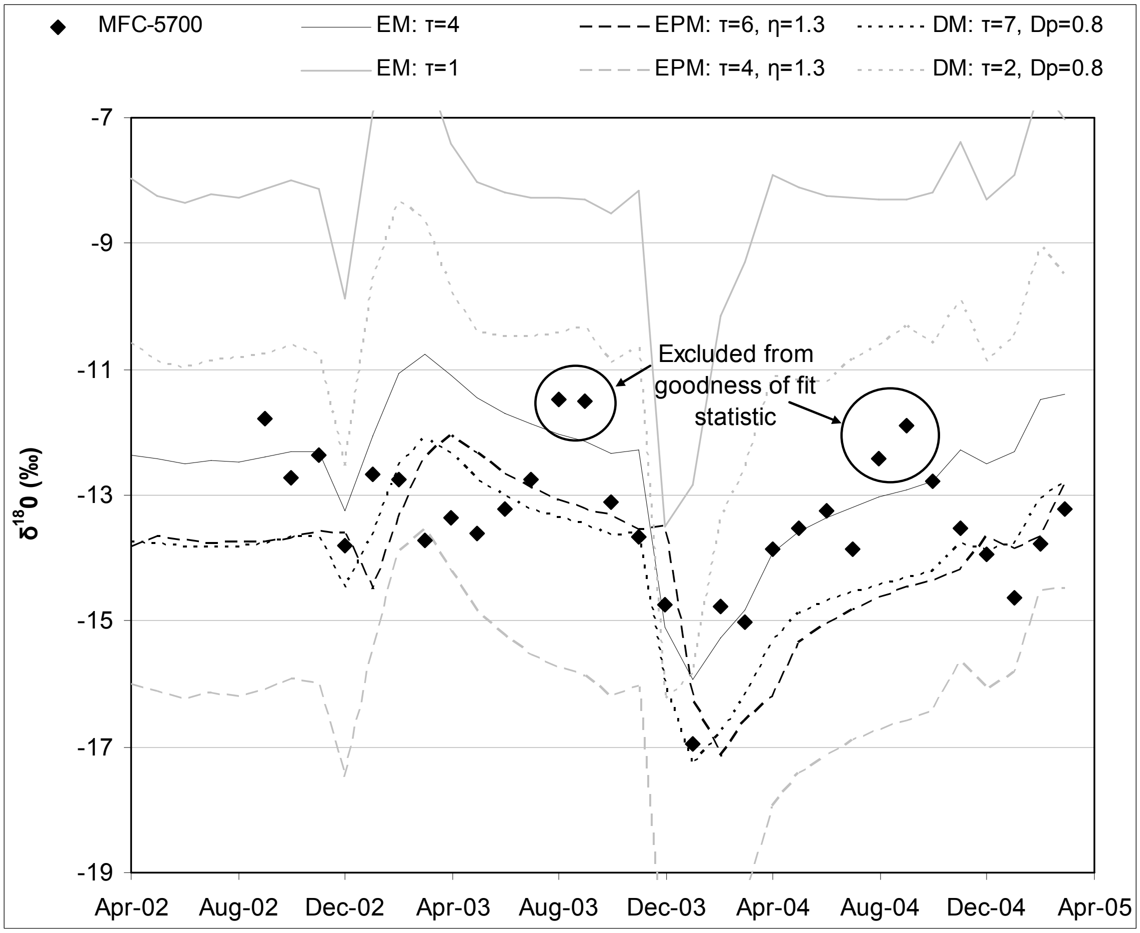

Figure 9: MFC-5700 model results. DM with a τ (mean residence time) of 7 months and a Dp (dispersion parameter) of 0.8 shows the best match during Apr-02 to Jan-04. Another match is EM with τ of 4 months during Feb-04 to Oct-04. Goodness of fit statistics excluded some dry months in 2003 and 2004 due to suspect data points that might have undergone evaporation.

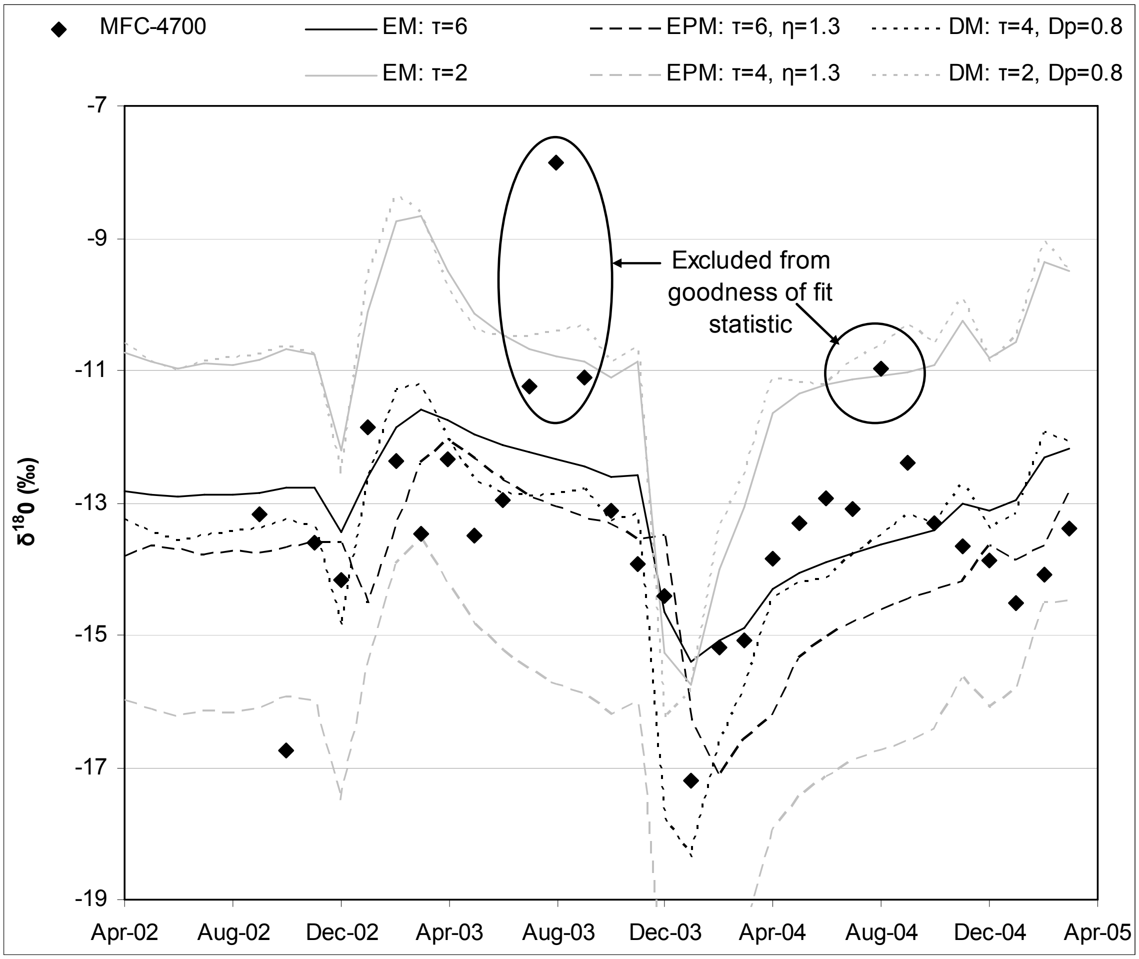

Figure 10: MFC-4700 model results. EM with a τ of 6 months shows the best match during Feb-04 to Oct-04. Another match is DM with a τ of 4 months and a Dp of 0.8 during Apr-02 to Jan-04. Goodness of fit statistics excluded some dry months in 2003 and 2004 due to suspect data points that might have undergone evaporation.

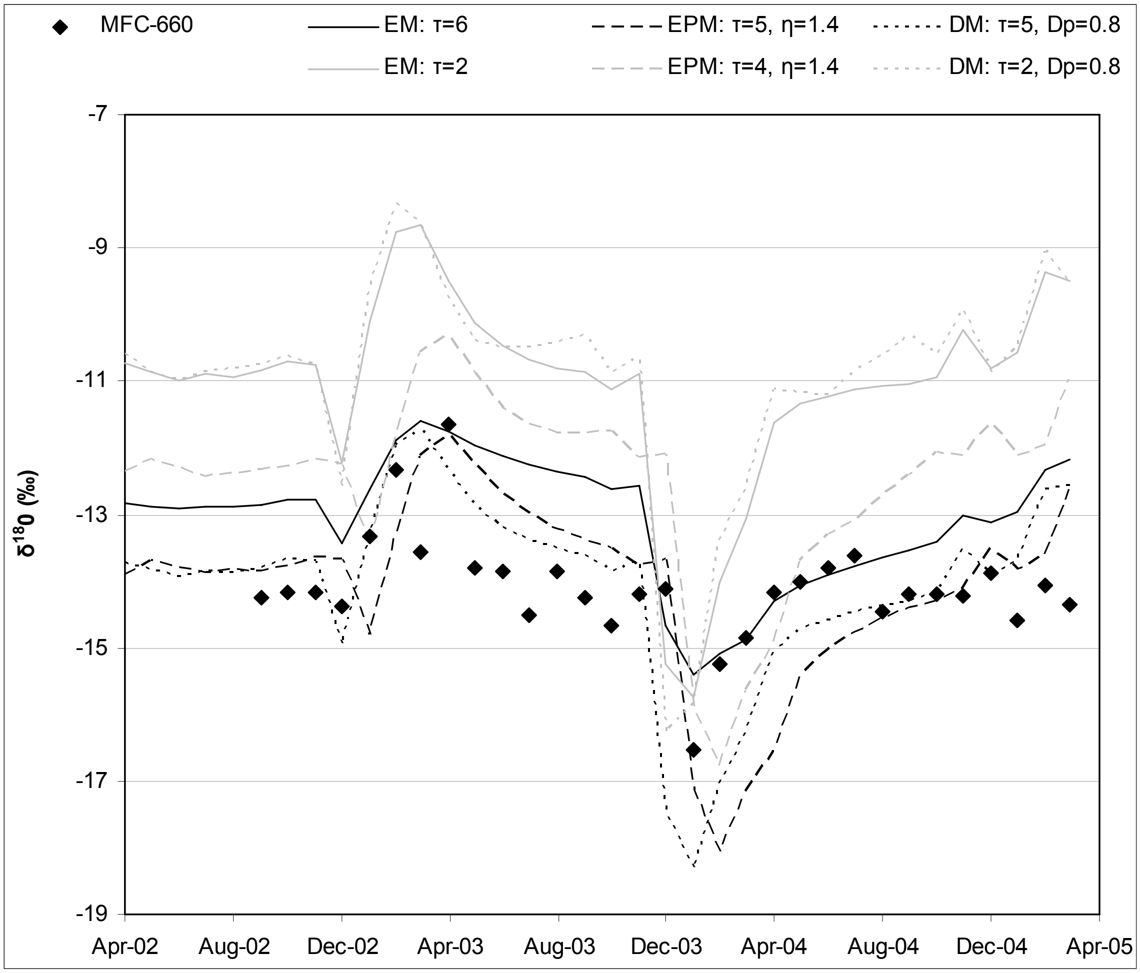

Figure 11: MFC-660 model results. DM with a τ of 5 months and Dp of 0.8 shows the best match during Apr-02 to Nov-03. Another match is EM with τ of 6 months during Feb-04 to Jul-04.

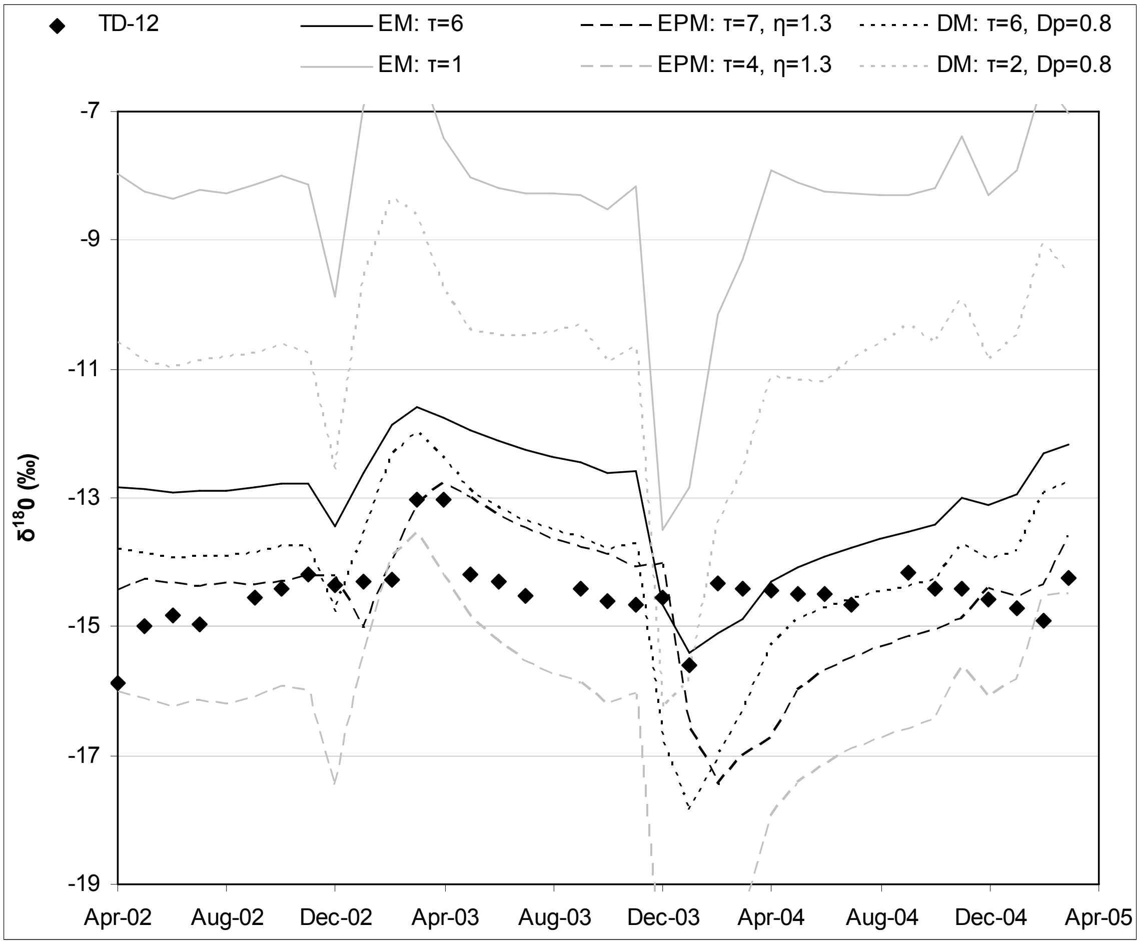

Figure 12: TD-12 model results. EPM with a τ of 7 months and η (fitting parameter) of 1.3 shows the best match during Apr-02 to Dec-03. Another match is EM with τ of 4 months during Jan-04 to Apr-04.

APPENDIX A: Analytical and method uncertainties

I. Storage Errors

Evaporation causes an increase in $\delta^{18}O$ values because it removes the lighter isotope (^{16}O) preferentially causing the $^{18}O/^{16}O$ ratio to increase. Some of the bottles used to store the water samples had defects in the lip of the openings and were not able to create an airtight seal. The defects include bumps, divots, burrs, and rough plastic. For future sampling, I suggest filling the sample bottle as much as possible to reduce the amount of headspace inside bottle. Also, turn sample bottle upside down since it is harder for the isotopes to move from liquid phase to the gas phase and leak out the cap. Most importantly, the samples should be analyzed soon after collection. Table A1 contain samples analyzed (Run #1) with the type of bottle defect and Table A2 contain the same samples with a replicate analysis (Run #2) along with their statistics.

II. Analytical Uncertainty

The standard deviation is a measure of the spread in our observations. Standard deviation of set z, expressed in terms of subsets x and y, is defined as:

$$S_z = \sqrt{S_x^2 + S_y^2} \qquad \text{(A1)}$$

Each run has approximately 8 standards analyzed for $\delta^{18}O$ and the analytical uncertainty uses the variance (S^2) of the standards for each analytical run (Appendix B). There is a variance of the standards for each run date; therefore there is a variance of the standards for each sample (Tables A1 and A2, 5th column). Using equation A1, the following standard deviation of the run standards, S_{std}, is defined as:

$$S_{std} = \sqrt{S_{Run1}^2 + S_{Run2}^2} \qquad \text{(A2)}$$

where S^2_{Run} is the variance of the standards of run 1 and 2 (Appendix B; Tables A1 and A2, 5th column). Table A3 (6th column) shows S_{std} for each sample; the average, $\bar{S}_{std}$, is 0.4‰. Using this value, the global analytical uncertainty for a single analysis, S', may be extracted from equation A1 by recasting it as:

$$S_z = \sqrt{S_x^2 + S_y^2}, \; where \; S_x = S_y = S' \; and \; S_z = \bar{S}_{std}$$
$$\bar{S}_{std} = \sqrt{2S'^2} \tag{A3}$$
$$S' = \sqrt{\frac{\bar{S}_{std}^2}{2}}$$

Analytical uncertainty is thus estimated as S'= ± 0.28‰.

III. Method Uncertainty – Option A

Sample bottle deformities and storage create uncertainty in addition to analytical uncertainty. Figure A1 shows the elapsed time between run analyses vs. the difference between the $\delta^{18}O$ results, X_{ij}. Option A estimates method uncertainty as the typical spread of these differences (e.g. the "box" at 100 days elapsed time in Figure A1). The global value S_A is estimated by:

$$S_A = \sqrt{\frac{\sum\left(X_{ij} - \bar{X}_{ij}\right)^2}{N-1}} \tag{A4}$$

where X_{ij} represents the differences in $\delta^{18}O$ between run 1 and 2 ($\delta^{18}Oa$ - $\delta^{18}Ob$) with i measurements made for each of j group of elapsed times, $\bar{X}_{ij}$ is the average difference for each j group of elapsed time (there are 9 $\bar{X}_{ij}$ values because there are 9 groups of elapsed times), and N is the total number of measurements (Table A3). Therefore, S_A = ± 0.35‰.

IV. Method Uncertainty – Option B

In order to determine the total uncertainty for the samples, the standard deviation was calculated on all differences between run 1 and 2 using the following equation:

$$S_B = \sqrt{\frac{\sum\left(X_i - \bar{X}_i\right)^2}{N-1}} \tag{A5}$$

where X_i represents the differences in $\delta^{18}O$ between run 1 and 2 (same as X_{ij} in option B) and $\bar{X}_i$ is the global average difference for the entire data set. Option B includes analytical and method uncertainties and shows the full spread of the differences. The result is $S_B = \pm$ 0.58‰. Figure A1 shows the average of all the differences ($\bar{X}_i$) is 0.33‰; the average of the differences 100 days between analysis dates is -0.11‰, which shows the storage effect is negligible; and the average of the differences after 100 days is 0.42‰, which shows a shift to enrichment ~0.42‰.

The method uncertainty – option B is most conservative, whereas option A could be underestimating the standard deviation. On the other hand, if option B is too conservative, then we are overly cautious and we attribute real trends to trends due to the method uncertainty. Figure A2 shows MFC-660 data points with $\pm$ 0.58‰ error bars.

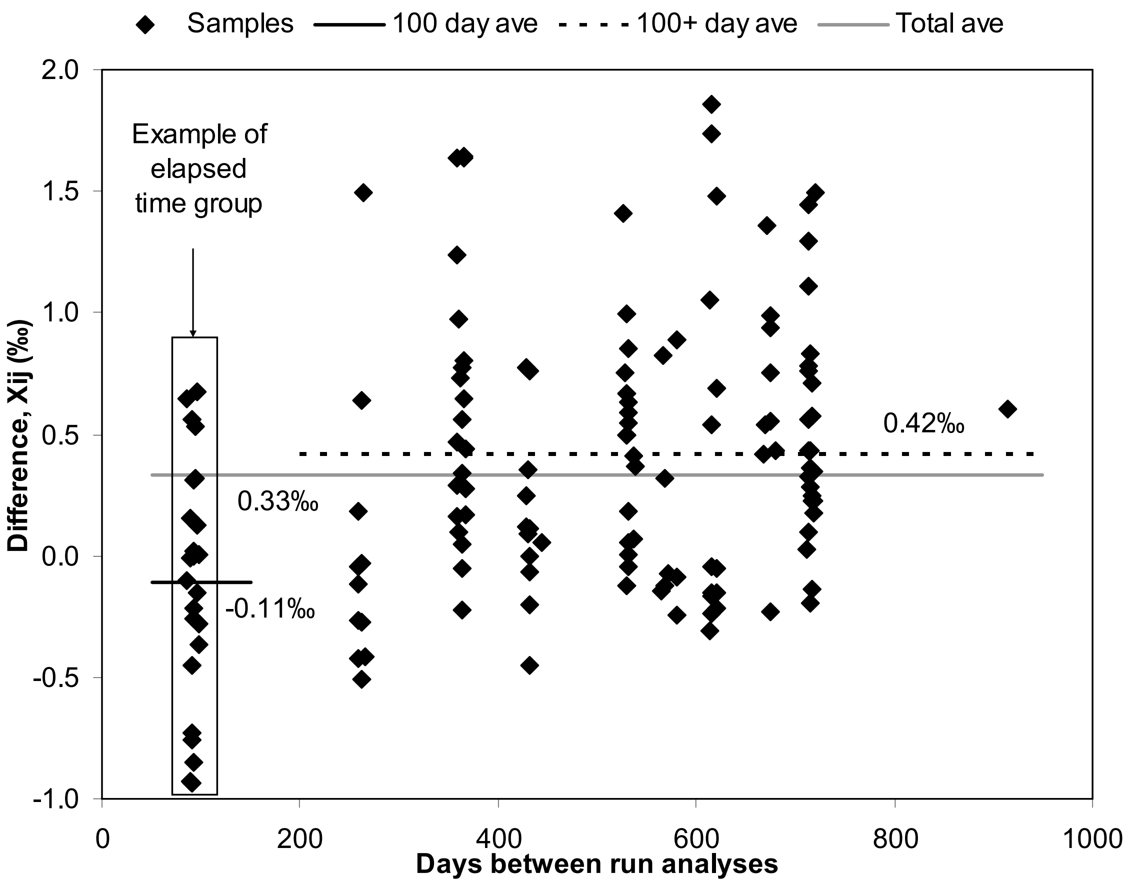

Figure A1: Elapsed time (days) between run 1 and 2 analyses vs. difference in $\delta^{18}O$ between run 1 and 2. Averages of differences for entire data set, 100 days, and 100+ days are given.

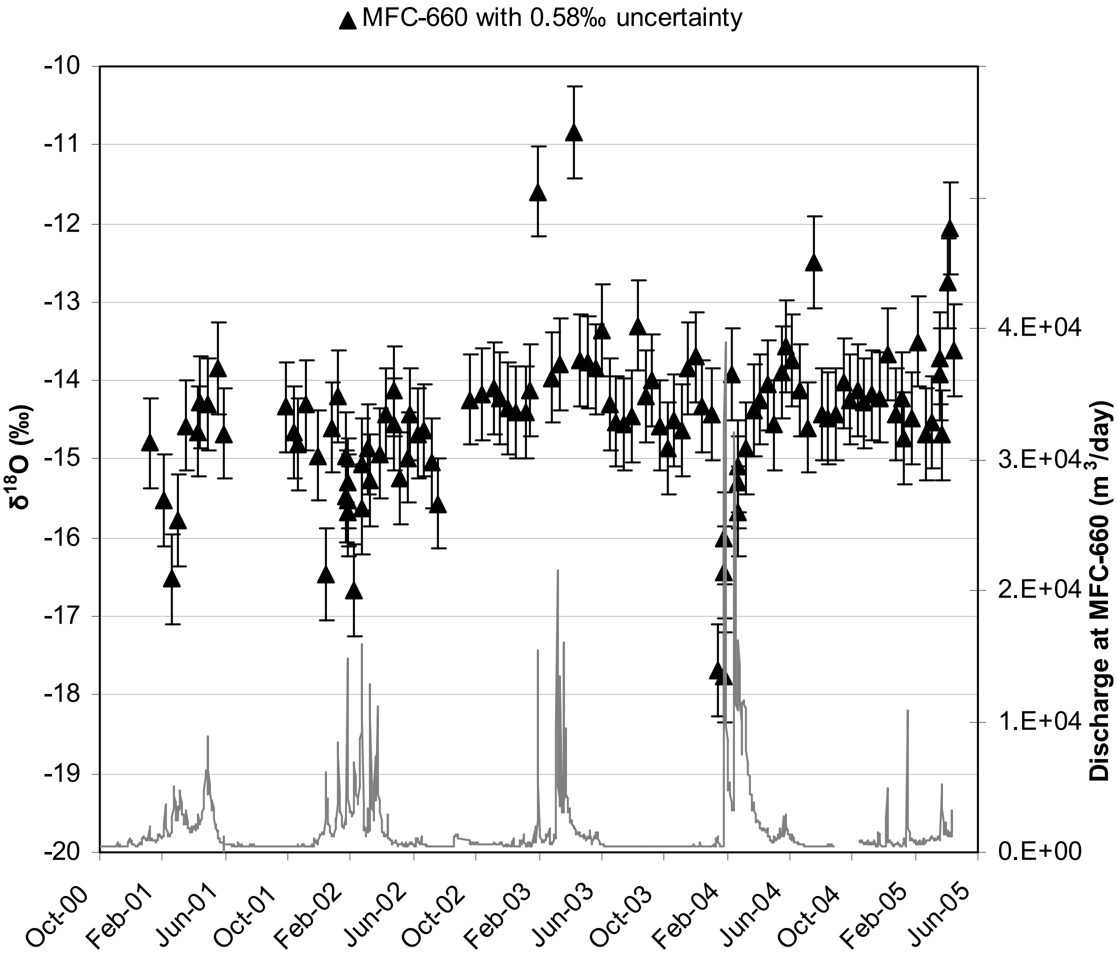

Figure A2: MFC-660 hydrograph and $\delta^{18}O$ values with 0.58‰ standard deviation error bars.

Table A1: First $\delta^{18}O$ run analysis with run dates and the variance of the run standards (see Appendix B). Also, shows days in the storage bottle from the sample date to the run analysis date. Descriptions of the bottle and cap deformities are stated.

Sample Date	Location	Run #	Run Date	S^2 of run stds. (‰)	$\delta^{18}O$-a (‰)	Storage (d)	Bottle/Cap Deformity
12/4/2002	MFC-4700	1	8/7/2003	0.01	-13.9124	246	burr
1/17/2003	MFC-4700	1	8/11/2003	0.06	-10.3513	206	
2/28/2003	MFC-4700	1	8/11/2003	0.06	-14.3345	164	
3/28/2003	MFC-4700	1	8/12/2003	0.06	-11.2519	137	little rough lip
5/23/2003	MFC-4700	1	8/13/2003	0.00	-13.4294	82	little burr
8/1/2003	MFC-4700	1	8/14/2003	0.00	-8.6456	13	little divot
8/15/2003	MFC-4700	1	2/11/2004	0.06	-7.1481	180	burr
9/12/2003	MFC-4700	1	2/11/2004	0.06	-10.1499	152	
1/16/2004	MFC-4700	1	2/14/2004	0.06	-16.4366	29	burr
1/29/2004	MFC-4700	1	2/15/2004	0.06	-17.3684	17	burr
3/12/2004	MFC-4700	1	7/29/2004	0.13	-15.0075	139	little bump
5/28/2004	MFC-4700	1	8/2/2004	0.00	-12.7453	66	
8/6/2004	MFC-4700	1	4/20/2005	0.02	-10.7492	257	
10/15/2004	MFC-4700	1	4/20/2005	0.02	-13.2941	187	
1/12/2005	MFC-4700	1	4/25/2005	0.12	-14.5864	103	little burr
4/8/2005	MFC-4700	1	4/28/2005	0.03	-13.3117	20	
9/20/2002	MFC-5700	1	8/7/2003	0.01	-11.7795	321	little burr
1/17/2003	MFC-5700	1	8/11/2003	0.06	-14.1527	206	burr
1/31/2003	MFC-5700	1	8/11/2003	0.06	-12.6160	192	little rough lip
2/28/2003	MFC-5700	1	8/11/2003	0.06	-13.9177	164	little divot
3/28/2003	MFC-5700	1	8/12/2003	0.06	-12.5930	137	little burr
5/23/2003	MFC-5700	1	8/13/2003	0.00	-13.6349	82	little bump
8/29/2003	MFC-5700	1	2/11/2004	0.06	-11.1611	166	
10/24/2003	MFC-5700	1	2/12/2004	0.08	-13.5141	111	little divot
12/19/2003	MFC-5700	1	2/13/2004	0.08	-15.0075	56	little burr
5/28/2004	MFC-5700	1	8/2/2004	0.00	-13.1081	66	
7/23/2004	MFC-5700	1	8/3/2004	0.00	-14.3216	11	little bump
9/3/2004	MFC-5700	1	4/20/2005	0.02	-10.9911	229	
12/27/2004	MFC-5700	1	4/24/2005	0.12	-14.3240	118	little bump
2/11/2005	MFC-5700	1	4/25/2005	0.12	-13.4962	73	burr
12/19/2002	MFC-660	1	8/7/2003	0.01	-14.4091	231	little rough lip
1/31/2003	MFC-660	1	8/11/2003	0.06	-11.5921	192	little rough lip
4/11/2003	MFC-660	1	8/12/2003	0.06	-10.8406	123	rough lip
5/9/2003	MFC-660	1	8/12/2003	0.06	-13.7615	95	
6/6/2003	MFC-660	1	8/13/2003	0.00	-13.3561	68	burr
7/18/2003	MFC-660	1	8/14/2003	0.00	-14.5530	27	
9/12/2003	MFC-660	1	2/11/2004	0.06	-14.0007	152	little bump
11/21/2003	MFC-660	1	2/12/2004	0.08	-13.8372	83	
12/5/2003	MFC-660	1	2/12/2004	0.08	-13.7014	69	little rough lip
1/29/2004	MFC-660	1	2/15/2004	0.06	-17.7726	17	burr
2/13/2004	MFC-660	1	7/27/2004	0.01	-13.9176	165	little divot

Sample Date	Location	Run #	Run Date	S^2 of run stds. (‰)	δ^{18}O-a (‰)	Storage (d)	Bottle/Cap Deformity
2/26/2004	MFC-660	1	7/29/2004	0.13	-15.6617	154	
5/28/2004	MFC-660	1	8/2/2004	0.00	-13.5631	66	little rough lip
11/29/2004	MFC-660	1	4/21/2005	0.02	-14.2114	143	
4/12/2005	MFC-660	1	4/28/2005	0.03	-12.0637	16	
4/8/2005	P 3	1	4/28/2005	0.03	-11.7766	20	divot
2/11/2005	P 4	1	4/25/2005	0.12	-13.1727	73	really rough lip
4/5/2002	P 8	1	9/22/2003	0.24	-14.8505	535	burr
4/5/2002	P 9	1	9/22/2003	0.24	-14.8335	535	burr
2/20/2004	P 9	1	7/27/2004	0.01	-13.3415	158	burr
7/26/2001	Precipitation	1	2/10/2004	0.06	-12.2188	929	little burr
1/10/2002	Precipitation	1	9/16/2003	0.18	-13.2147	614	little divot
1/24/2002	Precipitation	1	9/16/2003	0.18	-12.4957	600	little rough lip
1/25/2002	Precipitation	1	9/16/2003	0.18	-16.0815	599	burr
3/29/2002	Precipitation	1	4/18/2005	0.03	-8.4608	1116	little burr
4/26/2002	Precipitation	1	9/25/2003	0.24	-12.1573	517	
5/24/2002	Precipitation	1	9/27/2003	0.26	-12.2019	491	
6/11/2002	Precipitation	1	9/27/2003	0.26	-16.5085	473	rough lip
6/25/2002	Precipitation	1	9/30/2003	0.21	-15.1955	462	little bump
7/9/2002	Precipitation	1	10/1/2003	0.21	-11.4746	449	very little bump
9/20/2002	Precipitation	1	8/6/2003	0.01	-11.7513	320	little bump
10/16/2002	Precipitation	1	8/7/2003	0.01	-6.6438	295	little bump
11/8/2002	Precipitation	1	8/7/2003	0.01	-12.8144	272	rough lip
12/19/2002	Precipitation	1	8/7/2003	0.01	-15.7129	231	little bump
1/10/2003	Precipitation	1	8/7/2003	0.01	-17.2572	209	little bump
1/17/2003	Precipitation	1	8/11/2003	0.06	-13.6471	206	little burr
1/31/2003	Precipitation	1	8/11/2003	0.06	-11.8427	192	little burr
2/14/2003	Precipitation	1	8/11/2003	0.06	-14.7616	178	
3/28/2003	Precipitation	1	8/12/2003	0.06	-11.3296	137	little bump
4/11/2003	Precipitation	1	8/12/2003	0.06	-7.5035	123	little rough lip
4/25/2003	Precipitation	1	8/12/2003	0.06	-13.8259	109	rough lip
5/9/2003	Precipitation	1	8/12/2003	0.06	-13.5045	95	burr
5/23/2003	Precipitation	1	8/13/2003	0.00	-15.3992	82	bump
6/6/2003	Precipitation	1	8/13/2003	0.00	-7.0821	68	little burr
6/20/2003	Precipitation	1	4/18/2005	0.36	-8.0818	668	
9/12/2003	Precipitation	1	2/11/2004	0.06	-9.6071	152	
9/27/2003	Precipitation	1	2/11/2004	0.06	-7.7702	137	out of water
10/13/2003	Precipitation	1	2/12/2004	0.08	-15.5343	122	little rough lip
11/16/2003	Precipitation	1	2/12/2004	0.08	-13.7004	88	little rough lip
11/21/2003	Precipitation	1	2/12/2004	0.08	-11.9768	83	
12/5/2003	Precipitation	1	2/12/2004	0.08	-16.0485	69	rough lip
12/19/2003	Precipitation	1	2/13/2004	0.08	-18.2346	56	bump
1/9/2004	Precipitation	1	2/13/2004	0.08	-17.0541	35	little bump
1/16/2004	Precipitation	1	2/14/2004	0.06	-14.2345	29	little rough lip
1/29/2004	Precipitation	1	2/15/2004	0.06	-17.9271	17	little burr

Sample Date	Location	Run #	Run Date	S^2 of run stds. (‰)	$\delta^{18}O$-a (‰)	Storage (d)	Bottle/Cap Deformity
1/30/2004	Precipitation	1	2/15/2004	0.06	-12.7285	16	very little burr
2/13/2004	Precipitation	1	7/27/2004	0.01	-14.4054	165	
2/24/2004	Precipitation	1	7/28/2004	0.13	-14.6483	155	rough lip
2/26/2004	Precipitation	1	7/29/2004	0.13	-16.4531	154	
3/12/2004	Precipitation	1	7/29/2004	0.13	-16.2083	139	
4/9/2004	Precipitation	1	7/30/2004	0.13	-13.1123	112	little bump
4/23/2004	Precipitation	1	7/30/2004	0.13	-11.8157	98	bump
5/7/2004	Precipitation	1	8/2/2004	0.00	-8.5797	87	
5/21/2004	Precipitation	1	8/2/2004	0.00	-12.6017	73	
5/28/2004	Precipitation	1	8/2/2004	0.00	-10.1931	66	
6/11/2004	Precipitation	1	8/2/2004	0.00	-12.1155	52	very little bump
7/23/2004	Precipitation	1	8/3/2004	0.00	-8.5318	11	burr
2/20/2004	SC 10	1	7/28/2004	0.13	-16.9929	159	divot
5/31/2001	SC 11	1	2/7/2004	0.01	-14.5592	982	burr
4/8/2005	SC 11	1	4/28/2005	0.03	-11.8851	20	burr
3/10/2005	SC 12	1	4/26/2005	0.03	-13.6583	47	rough lip
4/8/2005	SC 12	1	4/28/2005	0.03	-12.8664	20	burr
5/30/2002	SC 15	1	9/27/2003	0.26	-15.3733	485	burr
3/12/2004	SC 16	1	7/30/2004	0.13	-15.5783	140	bump
3/26/2004	SC 16	1	7/30/2004	0.13	-14.4061	126	bump
5/16/2002	SC 17	1	9/26/2003	0.26	-15.3219	498	burr
2/20/2004	SC 17	1	7/28/2004	0.13	-15.2624	159	burr
5/28/2004	SC 18	1	8/2/2004	0.00	-13.7218	66	divot
3/10/2005	SC 18	1	4/26/2005	0.03	-12.8534	47	burr
3/26/2004	SC 3	1	7/30/2004	0.13	-13.7454	126	burr
5/7/2004	SC 3	1	8/2/2004	0.00	-13.9477	87	bump
2/15/2002	SC 6	1	9/17/2003	0.18	-13.6032	579	burr
3/15/2002	SC 6	1	9/22/2003	0.24	-13.7647	556	burr
1/30/2004	SC 6	1	7/26/2004	0.01	-13.9412	178	rough lip
3/21/2001	SC 8	1	2/5/2004	0.03	-12.9236	1051	burr
1/30/2004	SC 8	1	7/26/2004	0.01	-12.9123	178	burr
6/13/2002	SC 9	1	9/30/2003	0.21	-14.0307	474	burr
12/13/2004	SC 9	1	4/23/2005	0.03	-14.2201	131	divot
3/10/2005	SC 9	1	4/26/2005	0.03	-13.4622	47	rough lip
5/17/2001	SS 2	1	2/7/2004	0.01	-13.5517	996	burr
3/26/2004	SS 2	1	7/30/2004	0.13	-15.6219	126	burr
2/20/2004	SS 4	1	7/28/2004	0.13	-17.1243	159	rough lip
3/15/2002	SS 5	1	9/22/2003	0.24	-14.7924	556	burr
4/5/2002	SS 5	1	9/22/2003	0.24	-15.5223	535	burr
4/8/2005	SS 7	1	4/28/2005	0.03	-12.8225	20	divot
3/10/2005	SS 8	1	4/26/2005	0.03	-13.1629	47	burr
4/8/2005	SS 8	1	4/28/2005	0.03	-12.5179	20	burr
3/20/2001	TD-12	1	1/23/2003	-	-14.8633	674	little divot
11/20/2002	TD-12	1	8/7/2003	0.01	-14.2219	260	rough lip

Sample Date	Location	Run #	Run Date	S^2 of run stds. (‰)	δ^{18}O-a (‰)	Storage (d)	Bottle/Cap Deformity
1/17/2003	TD-12	1	8/11/2003	0.06	-13.3625	206	little bump
3/14/2003	TD-12	1	8/11/2003	0.06	-13.6772	150	rough lip
3/28/2003	TD-12	1	8/12/2003	0.06	-12.4662	137	burr
4/11/2003	TD-12	1	8/12/2003	0.06	-12.7455	123	rough lip
6/6/2003	TD-12	1	8/13/2003	0.00	-14.2798	68	little bump
8/15/2003	TD-12	1	2/11/2004	0.06	-14.2433	180	
8/29/2003	TD-12	1	2/11/2004	0.06	-14.4370	166	
9/12/2003	TD-12	1	2/11/2004	0.06	-14.2474	152	little bump
11/7/2003	TD-12	1	2/12/2004	0.08	-15.0559	97	little bump
1/30/2004	TD-12	1	7/26/2004	0.01	-15.7422	178	rough lip
4/23/2004	TD-12	1	8/2/2004	0.00	-14.4082	101	little bump
12/13/2004	TD-12	1	4/21/2005	0.02	-14.5291	129	little bump
4/12/2005	TD-12	1	4/28/2005	0.03	-14.0130	16	

Table A2: Second $\delta^{18}O$ run analysis with run dates and the variance of the run standards (see Appendix B). Also, shows days in the storage bottle from the sample date to the run analyses date and the elapsed time in days between the first and second run analyses.

Sample Date	Location	Run #	Run Date	S^2 of run stds. (‰)	New $\delta^{18}O$-b (‰)	Storage (d)	Elapsed time (d)
12/4/2002	MFC-4700	2	7/26/2005	0.03	-13.6847	965	719
1/17/2003	MFC-4700	2	7/27/2005	0.03	-10.4901	922	716
2/28/2003	MFC-4700	2	7/27/2005	0.03	-14.0868	880	716
3/28/2003	MFC-4700	2	7/27/2005	0.03	-11.4466	852	715
5/23/2003	MFC-4700	2	7/27/2005	0.03	-12.9969	796	714
8/1/2003	MFC-4700	2	7/27/2005	0.03	-7.5389	726	713
8/15/2003	MFC-4700	2	7/27/2005	0.03	-6.6026	712	532
9/12/2003	MFC-4700	2	7/27/2005	0.03	-9.9644	684	532
1/16/2004	MFC-4700	2	7/27/2005	0.03	-15.7679	558	529
1/29/2004	MFC-4700	2	7/27/2005	0.03	-16.6123	545	528
3/12/2004	MFC-4700	2	7/27/2005	0.03	-14.4491	502	363
5/28/2004	MFC-4700	2	7/27/2005	0.03	-12.4522	425	359
8/6/2004	MFC-4700	2	7/27/2005	0.03	-11.1176	355	98
10/15/2004	MFC-4700	2	7/27/2005	0.03	-13.2905	285	98
1/12/2005	MFC-4700	2	7/27/2005	0.03	-14.2735	196	93
4/8/2005	MFC-4700	2	7/27/2005	0.03	-13.3212	110	90
9/20/2002	MFC-5700	2	7/27/2005	0.03	-10.2824	1041	720
1/17/2003	MFC-5700	2	7/27/2005	0.03	-13.4404	922	716
1/31/2003	MFC-5700	2	7/27/2005	0.03	-12.0445	908	716
2/28/2003	MFC-5700	2	7/27/2005	0.03	-13.6924	880	716
3/28/2003	MFC-5700	2	7/27/2005	0.03	-12.2350	852	715
5/23/2003	MFC-5700	2	7/27/2005	0.03	-13.3100	796	714
8/29/2003	MFC-5700	2	7/27/2005	0.03	-11.2056	698	532
10/24/2003	MFC-5700	2	7/27/2005	0.03	-12.9251	642	531
12/19/2003	MFC-5700	2	7/27/2005	0.03	-14.5105	586	530
5/28/2004	MFC-5700	2	7/27/2005	0.03	-12.9446	425	359
7/23/2004	MFC-5700	2	7/27/2005	0.03	-13.0808	369	358
9/3/2004	MFC-5700	2	7/27/2005	0.03	-11.2728	327	98
12/27/2004	MFC-5700	2	7/27/2005	0.03	-13.7937	212	94
2/11/2005	MFC-5700	2	7/27/2005	0.03	-13.7535	166	93
12/19/2002	MFC-660	2	7/26/2005	0.03	-14.0589	950	719
1/31/2003	MFC-660	2	7/26/2005	0.03	-11.1570	907	715
4/11/2003	MFC-660	2	7/26/2005	0.03	-9.3978	837	714
5/9/2003	MFC-660	2	7/26/2005	0.03	-13.6661	809	714
6/6/2003	MFC-660	2	7/26/2005	0.03	-12.5748	781	713
7/18/2003	MFC-660	2	7/26/2005	0.03	-14.5301	739	712
9/12/2003	MFC-660	2	7/26/2005	0.03	-13.1450	683	531
11/21/2003	MFC-660	2	7/26/2005	0.03	-13.9633	613	530
12/5/2003	MFC-660	2	7/26/2005	0.03	-13.2041	599	530
1/29/2004	MFC-660	2	7/26/2005	0.03	-16.3652	544	527
2/13/2004	MFC-660	2	7/26/2005	0.03	-13.5810	529	364

Sample Date	Location	Run #	Run Date	S^2 of run stds. (‰)	New $\delta^{18}O$-b (‰)	Storage (d)	Elapsed time (d)
2/26/2004	MFC-660	2	7/26/2005	0.03	-14.9305	516	362
5/28/2004	MFC-660	2	7/26/2005	0.03	-11.9288	424	358
11/29/2004	MFC-660	2	7/26/2005	0.03	-14.3624	239	96
4/12/2005	MFC-660	2	7/26/2005	0.03	-12.9926	105	89
4/8/2005	P 3	2	7/28/2005	0.03	-12.5071	111	91
2/11/2005	P 4	2	7/28/2005	0.03	-12.8544	167	94
4/5/2002	P 8	2	7/28/2005	0.03	-13.8622	1210	675
4/5/2002	P 9	2	7/28/2005	0.03	-14.0794	1210	675
2/20/2004	P 9	2	7/29/2005	0.03	-13.1736	525	367
7/26/2001	Precipitation	2	4/29/2005	0.03	-12.1655	1373	444
1/10/2002	Precipitation	2	4/18/2005	0.03	-12.3241	1194	580
1/24/2002	Precipitation	2	4/18/2005	0.03	-12.7423	1180	580
1/25/2002	Precipitation	2	4/18/2005	0.03	-16.1687	1179	580
3/29/2002	Precipitation	2	7/12/2005	0.10	-8.5602	1201	85
4/26/2002	Precipitation	2	4/18/2005	0.03	-12.2286	1088	571
5/24/2002	Precipitation	2	4/18/2005	0.03	-12.3222	1060	569
6/11/2002	Precipitation	2	4/18/2005	0.03	-16.1931	1042	569
6/25/2002	Precipitation	2	4/18/2005	0.03	-14.3742	1028	566
7/9/2002	Precipitation	2	4/18/2005	0.36	-11.6186	1014	565
9/20/2002	Precipitation	2	4/18/2005	0.36	-11.9681	941	621
10/16/2002	Precipitation	2	4/18/2005	0.36	-6.7984	915	620
11/8/2002	Precipitation	2	4/18/2005	0.36	-11.3322	892	620
12/19/2002	Precipitation	2	4/18/2005	0.36	-15.7677	851	620
1/10/2003	Precipitation	2	4/18/2005	0.36	-16.5693	829	620
1/17/2003	Precipitation	2	4/18/2005	0.36	-13.1073	822	616
1/31/2003	Precipitation	2	4/18/2005	0.36	-12.0071	808	616
2/14/2003	Precipitation	2	4/18/2005	0.36	-14.8062	794	616
3/28/2003	Precipitation	2	4/18/2005	0.36	-11.5690	752	615
4/11/2003	Precipitation	2	4/18/2005	0.36	-5.6458	738	615
4/25/2003	Precipitation	2	4/18/2005	0.36	-12.0925	724	615
5/9/2003	Precipitation	2	4/18/2005	0.36	-13.6543	710	615
5/23/2003	Precipitation	2	4/18/2005	0.36	-14.3487	696	614
6/6/2003	Precipitation	2	4/18/2005	0.36	-7.3884	682	614
6/20/2003	Precipitation	2	7/12/2005	0.10	-7.4322	753	85
9/12/2003	Precipitation	2	4/18/2005	0.36	-9.6722	584	432
9/27/2003	Precipitation	2	4/18/2005	0.36	-7.7728	569	432
10/13/2003	Precipitation	2	4/18/2005	0.36	-15.9831	553	431
11/16/2003	Precipitation	2	4/18/2005	0.36	-13.5890	519	431
11/21/2003	Precipitation	2	4/18/2005	0.36	-12.1821	514	431
12/5/2003	Precipitation	2	4/18/2005	0.36	-15.2864	500	431
12/19/2003	Precipitation	2	4/18/2005	0.36	-17.8833	486	430
1/9/2004	Precipitation	2	4/18/2005	0.36	-16.9660	465	430
1/16/2004	Precipitation	2	4/18/2005	0.36	-14.1182	458	429
1/29/2004	Precipitation	2	4/18/2005	0.36	-17.1503	445	428
1/30/2004	Precipitation	2	4/18/2005	0.36	-12.4783	444	428
2/13/2004	Precipitation	2	4/18/2005	0.36	-14.8228	430	265

Sample Date	Location	Run #	Run Date	S^2 of run stds. (‰)	New $\delta^{18}O$-b (‰)	Storage (d)	Elapsed time (d)
2/24/2004	Precipitation	2	4/18/2005	0.36	-13.1538	419	264
2/26/2004	Precipitation	2	4/18/2005	0.36	-16.7279	417	263
3/12/2004	Precipitation	2	4/18/2005	0.36	-16.2420	402	263
4/9/2004	Precipitation	2	4/18/2005	0.36	-13.6179	374	262
4/23/2004	Precipitation	2	4/18/2005	0.36	-11.1764	360	262
5/7/2004	Precipitation	2	4/18/2005	0.36	-8.6262	346	259
5/21/2004	Precipitation	2	4/18/2005	0.36	-12.8662	332	259
5/28/2004	Precipitation	2	4/18/2005	0.36	-10.6189	325	259
6/11/2004	Precipitation	2	4/18/2005	0.36	-11.9322	311	259
7/23/2004	Precipitation	2	4/18/2005	0.36	-8.6480	269	258
2/20/2004	SC 10	2	7/29/2005	0.03	-15.3471	525	366
5/31/2001	SC 11	2	7/28/2005	0.03	-14.1471	1519	537
4/8/2005	SC 11	2	7/28/2005	0.03	-12.3347	111	91
3/10/2005	SC 12	2	7/28/2005	0.03	-13.6589	140	93
4/8/2005	SC 12	2	7/28/2005	0.03	-13.8003	111	91
5/30/2002	SC 15	2	7/28/2005	0.03	-14.8327	1155	670
3/12/2004	SC 16	2	7/28/2005	0.03	-15.8021	503	363
3/26/2004	SC 16	2	7/28/2005	0.03	-14.4612	489	363
5/16/2002	SC 17	2	7/28/2005	0.03	-13.9644	1169	671
2/20/2004	SC 17	2	7/29/2005	0.03	-14.6141	525	366
5/28/2004	SC 18	2	7/28/2005	0.03	-13.6232	426	360
3/10/2005	SC 18	2	7/28/2005	0.03	-13.0700	140	93
3/26/2004	SC 3	2	7/29/2005	0.03	-13.6999	490	364
5/7/2004	SC 3	2	7/28/2005	0.03	-12.9719	447	360
2/15/2002	SC 6	2	7/28/2005	0.03	-13.1730	1259	680
3/15/2002	SC 6	2	7/28/2005	0.03	-13.2079	1231	675
1/30/2004	SC 6	2	7/28/2005	0.03	-13.5042	545	367
3/21/2001	SC 8	2	7/28/2005	0.03	-12.5563	1590	539
1/30/2004	SC 8	2	7/28/2005	0.03	-12.6399	545	367
6/13/2002	SC 9	2	7/28/2005	0.03	-13.6112	1141	667
12/13/2004	SC 9	2	7/28/2005	0.03	-14.0912	227	96
3/10/2005	SC 9	2	7/28/2005	0.03	-14.3138	140	93
5/17/2001	SS 2	2	7/28/2005	0.03	-13.4829	1533	537
3/26/2004	SS 2	2	7/28/2005	0.03	-14.8456	489	363
2/20/2004	SS 4	2	7/29/2005	0.03	-15.4875	525	366
3/15/2002	SS 5	2	7/28/2005	0.03	-15.0200	1231	675
4/5/2002	SS 5	2	7/28/2005	0.03	-14.5836	1210	675
4/8/2005	SS 7	2	7/28/2005	0.03	-13.5816	111	91
3/10/2005	SS 8	2	7/28/2005	0.03	-13.1454	140	93
4/8/2005	SS 8	2	7/28/2005	0.03	-11.9582	111	91
3/20/2001	TD-12	2	7/26/2005	0.03	-14.2575	1589	915
11/20/2002	TD-12	2	7/26/2005	0.03	-14.0440	979	719
1/17/2003	TD-12	2	7/26/2005	0.03	-12.5307	921	715
3/14/2003	TD-12	2	7/26/2005	0.03	-13.3918	865	715
3/28/2003	TD-12	2	7/26/2005	0.03	-11.1724	851	714
4/11/2003	TD-12	2	7/26/2005	0.03	-12.1851	837	714

Sample Date	Location	Run #	Run Date	S^2 of run stds. (‰)	New $\delta^{18}O$-b (‰)	Storage (d)	Elapsed time (d)
6/6/2003	TD-12	2	7/26/2005	0.03	-13.5186	781	713
8/15/2003	TD-12	2	7/26/2005	0.03	-14.1896	711	531
8/29/2003	TD-12	2	7/26/2005	0.03	-14.4321	697	531
9/12/2003	TD-12	2	7/26/2005	0.03	-13.6141	683	531
11/7/2003	TD-12	2	7/26/2005	0.03	-14.0642	627	530
1/30/2004	TD-12	2	7/26/2005	0.03	-14.9379	543	365
4/23/2004	TD-12	2	7/26/2005	0.03	-13.9434	459	358
12/13/2004	TD-12	2	7/26/2005	0.03	-13.8513	225	96
4/12/2005	TD-12	2	7/26/2005	0.03	-13.8575	105	89

Table A3: Shows statistics (standard deviations, differences, and averages) between first and second run analyses. Also, shows S_{std} results from equation A2 and $\left(X_{ij}-\bar{X}_{ij}\right)^2$ to calculate S_A for equation A4.

Sample Date	Location	S observed (‰)	Differences X_{ij} and X_i(‰)	Ave $\delta^{18}O$ between run 1 and 2 (‰)	S_{std} from Eq. A2	$\left(X_{ij}-\bar{X}_{ij}\right)^2$ for Eq. A4
12/4/2002	MFC-4700	0.16	0.23	-13.80	0.19	0.08
1/17/2003	MFC-4700	0.10	-0.14	-10.42	0.31	0.43
2/28/2003	MFC-4700	0.18	0.25	-14.21	0.31	0.07
3/28/2003	MFC-4700	0.14	-0.19	-11.35	0.31	0.51
5/23/2003	MFC-4700	0.31	0.43	-13.21	0.18	0.01
8/1/2003	MFC-4700	0.78	1.11	-8.09	0.18	0.35
8/15/2003	MFC-4700	0.39	0.55	-6.88	0.30	0.01
9/12/2003	MFC-4700	0.13	0.19	-10.06	0.30	0.08
1/16/2004	MFC-4700	0.47	0.67	-16.10	0.30	0.04
1/29/2004	MFC-4700	0.53	0.76	-16.99	0.30	0.08
3/12/2004	MFC-4700	0.39	0.56	-14.73	0.40	0.00
5/28/2004	MFC-4700	0.21	0.29	-12.60	0.18	0.10
8/6/2004	MFC-4700	0.26	-0.37	-10.93	0.22	0.07
10/15/2004	MFC-4700	0.00	0.00	-13.29	0.22	0.01
1/12/2005	MFC-4700	0.22	0.31	-14.43	0.38	0.18
4/8/2005	MFC-4700	0.01	-0.01	-13.32	0.25	0.01
9/20/2002	MFC-5700	1.06	1.50	-11.03	0.19	0.96
1/17/2003	MFC-5700	0.50	0.71	-13.80	0.31	0.04
1/31/2003	MFC-5700	0.40	0.57	-12.33	0.31	0.00
2/28/2003	MFC-5700	0.16	0.23	-13.81	0.31	0.09
3/28/2003	MFC-5700	0.25	0.36	-12.41	0.31	0.03
5/23/2003	MFC-5700	0.23	0.32	-13.47	0.18	0.04
8/29/2003	MFC-5700	0.03	-0.04	-11.18	0.30	0.26
10/24/2003	MFC-5700	0.42	0.59	-13.22	0.33	0.02
12/19/2003	MFC-5700	0.35	0.50	-14.76	0.33	0.00
5/28/2004	MFC-5700	0.12	0.16	-13.03	0.18	0.19
7/23/2004	MFC-5700	0.88	1.24	-13.70	0.18	0.41
9/3/2004	MFC-5700	0.20	-0.28	-11.13	0.22	0.03
12/27/2004	MFC-5700	0.37	0.53	-14.06	0.38	0.41
2/11/2005	MFC-5700	0.18	-0.26	-13.62	0.38	0.02
12/19/2002	MFC-660	0.25	0.35	-14.23	0.19	0.03
1/31/2003	MFC-660	0.31	0.44	-11.37	0.31	0.01
4/11/2003	MFC-660	1.02	1.44	-10.12	0.31	0.86
5/9/2003	MFC-660	0.07	0.10	-13.71	0.31	0.18
6/6/2003	MFC-660	0.55	0.78	-12.97	0.18	0.07
7/18/2003	MFC-660	0.02	0.02	-14.54	0.18	0.24
9/12/2003	MFC-660	0.61	0.86	-13.57	0.30	0.15
11/21/2003	MFC-660	0.09	-0.13	-13.90	0.33	0.35
12/5/2003	MFC-660	0.35	0.50	-13.45	0.33	0.00
1/29/2004	MFC-660	1.00	1.41	-17.07	0.30	0.89
2/13/2004	MFC-660	0.24	0.34	-13.75	0.19	0.07

Sample Date	Location	S observed (‰)	Differences X_{ij} and X_i(‰)	Ave $\delta^{18}O$ between run 1 and 2 (‰)	S_{std} from Eq. A2	$\left(X_{ij}-\bar{X}_{ij}\right)^2$ for Eq. A4
2/26/2004	MFC-660	0.52	0.73	-15.30	0.40	0.02
5/28/2004	MFC-660	1.16	1.63	-12.75	0.18	1.06
11/29/2004	MFC-660	0.11	-0.15	-14.29	0.22	0.00
4/12/2005	MFC-660	0.66	-0.93	-12.53	0.25	0.67
4/8/2005	P 3	0.52	-0.73	-12.14	0.24	0.38
2/11/2005	P 4	0.23	0.32	-13.01	0.38	0.18
4/5/2002	P 8	0.70	0.99	-14.36	0.52	0.12
4/5/2002	P 9	0.53	0.75	-14.46	0.52	0.01
2/20/2004	P 9	0.12	0.17	-13.26	0.19	0.19
7/26/2001	Precipitation	0.04	0.05	-12.19	0.30	0.01
1/10/2002	Precipitation	0.63	0.89	-12.77	0.46	0.52
1/24/2002	Precipitation	0.17	-0.25	-12.62	0.46	0.17
1/25/2002	Precipitation	0.06	-0.09	-16.13	0.46	0.07
3/29/2002	Precipitation	0.07	-0.10	-8.51	0.36	0.00
4/26/2002	Precipitation	0.05	-0.07	-12.19	0.51	0.06
5/24/2002	Precipitation	0.09	-0.12	-12.26	0.53	0.08
6/11/2002	Precipitation	0.22	0.32	-16.35	0.53	0.02
6/25/2002	Precipitation	0.58	0.82	-14.78	0.48	0.42
7/9/2002	Precipitation	0.10	-0.14	-11.55	0.75	0.10
9/20/2002	Precipitation	0.15	-0.22	-11.86	0.61	0.42
10/16/2002	Precipitation	0.11	-0.15	-6.72	0.61	0.34
11/8/2002	Precipitation	1.05	1.48	-12.07	0.61	1.11
12/19/2002	Precipitation	0.04	-0.05	-15.74	0.61	0.24
1/10/2003	Precipitation	0.49	0.69	-16.91	0.61	0.07
1/17/2003	Precipitation	0.38	0.54	-13.38	0.65	0.01
1/31/2003	Precipitation	0.12	-0.16	-11.92	0.65	0.35
2/14/2003	Precipitation	0.03	-0.04	-14.78	0.65	0.23
3/28/2003	Precipitation	0.17	-0.24	-11.45	0.65	0.45
4/11/2003	Precipitation	1.31	1.86	-6.57	0.65	2.04
4/25/2003	Precipitation	1.23	1.73	-12.96	0.65	1.70
5/9/2003	Precipitation	0.11	-0.15	-13.58	0.65	0.34
5/23/2003	Precipitation	0.74	1.05	-14.87	0.61	0.38
6/6/2003	Precipitation	0.22	-0.31	-7.24	0.61	0.54
6/20/2003	Precipitation	0.46	0.65	-7.76	0.68	0.58
9/12/2003	Precipitation	0.05	-0.07	-9.64	0.65	0.05
9/27/2003	Precipitation	0.00	0.00	-7.77	0.65	0.02
10/13/2003	Precipitation	0.32	-0.45	-15.76	0.67	0.36
11/16/2003	Precipitation	0.08	0.11	-13.64	0.67	0.00
11/21/2003	Precipitation	0.15	-0.21	-12.08	0.67	0.13
12/5/2003	Precipitation	0.54	0.76	-15.67	0.67	0.38
12/19/2003	Precipitation	0.25	0.35	-18.06	0.67	0.04
1/9/2004	Precipitation	0.06	0.09	-17.01	0.67	0.00
1/16/2004	Precipitation	0.08	0.12	-14.18	0.65	0.00
1/29/2004	Precipitation	0.55	0.78	-17.54	0.65	0.39
1/30/2004	Precipitation	0.18	0.25	-12.60	0.65	0.01
2/13/2004	Precipitation	0.30	-0.42	-14.61	0.61	0.19

Sample Date	Location	S observed (‰)	Differences X_{ij} and X_i(‰)	Ave $\delta^{18}O$ between run 1 and 2 (‰)	S_{std} from Eq. A2	$\left(X_{ij}-\bar{X}_{ij}\right)^2$ for Eq. A4
2/24/2004	Precipitation	1.06	1.49	-13.90	0.70	2.17
2/26/2004	Precipitation	0.19	-0.27	-16.59	0.70	0.09
3/12/2004	Precipitation	0.02	-0.03	-16.23	0.70	0.00
4/9/2004	Precipitation	0.36	-0.51	-13.37	0.70	0.28
4/23/2004	Precipitation	0.45	0.64	-11.50	0.70	0.38
5/7/2004	Precipitation	0.03	-0.05	-8.60	0.61	0.00
5/21/2004	Precipitation	0.19	-0.26	-12.73	0.61	0.08
5/28/2004	Precipitation	0.30	-0.43	-10.41	0.61	0.20
6/11/2004	Precipitation	0.13	0.18	-12.02	0.61	0.03
7/23/2004	Precipitation	0.08	-0.12	-8.59	0.61	0.02
2/20/2004	SC 10	1.16	1.65	-16.17	0.40	1.09
5/31/2001	SC 11	0.29	0.41	-14.35	0.20	0.00
4/8/2005	SC 11	0.32	-0.45	-12.11	0.24	0.11
3/10/2005	SC 12	0.00	0.00	-13.66	0.25	0.01
4/8/2005	SC 12	0.66	-0.93	-13.33	0.24	0.68
5/30/2002	SC 15	0.38	0.54	-15.10	0.53	0.01
3/12/2004	SC 16	0.16	-0.22	-15.69	0.40	0.68
3/26/2004	SC 16	0.04	-0.06	-14.43	0.40	0.43
5/16/2002	SC 17	0.96	1.36	-14.64	0.53	0.52
2/20/2004	SC 17	0.46	0.65	-14.94	0.40	0.00
5/28/2004	SC 18	0.07	0.10	-13.67	0.18	0.25
3/10/2005	SC 18	0.15	-0.22	-12.96	0.25	0.01
3/26/2004	SC 3	0.03	0.05	-13.72	0.40	0.31
5/7/2004	SC 3	0.69	0.98	-13.46	0.18	0.14
2/15/2002	SC 6	0.30	0.43	-13.39	0.46	0.04
3/15/2002	SC 6	0.39	0.56	-13.49	0.52	0.01
1/30/2004	SC 6	0.31	0.44	-13.72	0.19	0.03
3/21/2001	SC 8	0.26	0.37	-12.74	0.24	0.01
1/30/2004	SC 8	0.19	0.27	-12.78	0.19	0.11
6/13/2002	SC 9	0.30	0.42	-13.82	0.48	0.05
12/13/2004	SC 9	0.09	0.13	-14.16	0.25	0.06
3/10/2005	SC 9	0.60	-0.85	-13.89	0.25	0.55
5/17/2001	SS 2	0.05	0.07	-13.52	0.20	0.16
3/26/2004	SS 2	0.55	0.78	-15.23	0.40	0.03
2/20/2004	SS 4	1.16	1.64	-16.31	0.40	1.07
3/15/2002	SS 5	0.16	-0.23	-14.91	0.52	0.75
4/5/2002	SS 5	0.66	0.94	-15.05	0.52	0.09
4/8/2005	SS 7	0.54	-0.76	-13.20	0.24	0.42
3/10/2005	SS 8	0.01	0.02	-13.15	0.25	0.02
4/8/2005	SS 8	0.40	0.56	-12.24	0.24	0.45
3/20/2001	TD-12	0.43	0.61	-14.56		
11/20/2002	TD-12	0.13	0.18	-14.13	0.19	0.12
1/17/2003	TD-12	0.59	0.83	-12.95	0.31	0.10
3/14/2003	TD-12	0.20	0.29	-13.53	0.31	0.05
3/28/2003	TD-12	0.91	1.29	-11.82	0.31	0.60
4/11/2003	TD-12	0.40	0.56	-12.47	0.31	0.00

Sample Date	Location	S observed (‰)	Differences X_{ij} and X_i(‰)	Ave $\delta^{18}O$ between run 1 and 2 (‰)	S_{std} from Eq. A2	$\left(X_{ij}-\bar{X}_{ij}\right)^2$ for Eq. A4
6/6/2003	TD-12	0.54	0.76	-13.90	0.18	0.06
8/15/2003	TD-12	0.04	0.05	-14.22	0.30	0.17
8/29/2003	TD-12	0.00	0.00	-14.43	0.30	0.21
9/12/2003	TD-12	0.45	0.63	-13.93	0.30	0.03
11/7/2003	TD-12	0.70	0.99	-14.56	0.33	0.28
1/30/2004	TD-12	0.57	0.80	-15.34	0.19	0.04
4/23/2004	TD-12	0.33	0.46	-14.18	0.18	0.02
12/13/2004	TD-12	0.48	0.68	-14.19	0.22	0.62
4/12/2005	TD-12	0.11	0.16	-13.94	0.25	0.07

APPENDIX B: Gas bench methodology and standards results

Gas Bench Methodology

The continuous flow gas bench measures the oxygen ratios in the water sample in conjunction with the Finnigan Delta S gas source isotope ratio mass spectrometer. The gas bench has a robotic sampling arm that sends the sample to the mass spectrometer. The gas bench can analyze 80 samples including standards in each run analysis. The gas bench uses glass vials with rubber septum caps that hold an airtight seal after being punctured with a needle. Each vial has 500 μL of sample or standard and capped tightly. A duplicate aliquot was made every 11th sample and later checked if they were in the accepted range of 0.2 ‰ difference; if not, additional aliquots were re-analyzed. The standards were interspaced about every 9 samples.

The gas bench is controlled by the Isotope Data (ISODAT) computer program which contains sample identifications and creates output files. After the vials are loaded into the gas bench (which remains at a constant 32°C), they are automatically injected and flushed with a helium reference gas that replaces the atmosphere in the vial and equilibrates over night. After equilibration, the atmosphere should have the same isotopic value as the water sample. The sample is analyzed for $\delta^{18}O$ using a needle that sends the sample's atmosphere to the mass spectrometer. The mass spectrometer measures the isotope ratio in a series of 16 peaks. Only peaks 5-14 are averaged to obtain a $\delta^{18}O$ value. The data are temperature corrected for the oxygen fractionation between CO_2 (gas) and H_2O (liquid) using an equation from Bottinga (1969 and corrected in 1973), which subtracts 38.775 from the averaged raw data.

A normalization of the temperature corrected oxygen isotope data was done in two ways. For samples analyzed in 2003-2004, each run was normalized to the standard WAWA 1 (Washington water-1st aliquot) by averaging the all the standards' $\delta^{18}O$ values in the run and subtracting it by its true value (-16.4780‰) then applying it to the samples in that run. Samples analyzed in 2005 were normalized to the VSMOW/SLAP scale (Coplen, 1988 and Nelson, 2000). The standards used in this processes are VSMOW, SLAP, GISP, WAWA 1, WAWA 2 (Washington water-2nd aliquot), and DIWA (deionized water). April-May 2005 only used WAWA 2 and DIWA. The standards' analyzed $\delta^{18}O$ values in an analysis run are plotted against the standards' true values and a linear regression is applied. The resulting equation is applied to normalize the temperature corrected $\delta^{18}O$ values of the run.

Table B1: Shows standards for each run date, the standard's true value, analyzed $\delta^{18}O$ value normalized, average and standard deviation of the standard's value (not normalized), and the difference between the true $\delta^{18}O$ value and the average $\delta^{18}O$ value.

Run Date	**Standard Name**	**True $\delta^{18}O$ (‰)**	**Normalized $\delta^{18}O$ (‰)**	**Average (‰)**	**Std Dev. (‰)**	**True-Ave. (‰)**
8/6/2003	WAWA1	-16.478	-16.4092	-17.0505	0.0755	0.5725
8/6/2003	WAWA1	-16.478	-16.5849	-17.0505	0.0755	0.5725
8/6/2003	WAWA1	-16.478	-16.4482	-17.0505	0.0755	0.5725
8/6/2003	WAWA1	-16.478	-16.4698	-17.0505	0.0755	0.5725
Variance for 8/6/2003 analysis run				***0.0057***		
8/7/2003	WAWA1	-16.478	-16.3861	-16.9242	0.0928	0.4462
8/7/2003	WAWA1	-16.478	-16.4971	-16.9242	0.0928	0.4462
8/7/2003	WAWA1	-16.478	-16.5992	-16.9242	0.0928	0.4462
8/7/2003	WAWA1	-16.478	-16.4297	-16.9242	0.0928	0.4462
Variance for 8/7/2003 analysis run				***0.0086***		
8/11/2003	WAWA1	-16.478	-16.5444	-17.0072	0.2543	0.5292
8/11/2003	WAWA1	-16.478	-16.4076	-17.0072	0.2543	0.5292
8/11/2003	WAWA1	-16.478	-16.3842	-17.0072	0.2543	0.5292
8/11/2003	WAWA1	-16.478	-17.0812	-17.0072	0.2543	0.5292
8/12/2003	WAWA1	-16.478	-16.3327	-17.0072	0.2543	0.5292
8/12/2003	WAWA1	-16.478	-16.3420	-17.0072	0.2543	0.5292
8/12/2003	WAWA1	-16.478	-16.4207	-17.0072	0.2543	0.5292
8/12/2003	WAWA1	-16.478	-16.3115	-17.0072	0.2543	0.5292
Variance for 8/11-12/2003 analysis run				***0.0647***		
8/13/2003	WAWA1	-16.478	-16.5125	-16.8944	0.0627	0.4164
8/14/2003	WAWA1	-16.478	-16.5294	-16.8944	0.0627	0.4164
8/14/2003	WAWA1	-16.478	-16.5063	-16.8944	0.0627	0.4164
8/14/2003	WAWA1	-16.478	-16.3984	-16.8944	0.0627	0.4164
Variance for 8/13-14/2003 analysis run				***0.0039***		
9/16/2003	WAWA1	-16.478	-16.2559	-17.1970	0.4292	0.7190
9/17/2003	WAWA1	-16.478	-16.2768	-17.1970	0.4292	0.7190
9/17/2003	WAWA1	-16.478	-16.3595	-17.1970	0.4292	0.7190
9/17/2003	WAWA1	-16.478	-16.1342	-17.1970	0.4292	0.7190
9/17/2003	WAWA1	-16.478	-16.1569	-17.1970	0.4292	0.7190
9/17/2003	WAWA1	-16.478	-16.9199	-17.1970	0.4292	0.7190
9/17/2003	WAWA1	-16.478	-17.2427	-17.1970	0.4292	0.7190
Variance for 9/16-17/2003 analysis run				***0.1842***		
9/21/2003	WAWA1	-16.478	-15.7782	-17.5212	0.4944	1.0432
9/21/2003	WAWA1	-16.478	-16.6567	-17.5212	0.4944	1.0432

Run Date	Standard Name	True $\delta^{18}O$ (‰)	Normalized $\delta^{18}O$ (‰)	Average (‰)	Std Dev. (‰)	True-Ave. (‰)
9/22/2003	WAWA1	-16.478	-15.7553	-17.5212	0.4944	1.0432
9/22/2003	WAWA1	-16.478	-16.6290	-17.5212	0.4944	1.0432
9/22/2003	WAWA1	-16.478	-16.8482	-17.5212	0.4944	1.0432
9/22/2003	WAWA1	-16.478	-16.8643	-17.5212	0.4944	1.0432
9/22/2003	WAWA1	-16.478	-16.8146	-17.5212	0.4944	1.0432
Variance for 9/21-22/2003 analysis run				***0.2444***		
9/24/2003	WAWA1	-16.478	-15.6447	-17.6974	0.4871	1.2194
9/24/2003	WAWA1	-16.478	-16.7640	-17.6974	0.4871	1.2194
9/24/2003	WAWA1	-16.478	-16.6761	-17.6974	0.4871	1.2194
9/25/2003	WAWA1	-16.478	-16.6092	-17.6974	0.4871	1.2194
9/25/2003	WAWA1	-16.478	-16.6528	-17.6974	0.4871	1.2194
9/25/2003	WAWA1	-16.478	-15.7742	-17.6974	0.4871	1.2194
9/25/2003	WAWA1	-16.478	-16.9603	-17.6974	0.4871	1.2194
9/25/2003	WAWA1	-16.478	-16.7424	-17.6974	0.4871	1.2194
Variance for 9/24-25/2003 analysis run				***0.2373***		
9/26/2003	WAWA1	-16.478	-16.0756	-17.4860	0.5072	1.0080
9/26/2003	WAWA1	-16.478	-17.0438	-17.4860	0.5072	1.0080
9/26/2003	WAWA1	-16.478	-17.0852	-17.4860	0.5072	1.0080
9/26/2003	WAWA1	-16.478	-16.0598	-17.4860	0.5072	1.0080
9/27/2003	WAWA1	-16.478	-15.9546	-17.4860	0.5072	1.0080
9/27/2003	WAWA1	-16.478	-16.5009	-17.4860	0.5072	1.0080
9/27/2003	WAWA1	-16.478	-17.0467	-17.4860	0.5072	1.0080
9/27/2003	WAWA1	-16.478	-16.0574	-17.4860	0.5072	1.0080
Variance for 9/26-27/2003 analysis run				***0.2572***		
9/30/2003	WAWA1	-16.478	-16.2061	-17.3360	0.4545	0.8580
9/30/2003	WAWA1	-16.478	-17.1215	-17.3360	0.4545	0.8580
9/30/2003	WAWA1	-16.478	-17.1768	-17.3360	0.4545	0.8580
10/1/2003	WAWA1	-16.478	-16.2660	-17.3360	0.4545	0.8580
10/1/2003	WAWA1	-16.478	-16.1470	-17.3360	0.4545	0.8580
10/1/2003	WAWA1	-16.478	-16.1089	-17.3360	0.4545	0.8580
10/1/2003	WAWA1	-16.478	-16.6871	-17.3360	0.4545	0.8580
10/1/2003	WAWA1	-16.478	-16.1103	-17.3360	0.4545	0.8580
Variance for 9/30/2003-10/1/2003 analysis run				***0.2066***		
12/18/2003	WAWA1	-16.478	-15.8426	-17.6768	0.3879	1.1988
12/18/2003	WAWA1	-16.478	-16.1551	-17.6768	0.3879	1.1988
12/19/2003	WAWA1	-16.478	-16.7084	-17.6768	0.3879	1.1988
12/19/2003	WAWA1	-16.478	-16.6624	-17.6768	0.3879	1.1988
12/19/2003	WAWA1	-16.478	-16.6800	-17.6768	0.3879	1.1988

Run Date	Standard Name	True $\delta^{18}O$ (‰)	Normalized $\delta^{18}O$ (‰)	Average (‰)	Std Dev. (‰)	True-Ave. (‰)
12/19/2003	WAWA1	-16.478	-16.8195	-17.6768	0.3879	1.1988
Variance for 12/18-19/2003 analysis run				***0.1505***		
2/4/2004	WAWA1	-16.478	-16.2579	-16.2392	0.1670	-0.2388
2/4/2004	WAWA1	-16.478	-16.5946	-16.2392	0.1670	-0.2388
2/4/2004	WAWA1	-16.478	-16.6045	-16.2392	0.1670	-0.2388
2/5/2004	WAWA1	-16.478	-16.4549	-16.2392	0.1670	-0.2388
2/5/2004	WAWA1	-16.478	-16.5856	-16.2392	0.1670	-0.2388
2/5/2004	WAWA1	-16.478	-16.2354	-16.2392	0.1670	-0.2388
2/5/2004	WAWA1	-16.478	-16.6134	-16.2392	0.1670	-0.2388
Variance for 2/4-5/2004 analysis run				***0.0279***		
2/6/2004	WAWA1	-16.478	-16.6092	-16.1985	0.1169	-0.2795
2/6/2004	WAWA1	-16.478	-16.3464	-16.1985	0.1169	-0.2795
2/6/2004	WAWA1	-16.478	-16.4409	-16.1985	0.1169	-0.2795
2/7/2004	WAWA1	-16.478	-16.3509	-16.1985	0.1169	-0.2795
2/7/2004	WAWA1	-16.478	-16.3893	-16.1985	0.1169	-0.2795
2/7/2004	WAWA1	-16.478	-16.4647	-16.1985	0.1169	-0.2795
2/7/2004	WAWA1	-16.478	-16.6103	-16.1985	0.1169	-0.2795
2/7/2004	WAWA1	-16.478	-16.6123	-16.1985	0.1169	-0.2795
Variance for 2/6-7/2004 analysis run				***0.0137***		
2/10/2004	WAWA1	-16.478	-16.4019	-16.4806	0.2465	0.0026
2/10/2004	WAWA1	-16.478	-18.2032	-16.4806	0.2465	0.0026
2/10/2004	WAWA1	-16.478	-16.7761	-16.4806	0.2465	0.0026
2/11/2004	WAWA1	-16.478	-16.3386	-16.4806	0.2465	0.0026
2/11/2004	WAWA1	-16.478	-16.3070	-16.4806	0.2465	0.0026
2/11/2004	WAWA1	-16.478	-16.2680	-16.4806	0.2465	0.0026
2/11/2004	WAWA1	-16.478	-16.3695	-16.4806	0.2465	0.0026
2/11/2004	WAWA1	-16.478	-16.8847	-16.4806	0.2465	0.0026
Variance for 2/10-11/2004 analysis run				***0.0608***		
2/12/2004	WAWA1	-16.478	-16.1880	-16.6119	0.2850	0.1339
2/12/2004	WAWA1	-16.478	-16.7870	-16.6119	0.2850	0.1339
2/12/2004	WAWA1	-16.478	-16.3248	-16.6119	0.2850	0.1339
2/12/2004	WAWA1	-16.478	-16.1171	-16.6119	0.2850	0.1339
2/13/2004	WAWA1	-16.478	-16.2485	-16.6119	0.2850	0.1339
2/13/2004	WAWA1	-16.478	-16.7539	-16.6119	0.2850	0.1339
2/13/2004	WAWA1	-16.478	-16.7558	-16.6119	0.2850	0.1339
2/13/2004	WAWA1	-16.478	-16.6491	-16.6119	0.2850	0.1339
Variance for 2/12-13/2004 analysis run				***0.0812***		
2/14/2004	WAWA1	-16.478	-16.1689	-16.6827	0.2473	0.2047

Run Date	Standard Name	True δ18O (‰)	Normalized δ18O (‰)	Average (‰)	Std Dev. (‰)	True-Ave. (‰)
2/14/2004	WAWA1	-16.478	-16.3785	-16.6827	0.2473	0.2047
2/14/2004	WAWA1	-16.478	-16.5580	-16.6827	0.2473	0.2047
2/14/2004	WAWA1	-16.478	-16.6740	-16.6827	0.2473	0.2047
2/15/2004	WAWA1	-16.478	-16.7212	-16.6827	0.2473	0.2047
2/15/2004	WAWA1	-16.478	-16.6976	-16.6827	0.2473	0.2047
2/15/2004	WAWA1	-16.478	-16.1475	-16.6827	0.2473	0.2047
Variance for 2/14-15/2004 analysis run				***0.0611***		
7/26/2004	WAWA1	-16.478	-16.5135	-16.6766	0.0961	0.1985
7/26/2004	WAWA1	-16.478	-16.3780	-16.6766	0.0961	0.1985
7/26/2004	WAWA1	-16.478	-16.4804	-16.6766	0.0961	0.1985
7/26/2004	WAWA1	-16.478	-16.4258	-16.6766	0.0961	0.1985
7/26/2004	WAWA1	-16.478	-16.4170	-16.6766	0.0961	0.1985
7/26/2004	WAWA1	-16.478	-16.6929	-16.6766	0.0961	0.1985
7/27/2004	WAWA1	-16.478	-16.4560	-16.6766	0.0961	0.1985
7/27/2004	WAWA1	-16.478	-16.4608	-16.6766	0.0961	0.1985
Variance for 7/26-27/2004 analysis run				***0.0092***		
7/28/2004	WAWA1	-16.478	-16.2787	-16.8305	0.3658	0.3524
7/28/2004	WAWA1	-16.478	-16.2354	-16.8305	0.3658	0.3524
7/28/2004	WAWA1	-16.478	-16.2378	-16.8305	0.3658	0.3524
7/28/2004	WAWA1	-16.478	-16.2742	-16.8305	0.3658	0.3524
7/29/2004	WAWA1	-16.478	-16.9496	-16.8305	0.3658	0.3524
7/29/2004	WAWA1	-16.478	-17.1695	-16.8305	0.3658	0.3524
7/29/2004	WAWA1	-16.478	-16.3393	-16.8305	0.3658	0.3524
7/29/2004	WAWA1	-16.478	-16.3399	-16.8305	0.3658	0.3524
Variance for 7/28-29/2004 analysis run				***0.1338***		
7/29/2004	WAWA1	-16.478	-16.7210	-16.6807	0.1135	0.2027
7/30/2004	WAWA1	-16.478	-16.4725	-16.6807	0.1135	0.2027
7/30/2004	WAWA1	-16.478	-16.4583	-16.6807	0.1135	0.2027
7/30/2004	WAWA1	-16.478	-16.4908	-16.6807	0.1135	0.2027
7/30/2004	WAWA1	-16.478	-16.3887	-16.6807	0.1135	0.2027
7/30/2004	WAWA1	-16.478	-16.3341	-16.6807	0.1135	0.2027
7/30/2004	WAWA1	-16.478	-16.5099	-16.6807	0.1135	0.2027
7/30/2004	WAWA1	-16.478	-16.4486	-16.6807	0.1135	0.2027
Variance for 7/29-30/2004 analysis run				***0.0129***		
8/2/2004	WAWA1	-16.478	-16.4301	-16.5933	0.0678	0.1153
8/2/2004	WAWA1	-16.478	-16.4831	-16.5933	0.0678	0.1153
8/2/2004	WAWA1	-16.478	-16.4488	-16.5933	0.0678	0.1153
8/2/2004	WAWA1	-16.478	-16.4672	-16.5933	0.0678	0.1153

Run Date	Standard Name	True $\delta^{18}O$ (‰)	Normalized $\delta^{18}O$ (‰)	Average (‰)	Std Dev. (‰)	True-Ave. (‰)
8/2/2004	WAWA1	-16.478	-16.5027	-16.5933	0.0678	0.1153
8/2/2004	WAWA1	-16.478	-16.6119	-16.5933	0.0678	0.1153
8/2/2004	WAWA1	-16.478	-16.4020	-16.5933	0.0678	0.1153
Variance for 8/2/2004 analysis run				***0.0046***		
8/3/2004	WAWA1	-16.478	-16.7843	-16.6016	0.0658	-0.1236
8/3/2004	WAWA1	-16.478	-16.8016	-16.6016	0.0658	-0.1236
8/3/2004	WAWA1	-16.478	-16.6542	-16.6016	0.0658	-0.1236
8/3/2004	WAWA1	-16.478	-16.7703	-16.6016	0.0658	-0.1236
8/3/2004	WAWA1	-16.478	-16.6517	-16.6016	0.0658	-0.1236
8/3/2004	WAWA1	-16.478	-16.7489	-16.6016	0.0658	-0.1236
8/3/2004	WAWA1	-16.478	-16.6652	-16.6016	0.0658	-0.1236
Variance for 8/3/2004 analysis run				***0.0043***		
4/18/2005	WAWA2	-16.6714	-16.6714	-17.0338	-	0.3624
4/18/2005	WAWA2	-16.6714	-16.7872	-16.6675	0.1637	-0.0040
4/18/2005	WAWA2	-16.6714	-16.5557	-16.6675	0.1637	-0.0040
Variance for 4/18/2005 analysis run				***0.0268***		
4/18/2005	WAWA2	-16.6714	-17.1460	-16.3501	0.6024	-0.3213
4/18/2005	WAWA2	-16.6714	-15.7943	-16.3501	0.6024	-0.3213
4/18/2005	WAWA2	-16.6714	-16.7910	-16.3501	0.6024	-0.3213
4/19/2005	WAWA2	-16.6714	-16.9542	-16.3501	0.6024	-0.3213
Variance for 4/18/2005 analysis run				***0.3629***		
4/20/2005	WAWA2	-16.6714	-16.8637	-16.8050	0.1568	0.1336
4/20/2005	DIWA	-18.8742	-18.9606	-18.9021	0.1375	0.0279
4/20/2005	WAWA2	-16.6714	-16.4897	-16.8050	0.1568	0.1336
4/20/2005	DIWA	-18.8742	-18.9932	-18.9021	0.1375	0.0279
4/20/2005	WAWA2	-16.6714	-16.7413	-16.8050	0.1568	0.1336
4/20/2005	DIWA	-18.8742	-18.6719	-18.9021	0.1375	0.0279
4/21/2005	WAWA2	-16.6714	-16.5908	-16.8050	0.1568	0.1336
4/21/2005	DIWA	-18.8742	-18.8710	-18.9021	0.1375	0.0279
Variance for 4/20-21/2005 analysis run				***0.0217***		
4/22/2005	WAWA2	-16.6714	-16.9224	-16.8861	0.1813	0.2147
4/22/2005	DIWA	-18.8742	-18.9268	-18.9226	0.1451	0.0484
4/22/2005	WAWA2	-16.6714	-16.6430	-16.8861	0.1813	0.2147
4/22/2005	DIWA	-18.8742	-18.8456	-18.9226	0.1451	0.0484
4/22/2005	WAWA2	-16.6714	-16.4443	-16.8861	0.1813	0.2147
4/22/2005	DIWA	-18.8742	-19.0473	-18.9226	0.1451	0.0484
4/23/2005	WAWA2	-16.6714	-16.6726	-16.8861	0.1813	0.2147

Run Date	Standard Name	True $\delta^{18}O$ (‰)	Normalized $\delta^{18}O$ (‰)	Average (‰)	Std Dev. (‰)	True-Ave. (‰)
4/23/2005	DIWA	-18.8742	-18.6734	-18.9226	0.1451	0.0484
Variance for 4/22-23/2005 analysis run			***0.0329***			
4/24/2005	WAWA2	-16.6714	-16.9675	-16.7108	0.4672	0.0393
4/25/2005	DIWA	-18.8742	-18.9824	-19.0588	0.1082	0.1846
4/25/2005	WAWA2	-16.6714	-16.0201	-16.7108	0.4672	0.0393
4/25/2005	DIWA	-18.8742	-18.8418	-19.0588	0.1082	0.1846
4/25/2005	WAWA2	-16.6714	-16.8684	-16.7108	0.4672	0.0393
4/25/2005	DIWA	-18.8742	-18.7497	-19.0588	0.1082	0.1846
4/25/2005	WAWA2	-16.6714	-16.8320	-16.7108	0.4672	0.0393
4/25/2005	DIWA	-18.8742	-18.9257	-19.0588	0.1082	0.1846
Variance for 4/24-25/2005 analysis run			***0.1150***			
4/26/2005	WAWA2	-16.6714	-16.9387	-16.8888	0.1713	0.2174
4/26/2005	DIWA	-18.8742	-18.9848	-18.9299	0.1890	0.0557
4/26/2005	WAWA2	-16.6714	-16.5291	-16.8888	0.1713	0.2174
4/26/2005	DIWA	-18.8742	-18.6724	-18.9299	0.1890	0.0557
4/26/2005	WAWA2	-16.6714	-16.6458	-16.8888	0.1713	0.2174
4/26/2005	DIWA	-18.8742	-19.1032	-18.9299	0.1890	0.0557
4/27/2005	WAWA2	-16.6714	-16.5706	-16.8888	0.1713	0.2174
4/27/2005	DIWA	-18.8742	-18.7350	-18.9299	0.1890	0.0557
Variance for 4/26-27/2005 analysis run			***0.0325***			
4/28/2005	WAWA2	-16.6714	-16.6715	-17.1547	-	0.4833
4/28/2005	DIWA	-18.8742	-18.8743	-19.1273	-	0.2531
4/28/2005	WAWA2	-16.6714	-16.8643	-16.9059	0.1443	0.2345
4/28/2005	DIWA	-18.8742	-18.8264	-18.8108	0.2077	-0.0634
4/28/2005	WAWA2	-16.6714	-16.5723	-16.9059	0.1443	0.2345
4/28/2005	DIWA	-18.8742	-19.1352	-18.8108	0.2077	-0.0634
4/29/2005	WAWA2	-16.6714	-16.5784	-16.9059	0.1443	0.2345
4/29/2005	DIWA	-18.8742	-18.6620	-18.8108	0.2077	-0.0634
Variance for 4/28-29/2005 analysis run			***0.0320***			
5/1/2005	WAWA2	-16.6714	-16.3747	-16.8900	0.4036	0.2186
5/1/2005	DIWA	-18.8742	-18.8069	-19.0043	0.0923	0.1301
5/1/2005	WAWA2	-16.6714	-16.9694	-16.8900	0.4036	0.2186
5/1/2005	DIWA	-18.8742	-18.9430	-19.0043	0.0923	0.1301
Variance for 5/1/2005 analysis run			***0.0857***			
7/12/2005	DIWA	-18.8742	-19.0498	-19.0355	0.3572	0.1613
7/12/2005	WAWA1	-16.478	-16.5639	-16.6896	0.2112	0.2116
7/12/2005	WAWA2	-16.6714	-16.9308	-16.7819	0.5503	0.1105

Run Date	Standard Name	True $\delta^{18}O$ (‰)	Normalized $\delta^{18}O$ (‰)	Average (‰)	Std Dev. (‰)	True-Ave. (‰)
7/12/2005	GISP	-24.78	-24.8633	-25.1939	0.1379	0.4139
7/12/2005	SLAP	-55.5	-55.2576	-55.6986	0.3326	0.1986
7/12/2005	VSMOW	0	0.0015	-0.3193	0.0924	0.3193
7/13/2005	SLAP	-55.5	-55.7284	-55.6986	0.3326	0.1986
7/13/2005	DIWA	-18.8742	-18.5441	-19.0355	0.3572	0.1613
7/13/2005	WAWA1	-16.478	-16.2050	-16.6896	0.2112	0.2116
7/13/2005	WAWA1	-16.478	-16.5779	-16.6896	0.2112	0.2116
7/13/2005	WAWA2	-16.6714	-16.1519	-16.7819	0.5503	0.1105
7/13/2005	GISP	-24.78	-25.0585	-25.1939	0.1379	0.4139
7/13/2005	VSMOW	0	-0.1293	-0.3193	0.0924	0.3193
Variance for 7/12-13/2005 analysis run				***0.1022***		
7/26/2005	DIWA	-18.8742	-18.3815	-18.8564	-	-0.0178
7/26/2005	WAWA1	-16.478	-16.2270	-16.7796	0.1324	0.3016
7/26/2005	WAWA2	-16.6714	-16.3794	-16.9805	0.1993	0.3090
7/26/2005	SLAP	-55.5	-55.3622	-56.1090	-	0.6090
7/27/2005	GISP	-24.78	-25.6307	-26.1589	-	1.3789
7/27/2005	VSMOW	0	-0.0910	-0.4313	-	0.4313
7/27/2005	WAWA1	-16.478	-16.4128	-16.7796	0.1324	0.3016
7/27/2005	WAWA2	-16.6714	-16.6592	-16.9805	0.1993	0.3090
Variance for 7/26-27/2005 analysis run				***0.0286***		
7/28/2005	DIWA	-18.8742	-18.8434	-19.2607	0.0003	0.3865
7/28/2005	WAWA1	-16.478	-16.4319	-16.8491	0.0976	0.3711
7/28/2005	WAWA2	-16.6714	-16.7977	-17.2478	0.0954	0.5764
7/28/2005	SLAP	-55.5	-55.1886	-55.7033	0.3677	0.2033
7/28/2005	GISP	-24.78	-24.7849	-25.2481	0.1022	0.4680
7/28/2005	VSMOW	0	0.0638	-0.4177	0.0292	0.4177
7/29/2005	DIWA	-18.8742	-18.8430	-19.2607	0.0003	0.3865
7/29/2005	SLAP	-55.5	-55.7109	-55.7033	0.3677	0.2033
7/29/2005	GISP	-24.78	-24.9300	-25.2481	0.1022	0.4680
7/29/2005	VSMOW	0	0.1053	-0.4177	0.0292	0.4177
7/29/2005	WAWA1	-16.478	-16.3176	-16.8491	0.0976	0.3711
7/29/2005	WAWA1	-16.478	-16.5126	-16.8491	0.0976	0.3711
7/29/2005	WAWA2	-16.6714	-16.9266	-17.2478	0.0954	0.5764
7/29/2005	WAWA2	-16.6714	-16.7393	-17.2478	0.0954	0.5764
Variance for 7/28-29/2005 analysis run				***0.0275***		

APPENDIX C: Precipitation amounts and air temperatures

Table C1: Consists of monthly sums of precipitation (mm), volume-weighted $\delta^{18}O$ (‰) of precipitation, monthly average, min, max, and standard deviation of air temperatures (°C). The data logger did not record any precipitation or air temperature measurements for the months Oct-00, Nov-00, and Apr-02 to Oct-02; therefore used the National Atmospheric Deposition Program (NADP) located in Albion, WA for the precipitation amount.

	Precipitation	$\delta^{18}O$	Air Temp (°C)			
Month	**(mm)**	**(‰)**	**Ave**	**Min**	**Max**	**Std Dev**
Oct-00	27.70		Start of data collection, precipitation amount taken from NADP website			
Nov-00	40.20					
Dec-00	30.73		-3.19	-25.08	2.79	5.89
Jan-01	29.46		-1.37	-13.93	6.65	3.45
Feb-01	30.23		-1.21	-11.91	6.49	3.49
Mar-01	36.83		4.27	-5.12	18.46	4.45
Apr-01	61.72		5.99	-5.32	23.80	5.68
May-01	25.15		12.09	-3.17	31.35	6.84
Jun-01	32.77		12.71	0.32	28.71	6.11
Jul-01	11.68	-12.4370	17.18	3.57	33.37	7.05
Aug-01	1.52		17.70	0.94	36.34	8.72
Sep-01	8.13		13.83	-4.49	35.93	8.33
Oct-01	55.63		7.30	-3.93	28.30	4.33
Nov-01	81.54		3.62	-8.52	16.17	4.42
Dec-01	44.70		-1.34	-10.82	5.06	3.20
Jan-02	67.31	-15.5456	-0.87	-14.60	9.43	4.03
Feb-02	42.42		-0.15	-10.62	10.02	4.00
Mar-02	52.58		2.31	-10.10	16.66	4.63
Apr-02	26.67	-12.1654	6.57	-5.94	18.11	4.68
May-02	18.80	-13.3126	11.50	-3.43	36.19	7.45
Jun-02	41.91	-15.6875	13.93	-1.28	32.79	7.31
Jul-02	3.90	-11.4746	Data logger malfunction, precipitation amount taken from NADP website to use in monthly volume weighted $\delta^{18}O$ values			
Aug-02	10.20					
Sep-02	9.90	-11.7513				
Oct-02	17.30	-11.1175				
Nov-02	21.34	-14.2981	3.68	-7.06	13.92	4.28
Dec-02	62.48	-16.2465	1.03	-5.99	11.18	3.05
Jan-03	134.87	-12.8896	2.20	-4.62	12.18	3.44
Feb-03	34.80	-12.3817	0.66	-11.11	8.57	3.48
Mar-03	101.35	-11.3104	4.51	-11.38	19.41	4.60
Apr-03	30.23	-12.2572	6.76	-3.43	19.52	4.72
May-03	28.19	-11.8184	10.45	-3.86	30.70	6.21
Jun-03	3.56	-8.0818	14.60	0.39	31.47	7.10
Jul-03	1.78		18.92	1.05	35.98	9.25
Aug-03	13.97		18.02	1.84	34.63	8.05
Sep-03	19.05	-9.2445	13.72	-2.03	34.21	7.94
Oct-03	18.29	-15.5343	9.21	-12.61	28.37	7.69
Nov-03	48.77	-14.2375	0.30	-18.01	12.95	5.40
Dec-03	69.34	-16.9960	0.51	-14.22	6.64	3.21

	Precipitation	$\delta^{18}O$	Air Temp (°C)			
Month	(mm)	(‰)	Ave	Min	Max	Std Dev
Jan-04	61.72	-17.1731	-1.39	-31.10	8.57	6.02
Feb-04	41.40	-14.6210	0.54	-9.86	10.67	3.39
Mar-04	27.94	-14.8010	5.69	-4.48	22.99	5.45
Apr-04	14.73	-11.5257	8.37	-4.12	23.72	5.72
May-04	66.80	-11.3708	10.56	-1.81	23.66	4.84
Jun-04	11.94	-12.1155	15.03	-0.13	37.01	7.33
Jul-04	4.83	-8.5318	18.39	0.82	35.26	8.25
Aug-04	34.04	-8.1422	22.79	3.05	45.20	8.93
Sep-04	41.91	-9.1894	12.36	-0.19	27.55	6.23
Oct-04	40.64	-13.3759	9.52	-1.23	24.68	5.94
Nov-04	30.73	-12.2633	2.95	-7.83	25.82	4.97
Dec-04	28.45	-16.2690	2.18	-9.30	13.80	4.02
Jan-05	26.92	-12.4684	6.56	-6.00	19.14	4.43
Feb-05	4.06	-9.6562	3.78	-6.80	19.93	7.48
Mar-05	55.12	-11.8311	4.99	-9.73	18.62	4.84

APPENDIX D: Model methodology

Model Methodology

The program used to implement the models was created by Dr. Jerry Fairley. Dr. Fairley wrote the code in UNIX where I was able to enter in the models parameters (mean residence time, fitting parameter, and dispersion parameter). The number of data points the program uses has to be an integer power of two. The precipitation record has 36 months, but when modeled, the results increased significantly at the tail end of the data set. Therefore, it needed more data points at the end of the input record. The input function (δ_{in}) was assigned 28 more data points after the last month (average of input function values) for a total of 64 data points.

The precipitation record has 3 months that did not have any $\delta^{18}O$ analyzed due to the lack of rainfall during the dry seasons. If no data were entered then the program assumes a value of zero, which is considered enriched in $\delta^{18}O$; therefore, the averages from the months before and after were entered into months with the blanks. The resulting models showed extreme enrichment in the dry months. Since there could be some false enrichment in the precipitation due to delayed sample collection (see section 2.4), the months of June-September 2003 and July-September 2004 were replaced by the average of the input function (Table D1).

The monthly recharge factor (α) in the input function was calculated by shifting the discharge back 2 months (Table D1). The recharge factor was also calculated for no shifting between discharge and precipitation, discharge shifting back 1 month, and a constant value of 0.25. The discharge shifted 2 months back provided better fits to the data. Figure D1 shows the discharge lagging behind the precipitation about 2 months.

Table D1: Monthly α and input values with the gray values being the input function $\delta^{18}O$ average. The 28 data points after March 2005 were assigned 14.2534‰.

Month	α (Q_{i-2}/P_i)	δ_{in} (‰)
Apr-02	0.13	-13.3709
May-02	0.02	-14.4056
Jun-02	0.00	-14.4629
Jul-02	0.31	-13.9776
Aug-02	0.18	-14.2534
Sep-02	0.17	-13.8730
Oct-02	0.12	-13.5737
Nov-02	0.69	-14.1016
Dec-02	0.29	-18.7534
Jan-03	0.20	-8.9084
Feb-03	0.60	-8.6579
Mar-03	0.08	-11.0569
Apr-03	0.06	-13.9491
May-03	0.00	-14.4312
Jun-03	0.18	-14.2534
Jul-03	0.65	-14.2534
Aug-03	0.10	-14.2534
Sep-03	0.09	-14.2534
Oct-03	0.17	-14.9019
Nov-03	0.56	-13.6338
Dec-03	0.60	-28.5615
Jan-04	0.31	-21.3937
Feb-04	0.31	-14.7326
Mar-04	0.50	-15.0890
Apr-04	0.39	-12.2011
May-04	0.01	-14.1200
Jun-04	0.03	-14.3455
Jul-04	0.26	-14.2534
Aug-04	0.04	-14.2534
Sep-04	0.06	-14.2534
Oct-04	0.08	-13.9648
Nov-04	0.29	-11.8985
Dec-04	0.10	-15.1529
Jan-05	0.17	-13.2394
Feb-05	1.81	-9.7557
Mar-05	0.10	-12.5819

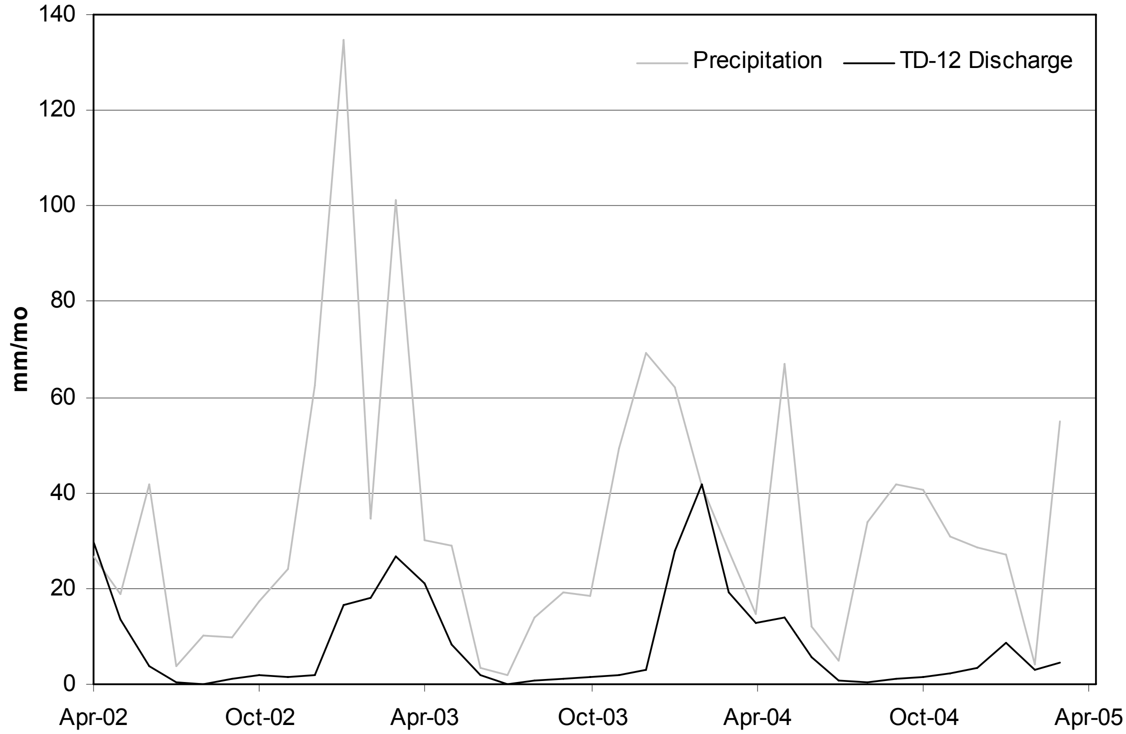

Figure D1: Monthly precipitation and TD-12 discharge amounts in mm.

APPENDIX E: Runoff to precipitation ratios

Precipitation (In)	mm/year
Oct-00 to Sep-01	336
Oct-01 to Sep-02	454
Oct-02 to Sep-03	472
Oct-03 to Sep-04	420
Total: Oct-00 to Sep-04	1682

TD-12 (Out)	mm/year
Oct-00 to Sep-01	51
Oct-01 to Sep-02	262
Oct-02 to Sep-03	99
Oct-03 to Sep-04	130
Total: Oct-00 to Sep-04	543

TD-12	Out/In
Oct-00 to Sep-01	0.15
Oct-01 to Sep-02	0.58
Oct-02 to Sep-03	0.21
Oct-03 to Sep-04	0.31
Total: Oct00-Sep04	0.32

MFC-660 (Out)	mm/year
Oct-00 to Sep-01	72
Oct-01 to Sep-02	95
Oct-02 to Sep-03	67
Oct-03 to Sep-04	124
Total: Oct-00 to Sep-04	358

MFC-660	Out/In
Oct-00 to Sep-01	0.21
Oct-01 to Sep-02	0.21
Oct-02 to Sep-03	0.14
Oct-03 to Sep-04	0.30
Total: Oct-00 to Sep-04	0.21

MFC-4700 (Out)	mm/year
Oct-00 to Sep-01	33
Oct-01 to Sep-02	149
Oct-02 to Sep-03	186
Oct-03 to Sep-04	204
Total: Oct-00 to Sep-04	571

MFC-4700	Out/In
Oct-00 to Sep-01	0.10
Oct-01 to Sep-02	0.33
Oct-02 to Sep-03	0.39
Oct-03 to Sep-04	0.49
Total: Oct-00 to Sep-04	0.34

Runoff to precipitation ratios were calculated by dividing the sampling station discharge (output) from the precipitation amount (input). The sampling stations for the calculations are TD-12, MFC-660, and MFC-4700. MFC-5700 data was too unreliable because of data logger malfunctions.

APPENDIX F: $\delta^{18}O$ data for Missouri Flat Creek sampling locations

Sample Location	Sample Date	Run Analysis Date	$\delta^{18}O$ (‰)
ES-6	2/5/2001	-	-15.6291
ES-6	2/6/2001	-	-15.7078
ES-6	2/19/2001	-	-16.8518
ES-6	3/3/2001	8/6/2003	-13.9411
ES-6	3/20/2001	-	-12.5921
ES-6	4/12/2001	-	-14.5008
ES-6	5/2/2001	-	-12.6887
ES-6	1/7/2002	-	-16.2732
ES-6	1/9/2002	-	-15.9585
ES-6	1/25/2002	8/6/2003	-15.6083
ES-6	1/26/2002	-	-15.8792
ES-6	1/27/2002	-	-16.0241
ES-6	1/29/2002	-	-17.2872
ES-6	2/8/2002	-	-16.4885
ES-6	2/22/2002	-	-16.1537
ES-6	3/8/2002	-	-16.2994
ES-6	3/11/2002	-	-14.9895
ES-6	3/29/2002	-	-15.4465
ES-6	4/12/2002	-	-13.7188
ES-6	4/26/2002	-	-13.6169
ES-6	4/27/2002	-	-13.6655
ES-6	5/10/2002	-	-13.6844
ES-6	1/31/2003	3/11/2003	-11.4323
ES-6	2/14/2003	3/11/2003	-15.1191
ES-6	3/14/2003	3/11/2003	-13.0195
ES-6	3/28/2003	3/12/2003	-11.0884
ES-6	4/11/2003	3/12/2003	-9.5290
ES-6	4/25/2003	3/12/2003	-13.5469
ES-6	1/29/2004	2/15/2004	-18.7552
ES-6	1/29/2004	2/15/2004	-17.7473
ES-6	1/30/2004	7/26/2004	-16.9998
ES-6	2/13/2004	7/29/2004	-15.5551
ES-6	2/24/2004	7/28/2004	-15.1540
ES-6	2/26/2004	7/29/2004	-15.4719
ES-6	3/12/2004	7/29/2004	-15.1493
ES-6	3/26/2004	7/30/2004	-13.7636

Sample Location	**Sample Date**	**Run Analysis Date**	**$\delta^{18}O$ (‰)**
ES-6	4/9/2004	7/30/2004	-13.1611
ES-6	4/23/2004	7/30/2004	-13.8842
ES-6	5/28/2004	8/2/2004	-12.6171
ES-6	2/11/2005	4/26/2005	-11.9334
ES-106	1/9/2001	-	-15.3279
ES-106	2/19/2001	-	-16.9165
ES-106	3/2/2001	-	-15.6178
ES-106	3/20/2001	-	-13.0053
ES-106	4/9/2001	-	-13.0589
ES-106	5/2/2001	-	-13.1639
ES-106	5/17/2001	-	-12.1641
ES-106		-	
ES-106	1/24/2002	-	-14.5316
ES-106	1/25/2002	-	-16.0626
ES-106	1/26/2002	-	-16.0495
ES-106	1/27/2002	-	-15.8111
ES-106	1/29/2002	-	-15.5210
ES-106	2/22/2002	8/6/2003	-14.8716
ES-106	3/8/2002	-	-14.9744
ES-106	3/11/2002	-	-14.9307
ES-106	3/12/2002	-	-14.4527
ES-106	3/29/2002	-	-14.6596
ES-106	4/12/2002	-	-14.1431
ES-106	4/26/2002	-	-14.0329
ES-106	4/27/2002	-	-14.0324
ES-106	5/10/2002	-	-14.0351
ES-106	5/24/2002	-	-13.3403
ES-106	5/28/2002	8/6/2003	-3.5037
ES-106	6/11/2002	-	-12.9184
ES-106	12/19/2002	2/13/2004	-13.9257
ES-106	1/31/2003	3/11/2003	-12.2987
ES-106	2/14/2003	3/11/2003	-14.2990
ES-106	2/28/2003	3/11/2003	-14.1026
ES-106	3/14/2003	3/11/2003	-13.7530
ES-106	3/28/2003	3/12/2003	-11.3439
ES-106	4/11/2003	3/12/2003	-12.5358
ES-106	4/25/2003	3/12/2003	-13.3854
ES-106	5/9/2003	3/12/2003	-13.6801

Sample Location	Sample Date	Run Analysis Date	$\delta^{18}O$ (‰)
ES-106	5/23/2003	8/13/2003	-13.7767
ES-106	12/22/2003	2/13/2004	-14.4440
ES-106	12/25/2003	2/13/2004	-15.1136
ES-106	1/11/2004	2/14/2004	-18.0392
ES-106	1/12/2004	2/14/2004	-18.2776
ES-106	1/16/2004	2/14/2004	-16.7748
ES-106	1/19/2004	2/15/2004	-16.2036
ES-106	1/29/2004	2/15/2004	-18.0425
ES-106	1/30/2004	7/26/2004	-16.5053
ES-106	2/13/2004	7/26/2004	-14.8090
ES-106	2/24/2004	7/28/2004	-15.5186
ES-106	2/26/2004	7/29/2004	-15.1681
ES-106	2/27/2004	7/29/2004	-15.2214
ES-106	3/12/2004	7/29/2004	-14.9178
ES-106	3/26/2004	7/30/2004	-14.1415
ES-106	4/9/2004	7/30/2004	-14.0591
ES-106	4/23/2004	7/30/2004	-14.3875
ES-106	5/7/2004	8/2/2004	-13.0379
ES-106	5/21/2004	8/2/2004	-13.0378
ES-106	5/28/2004	8/2/2004	-12.9875
ES-106	6/11/2004	8/2/2004	-12.8460
ES-106	12/13/2004	4/21/2005	-12.6126
ES-106	1/28/2005	4/25/2005	-13.3287
ES-106	2/11/2005	4/26/2005	-12.0036
ES-106	3/23/2005	4/26/2005	-12.7532
ES-106	3/29/2005	4/26/2005	-13.8021
ES-106	4/8/2005	4/28/2005	-12.0960
ES-106	4/12/2005	4/28/2005	-10.9403
TD-12	1/9/2001	-	-14.9306
TD-12	2/2/2001	-	-15.8868
TD-12	2/6/2001	-	-15.8564
TD-12	2/19/2001	-	-14.8805
TD-12	3/2/2001	-	-14.9315
TD-12	3/20/2001	-	-14.8633
TD-12	4/9/2001	-	-15.6162
TD-12	4/16/2001	-	-14.9935
TD-12	5/21/2001	-	-15.5540
TD-12	5/30/2001	-	-16.0558

Sample Location	**Sample Date**	**Run Analysis Date**	**$\delta^{18}O$ (‰)**
TD-12	10/13/2001	-	-15.0329
TD-12	10/24/2001	2/10/2004	-14.2452
TD-12	11/7/2001	-	-15.7095
TD-12	11/30/2001	-	-14.8777
TD-12	12/14/2001	-	-14.7937
TD-12	1/9/2002	-	-14.7235
TD-12	1/25/2002	-	-15.5091
TD-12	1/26/2002	-	-15.4862
TD-12	1/27/2002	-	-14.9005
TD-12	1/29/2002	-	-14.8855
TD-12	2/8/2002	-	-15.2218
TD-12	2/22/2002	-	-15.2772
TD-12	2/24/2002	-	-15.0678
TD-12	3/8/2002	-	-14.9787
TD-12	3/11/2002	-	-14.7607
TD-12	3/12/2002	-	-16.0500
TD-12	3/29/2002	-	-16.0622
TD-12	4/12/2002	-	-15.8832
TD-12	4/26/2002	-	-15.7651
TD-12	4/27/2002	-	-15.6763
TD-12	5/10/2002	-	-14.8735
TD-12	5/24/2002	-	-14.8550
TD-12	5/28/2002	-	-14.6730
TD-12	6/11/2002	-	-14.8823
TD-12	6/25/2002	-	-14.9108
TD-12	7/9/2002	-	-14.9690
TD-12	7/25/2002	12/4/2003	-14.6100
TD-12	9/20/2002	8/6/2003	-14.5470
TD-12	10/16/2002	8/7/2003	-14.4362
TD-12	11/8/2002	8/7/2003	-14.1259
TD-12	11/20/2002	8/7/2003	-14.2219
TD-12	12/4/2002	8/7/2003	-14.3416
TD-12	12/19/2002	8/7/2003	-14.3687
TD-12	1/10/2003	8/7/2003	-14.5713
TD-12	1/17/2003	8/11/2003	-13.3625
TD-12	1/31/2003	8/11/2003	-14.3280
TD-12	2/14/2003	8/11/2003	-14.0818
TD-12	2/28/2003	8/11/2003	-13.9340

Sample Location	Sample Date	Run Analysis Date	$\delta^{18}O$ (‰)
TD-12	3/14/2003	8/11/2003	-13.6772
TD-12	3/28/2003	8/12/2003	-12.4662
TD-12	4/11/2003	8/12/2003	-12.7455
TD-12	4/25/2003	8/12/2003	-14.0499
TD-12	5/9/2003	8/12/2003	-14.1751
TD-12	5/23/2003	8/13/2003	-14.2446
TD-12	6/6/2003	8/13/2003	-14.2798
TD-12	6/20/2003	8/14/2003	-14.3255
TD-12	7/4/2003	8/14/2003	-14.5279
TD-12	8/1/2003	8/14/2003	-14.6361
TD-12	8/15/2003	2/11/2004	-14.2433
TD-12	8/29/2003	2/11/2004	-14.4370
TD-12	9/12/2003	2/11/2004	-14.2474
TD-12	9/27/2003	2/11/2004	-14.5948
TD-12	10/13/2003	2/11/2004	-14.6350
TD-12	10/24/2003	2/12/2004	-14.6034
TD-12	11/7/2003	2/12/2004	-15.0559
TD-12	11/21/2003	2/12/2004	-14.3652
TD-12	12/5/2003	2/12/2004	-14.3280
TD-12	12/19/2003	2/13/2004	-14.7759
TD-12	12/22/2003	2/13/2004	-14.3261
TD-12	12/25/2003	2/13/2004	-14.4024
TD-12	12/28/2003	2/13/2004	-14.8859
TD-12	12/31/2003	2/13/2004	-14.8373
TD-12	1/5/2004	2/14/2004	-14.3035
TD-12	1/9/2004	2/13/2004	-14.8093
TD-12	1/10/2004	2/14/2004	-14.0096
TD-12	1/11/2004	2/14/2004	-14.7560
TD-12	1/12/2004	2/14/2004	-14.5152
TD-12	1/16/2004	2/14/2004	-14.7192
TD-12	1/19/2004	2/15/2004	-14.7313
TD-12	1/29/2004	2/15/2004	-16.0652
TD-12	1/29/2004	2/15/2004	-15.7913
TD-12	1/30/2004	7/26/2004	-15.7422
TD-12	2/13/2004	7/27/2004	-14.3517
TD-12	2/24/2004	7/28/2004	-13.9603
TD-12	3/12/2004	7/29/2004	-14.5994
TD-12	3/26/2004	7/30/2004	-14.5994

Sample Location	Sample Date	Run Analysis Date	$\delta^{18}O$ (‰)
TD-12	4/9/2004	-	-14.4550
TD-12	4/23/2004	8/2/2004	-14.4082
TD-12	5/7/2004	8/2/2004	-14.4416
TD-12	5/21/2004	8/2/2004	-14.4610
TD-12	5/28/2004	8/2/2004	-14.6125
TD-12	6/11/2004	8/2/2004	-14.4686
TD-12	6/25/2004	8/2/2004	-14.3114
TD-12	7/9/2004	8/3/2004	-14.7053
TD-12	7/23/2004	8/3/2004	-14.7263
TD-12	9/3/2004	4/20/2005	-14.2996
TD-12	9/17/2004	4/20/2005	-14.0144
TD-12	10/1/2004	4/20/2005	-14.3369
TD-12	10/15/2004	4/20/2005	-14.2991
TD-12	10/29/2004	4/20/2005	-14.5599
TD-12	11/12/2004	4/21/2005	-14.4761
TD-12	11/29/2004	4/21/2005	-14.2883
TD-12	12/13/2004	4/21/2005	-14.5291
TD-12	12/27/2004	4/24/2005	-14.8066
TD-12	1/11/2005	4/25/2005	-14.7699
TD-12	1/12/2005	4/25/2005	-14.7086
TD-12	1/28/2005	4/25/2005	-14.7308
TD-12	2/11/2005	4/25/2005	-15.0022
TD-12	2/25/2005	4/25/2005	-14.9009
TD-12	3/10/2005	4/26/2005	-13.7043
TD-12	3/23/2005	4/26/2005	-14.9053
TD-12	3/25/2005	4/26/2005	-14.2126
TD-12	4/8/2005	4/28/2005	-14.0710
TD-12	4/12/2005	4/28/2005	-14.0130
TD-12	4/22/2005	4/28/2005	-13.9551
MFC-660	1/9/2001	-	-14.7920
MFC-660	2/2/2001	-	-15.5272
MFC-660	2/19/2001	-	-16.5236
MFC-660	3/2/2001	-	-15.7779
MFC-660	3/20/2001	-	-14.5713
MFC-660	4/9/2001	-	-14.6452
MFC-660	4/16/2001	-	-14.2730
MFC-660	5/2/2001	-	-14.3002
MFC-660	5/21/2001	8/6/2003	-13.8383

Sample Location	Sample Date	Run Analysis Date	$\delta^{18}O$ (‰)
MFC-660	5/30/2001	-	-14.6738
MFC-660	9/27/2001	-	-14.3373
MFC-660	10/13/2001	-	-14.6613
MFC-660	10/24/2001	-	-14.8119
MFC-660	11/7/2001	-	-14.3092
MFC-660	11/30/2001	-	-14.9518
MFC-660	12/14/2001	-	-16.4566
MFC-660	12/27/2001	-	-14.5940
MFC-660	1/9/2002	2/11/2004	-14.1973
MFC-660	1/24/2002	-	-14.9706
MFC-660	1/25/2002	-	-15.4736
MFC-660	1/26/2002	-	-15.6649
MFC-660	1/27/2002	-	-15.5265
MFC-660	1/29/2002	-	-15.3038
MFC-660	2/8/2002	-	-16.6597
MFC-660	2/22/2002	-	-15.6310
MFC-660	2/24/2002	-	-15.0580
MFC-660	3/8/2002	-	-14.8712
MFC-660	3/12/2002	-	-15.2648
MFC-660	3/29/2002	-	-14.9246
MFC-660	4/12/2002	-	-14.4177
MFC-660	4/26/2002	-	-14.5476
MFC-660	4/27/2002	-	-14.1308
MFC-660	5/10/2002	-	-15.2422
MFC-660	5/24/2002	-	-14.9756
MFC-660	5/28/2002	-	-14.4344
MFC-660	6/11/2002	-	-14.6714
MFC-660	6/25/2002	-	-14.6275
MFC-660	7/9/2002	-	-15.0502
MFC-660	7/23/2002	-	-15.5646
MFC-660	9/20/2002	8/7/2003	-14.2372
MFC-660	10/16/2002	8/7/2003	-14.1796
MFC-660	11/8/2002	8/7/2003	-14.1023
MFC-660	11/20/2002	8/7/2003	-14.2299
MFC-660	12/4/2002	8/7/2003	-14.3472
MFC-660	12/19/2002	8/7/2003	-14.4091
MFC-660	1/10/2003	8/7/2003	-14.4092
MFC-660	1/17/2003	8/11/2003	-14.1236

Sample Location	Sample Date	Run Analysis Date	$\delta^{18}O$ (‰)
MFC-660	1/31/2003	8/11/2003	-11.5921
MFC-660	2/28/2003	8/11/2003	-13.9606
MFC-660	3/14/2003	8/11/2003	-13.7938
MFC-660	4/11/2003	8/12/2003	-10.8406
MFC-660	4/25/2003	8/12/2003	-13.7440
MFC-660	5/9/2003	8/12/2003	-13.7615
MFC-660	5/23/2003	8/13/2003	-13.8544
MFC-660	6/6/2003	8/13/2003	-13.3561
MFC-660	6/20/2003	8/14/2003	-14.3040
MFC-660	7/4/2003	8/14/2003	-14.5175
MFC-660	7/18/2003	8/14/2003	-14.5530
MFC-660	8/1/2003	8/14/2003	-14.4541
MFC-660	8/15/2003	2/11/2004	-13.2961
MFC-660	8/29/2003	2/11/2004	-14.2043
MFC-660	9/12/2003	2/11/2004	-14.0007
MFC-660	9/27/2003	2/11/2004	-14.5699
MFC-660	10/13/2003	2/11/2004	-14.8669
MFC-660	10/24/2003	2/12/2004	-14.5079
MFC-660	11/7/2003	2/12/2004	-14.6324
MFC-660	11/21/2003	2/12/2004	-13.8372
MFC-660	12/5/2003	2/12/2004	-13.7014
MFC-660	12/19/2003	2/13/2004	-14.3313
MFC-660	1/5/2004	2/14/2004	-14.4229
MFC-660	1/16/2004	2/15/2004	-17.6909
MFC-660	1/29/2004	2/15/2004	-17.7726
MFC-660	1/29/2004	2/15/2004	-16.0052
MFC-660	1/30/2004	7/26/2004	-16.4362
MFC-660	2/13/2004	7/27/2004	-13.9176
MFC-660	2/24/2004	7/28/2004	-15.0918
MFC-660	2/26/2004	7/29/2004	-15.6617
MFC-660	2/27/2004	7/29/2004	-15.2992
MFC-660	3/12/2004	7/29/2004	-14.8597
MFC-660	3/26/2004	7/30/2004	-14.3710
MFC-660	4/9/2004	7/30/2004	-14.2374
MFC-660	4/23/2004	8/2/2004	-14.0571
MFC-660	5/7/2004	8/2/2004	-14.5662
MFC-660	5/21/2004	8/2/2004	-13.8898
MFC-660	5/28/2004	8/2/2004	-13.5631

Sample Location	Sample Date	Run Analysis Date	$\delta^{18}O$ (‰)
MFC-660	6/11/2004	8/2/2004	-13.7374
MFC-660	6/25/2004	8/2/2004	-14.1185
MFC-660	7/9/2004	8/3/2004	-14.5965
MFC-660	7/23/2004	8/3/2004	-12.5011
MFC-660	8/6/2004	4/20/2005	-14.4290
MFC-660	8/20/2004	4/20/2005	-14.4787
MFC-660	9/3/2004	4/20/2005	-14.4202
MFC-660	9/17/2004	4/20/2005	-14.0286
MFC-660	10/1/2004	4/20/2005	-14.2403
MFC-660	10/15/2004	4/20/2005	-14.1224
MFC-660	10/29/2004	4/20/2005	-14.2853
MFC-660	11/12/2004	4/21/2005	-14.1838
MFC-660	11/29/2004	4/21/2005	-14.2114
MFC-660	12/13/2004	4/22/2005	-13.6680
MFC-660	12/27/2004	4/24/2005	-14.4287
MFC-660	1/11/2005	4/25/2005	-14.2183
MFC-660	1/12/2005	4/25/2005	-14.7293
MFC-660	1/28/2005	4/25/2005	-14.4840
MFC-660	2/11/2005	4/25/2005	-13.5033
MFC-660	2/25/2005	4/25/2005	-14.6792
MFC-660	3/10/2005	4/26/2005	-14.5311
MFC-660	3/23/2005	4/26/2005	-13.7099
MFC-660	3/25/2005	4/26/2005	-13.9147
MFC-660	3/29/2005	4/26/2005	-14.6935
MFC-660	4/8/2005	4/28/2005	-12.7589
MFC-660	4/12/2005	4/28/2005	-12.0637
MFC-660	4/22/2005	4/28/2005	-13.6174
MFC-4700	10/19/2000	-	-14.2065
MFC-4700	12/7/2000	-	-14.5017
MFC-4700	1/9/2001	-	-15.6661
MFC-4700	2/2/2001	-	-16.3426
MFC-4700	2/19/2001	-	-16.1048
MFC-4700	3/2/2001	-	-16.2039
MFC-4700	3/20/2001	-	-15.1859
MFC-4700	4/9/2001	-	-15.0434
MFC-4700	4/16/2001	-	-14.4965
MFC-4700	5/2/2001	-	-14.1016
MFC-4700	5/21/2001	-	-13.8362

Sample Location	Sample Date	Run Analysis Date	$\delta^{18}O$ (‰)
MFC-4700	5/30/2001	-	-13.3574
MFC-4700	6/15/2001	-	-6.5638
MFC-4700	7/11/2001	-	-12.5143
MFC-4700	9/27/2001	-	-12.607
MFC-4700	10/13/2001	-	-13.5242
MFC-4700	10/24/2001	-	-13.5478
MFC-4700	11/7/2001	-	-14.2965
MFC-4700	11/30/2001	-	-15.8829
MFC-4700	12/14/2001	-	-16.1281
MFC-4700	1/9/2002	-	-16.1232
MFC-4700	1/25/2002	-	-16.9164
MFC-4700	1/26/2002	-	-17.0888
MFC-4700	1/27/2002	-	-17.0339
MFC-4700	1/29/2002	-	-16.4845
MFC-4700	2/8/2002	-	-17.3847
MFC-4700	2/22/2002	-	-15.6448
MFC-4700	2/24/2002	-	-16.4706
MFC-4700	3/8/2002	-	-16.7827
MFC-4700	3/11/2002	-	-15.4401
MFC-4700	3/29/2002	-	-15.9561
MFC-4700	4/12/2002	-	-14.5192
MFC-4700	4/26/2002	-	-14.1684
MFC-4700	4/27/2002	-	-14.3864
MFC-4700	5/10/2002	-	-14.3507
MFC-4700	5/24/2002	-	-13.9922
MFC-4700	5/28/2002	-	-13.1335
MFC-4700	6/11/2002	-	-14.9991
MFC-4700	6/25/2002	-	-13.9361
MFC-4700	7/9/2002	-	-13.0075
MFC-4700	7/23/2002	-	-12.8051
MFC-4700	9/20/2002	8/7/2003	-13.1744
MFC-4700	11/8/2002	8/7/2003	-13.7558
MFC-4700	11/20/2002	8/7/2003	-13.3779
MFC-4700	12/4/2002	8/7/2003	-13.9124
MFC-4700	12/19/2002	8/7/2003	-14.2546
MFC-4700	1/10/2003	8/7/2003	-14.4075
MFC-4700	1/17/2003	8/11/2003	-10.3513
MFC-4700	1/31/2003	8/11/2003	-11.8048

Sample Location	Sample Date	Run Analysis Date	$\delta^{18}O$ (‰)
MFC-4700	2/14/2003	8/11/2003	-13.7005
MFC-4700	2/28/2003	8/11/2003	-14.3345
MFC-4700	3/14/2003	8/12/2003	-14.0851
MFC-4700	3/28/2003	8/12/2003	-11.2519
MFC-4700	4/25/2003	8/12/2003	-13.6194
MFC-4700	5/9/2003	8/12/2003	-13.5454
MFC-4700	5/23/2003	8/13/2003	-13.4294
MFC-4700	6/6/2003	8/13/2003	-13.1193
MFC-4700	6/20/2003	8/14/2003	-12.9339
MFC-4700	7/4/2003	8/14/2003	-12.0356
MFC-4700	7/18/2003	8/14/2003	-11.3318
MFC-4700	8/1/2003	8/14/2003	-8.6456
MFC-4700	8/15/2003	2/11/2004	-7.1481
MFC-4700	8/29/2003	2/11/2004	-8.2218
MFC-4700	9/12/2003	2/11/2004	-10.1499
MFC-4700	9/27/2003	2/11/2004	-12.9012
MFC-4700	10/13/2003	2/12/2004	-12.8276
MFC-4700	10/24/2003	2/12/2004	-13.3866
MFC-4700	11/7/2003	2/12/2004	-14.4715
MFC-4700	11/21/2003	2/12/2004	-13.5002
MFC-4700	12/5/2003	2/12/2004	-14.0533
MFC-4700	1/5/2004	2/13/2004	-15.0587
MFC-4700	1/16/2004	2/14/2004	-16.4366
MFC-4700	1/29/2004	2/15/2004	-17.3684
MFC-4700	1/29/2004	2/15/2004	-17.4885
MFC-4700	1/30/2004	7/26/2004	-16.6983
MFC-4700	2/13/2004	7/27/2004	-14.9710
MFC-4700	2/24/2004	7/29/2004	-15.0965
MFC-4700	2/26/2004	7/29/2004	-15.9140
MFC-4700	2/27/2004	7/29/2004	-15.9238
MFC-4700	3/12/2004	7/29/2004	-15.0075
MFC-4700	3/26/2004	7/30/2004	-14.2252
MFC-4700	4/9/2004	7/30/2004	-13.7566
MFC-4700	4/23/2004	8/2/2004	-13.8695
MFC-4700	5/7/2004	8/2/2004	-13.6881
MFC-4700	5/21/2004	8/2/2004	-13.4745
MFC-4700	5/28/2004	8/2/2004	-12.7453
MFC-4700	6/11/2004	8/2/2004	-13.2932

Sample Location	Sample Date	Run Analysis Date	δ^{18}O (‰)
MFC-4700	6/25/2004	8/2/2004	-12.4471
MFC-4700	7/9/2004	8/3/2004	-12.2971
MFC-4700	7/23/2004	8/3/2004	-14.2125
MFC-4700	8/6/2004	4/20/2005	-10.7492
MFC-4700	8/20/2004	4/20/2005	-10.9231
MFC-4700	9/3/2004	4/20/2005	-11.7327
MFC-4700	9/17/2004	4/20/2005	-12.5569
MFC-4700	10/1/2004	4/20/2005	-12.8929
MFC-4700	10/15/2004	4/20/2005	-13.2941
MFC-4700	10/29/2004	4/20/2005	-13.6005
MFC-4700	11/12/2004	4/21/2005	-13.6317
MFC-4700	11/29/2004	4/21/2005	-13.6753
MFC-4700	12/13/2004	4/22/2005	-13.6577
MFC-4700	12/27/2004	4/24/2005	-14.5844
MFC-4700	1/12/2005	4/25/2005	-14.5864
MFC-4700	1/28/2005	4/25/2005	-14.3400
MFC-4700	2/11/2005	4/25/2005	-13.8996
MFC-4700	2/25/2005	4/26/2005	-14.2638
MFC-4700	3/10/2005	4/26/2005	-13.4758
MFC-4700	3/25/2005	4/26/2005	-13.2893
MFC-4700	4/8/2005	4/28/2005	-13.3117
MFC-4700	4/22/2005	4/28/2005	-13.0294
MFC-5700	1/9/2001	-	-15.0255
MFC-5700	2/2/2001	-	-15.7519
MFC-5700	3/2/2001	-	-15.9390
MFC-5700	4/9/2001	-	-15.8461
MFC-5700	4/16/2001	-	-14.5432
MFC-5700	5/2/2001	-	-14.9592
MFC-5700	5/30/2001	-	-14.9627
MFC-5700	7/11/2001	-	-11.5414
MFC-5700	10/13/2001	-	-13.5371
MFC-5700	10/24/2001	-	-12.1859
MFC-5700	11/30/2001	-	-15.7046
MFC-5700	12/14/2001	-	-16.2030
MFC-5700	1/25/2002	-	-16.2722
MFC-5700	1/26/2002	-	-16.8038
MFC-5700	1/27/2002	-	-16.8548
MFC-5700	1/29/2002	-	-16.5686

Sample Location	Sample Date	Run Analysis Date	$\delta^{18}O$ (‰)
MFC-5700	2/8/2002	-	-16.2788
MFC-5700	2/22/2002	-	-16.5074
MFC-5700	3/8/2002	-	-16.2486
MFC-5700	3/11/2002	-	-16.1821
MFC-5700	4/12/2002	-	-15.4040
MFC-5700	5/28/2002	-	-10.5909
MFC-5700	6/11/2002	-	-14.3846
MFC-5700	6/25/2002	-	-13.9408
MFC-5700	7/9/2002	-	-13.9085
MFC-5700	7/23/2002	-	-14.2677
MFC-5700	9/20/2002	8/7/2003	-11.7795
MFC-5700	10/16/2002	8/7/2003	-12.8077
MFC-5700	11/8/2002	8/7/2003	-12.4195
MFC-5700	11/20/2002	8/7/2003	-12.1018
MFC-5700	12/4/2002	8/7/2003	-13.7717
MFC-5700	12/19/2002	8/7/2003	-14.2614
MFC-5700	1/10/2003	8/7/2003	-14.3800
MFC-5700	1/17/2003	8/11/2003	-14.1527
MFC-5700	1/31/2003	8/11/2003	-12.6160
MFC-5700	2/14/2003	8/11/2003	-14.0330
MFC-5700	2/28/2003	8/11/2003	-13.9177
MFC-5700	3/14/2003	8/12/2003	-14.0447
MFC-5700	3/28/2003	8/12/2003	-12.5930
MFC-5700	4/11/2003	8/12/2003	-13.2434
MFC-5700	4/25/2003	8/12/2003	-13.5612
MFC-5700	5/9/2003	8/13/2003	-13.6213
MFC-5700	5/23/2003	8/13/2003	-13.6349
MFC-5700	6/6/2003	8/13/2003	-13.2947
MFC-5700	6/20/2003	8/14/2003	-13.2986
MFC-5700	7/4/2003	8/14/2003	-12.8739
MFC-5700	7/18/2003	8/14/2003	-12.7991
MFC-5700	8/1/2003	8/14/2003	-12.3580
MFC-5700	8/15/2003	2/11/2004	-11.1075
MFC-5700	8/29/2003	2/11/2004	-11.1611
MFC-5700	9/12/2003	2/11/2004	-11.0398
MFC-5700	9/27/2003	2/11/2004	-12.3540
MFC-5700	10/13/2003	2/12/2004	-12.8508
MFC-5700	10/24/2003	2/12/2004	-13.5141

Sample Location	Sample Date	Run Analysis Date	$\delta^{18}O$ (‰)
MFC-5700	11/7/2003	2/12/2004	-13.7683
MFC-5700	11/21/2003	2/12/2004	-13.3800
MFC-5700	12/5/2003	2/12/2004	-14.0189
MFC-5700	12/19/2003	2/13/2004	-15.0075
MFC-5700	1/5/2004	2/14/2004	-14.4121
MFC-5700	1/16/2004	2/15/2004	-16.1032
MFC-5700	1/29/2004	2/15/2004	-17.0272
MFC-5700	1/29/2004	2/15/2004	-16.8883
MFC-5700	2/13/2004	7/27/2004	-14.6830
MFC-5700	2/24/2004	7/29/2004	-14.9906
MFC-5700	2/26/2004	7/29/2004	-15.9244
MFC-5700	2/27/2004	7/29/2004	-15.8506
MFC-5700	3/12/2004	7/29/2004	-14.7102
MFC-5700	3/26/2004	7/30/2004	-14.1481
MFC-5700	4/9/2004	7/30/2004	-13.8280
MFC-5700	4/9/2004	5/1/2005	-13.7063
MFC-5700	4/23/2004	8/2/2004	-13.8275
MFC-5700	5/7/2004	8/2/2004	-14.0415
MFC-5700	5/21/2004	8/2/2004	-13.5722
MFC-5700	5/28/2004	8/2/2004	-13.1081
MFC-5700	6/11/2004	8/2/2004	-13.2558
MFC-5700	6/25/2004	8/2/2004	-13.4017
MFC-5700	7/9/2004	8/3/2004	-13.6131
MFC-5700	7/23/2004	8/3/2004	-14.3216
MFC-5700	8/6/2004	4/20/2005	-12.8669
MFC-5700	8/20/2004	4/20/2005	-12.5142
MFC-5700	9/3/2004	4/20/2005	-10.9911
MFC-5700	9/17/2004	4/20/2005	-12.4583
MFC-5700	10/1/2004	4/20/2005	-11.9145
MFC-5700	10/15/2004	4/20/2005	-12.9040
MFC-5700	10/29/2004	4/20/2005	-13.1077
MFC-5700	11/12/2004	4/21/2005	-13.6777
MFC-5700	11/29/2004	4/21/2005	-13.5223
MFC-5700	12/13/2004	4/23/2005	-13.8669
MFC-5700	12/27/2004	4/24/2005	-14.3240
MFC-5700	1/12/2005	4/25/2005	-14.7948
MFC-5700	1/28/2005	4/25/2005	-14.2186
MFC-5700	2/11/2005	4/25/2005	-13.4962

Sample Location	Sample Date	Run Analysis Date	$\delta^{18}O$ (‰)
MFC-5700	2/25/2005	4/26/2005	-14.1206
MFC-5700	3/10/2005	4/26/2005	-13.6767
MFC-5700	3/25/2005	4/26/2005	-13.0686
MFC-5700	4/8/2005	4/28/2005	-13.4368
MFC-5700	4/22/2005	4/28/2005	-12.9794

APPENDIX G: $\delta^{18}O$ data for soil water

Lysimeter ID	Sample Location	Depth Below Land Surface (cm)	Sample Date	Run Date	$\delta^{18}O$ (‰)
SC 10	ES-6	25	2/6/2001	2/4/2004	-12.6978
SC 10	ES-6	25	2/19/2001	2/4/2004	-14.5767
SC 10	ES-6	25	3/3/2001	2/4/2004	-15.2312
SC 10	ES-6	25	3/21/2001	2/5/2004	-15.5043
SC 10	ES-6	25	4/9/2001	2/5/2004	-15.4903
SC 10	ES-6	25	4/16/2001	2/6/2004	-15.7140
SC 10	ES-6	25	5/3/2001	2/6/2004	-15.2628
SC 10	ES-6	25	5/17/2001	2/7/2004	-14.7107
SC 10	ES-6	25	1/30/2004	7/26/2004	-16.4743
SC 10	ES-6	25	2/20/2004	7/28/2004	-16.9929
SC 10	ES-6	25	5/7/2004	8/2/2004	-16.0343
SC 11	ES-6	45	2/6/2001	2/4/2004	-13.6748
SC 11	ES-6	45	2/19/2001	2/4/2004	-14.7700
SC 11	ES-6	45	3/3/2001	12/19/2003	-14.0682
SC 11	ES-6	45	3/21/2001	2/5/2004	-14.9964
SC 11	ES-6	45	4/9/2001	2/5/2004	-14.9691
SC 11	ES-6	45	4/16/2001	2/6/2004	-14.7065
SC 11	ES-6	45	5/3/2001	2/6/2004	-14.6791
SC 11	ES-6	45	5/17/2001	2/7/2004	-14.3088
SC 11	ES-6	45	5/31/2001	2/7/2004	-14.5592
SC 11	ES-6	45	6/14/2001	2/7/2004	-13.8018
SC 11	ES-6	45	1/7/2002	2/11/2004	-13.8450
SC 11	ES-6	45	3/15/2002	9/22/2003	-14.7063
SC 11	ES-6	45	4/5/2002	9/24/2003	-14.2328
SC 11	ES-6	45	4/19/2002	9/25/2003	-15.0878
SC 11	ES-6	45	5/3/2002	9/25/2003	-15.0824
SC 11	ES-6	45	5/16/2002	9/26/2003	-15.4087
SC 11	ES-6	45	5/30/2002	9/27/2003	-14.8760
SC 11	ES-6	45	6/13/2002	9/30/2003	-14.4837
SC 11	ES-6	45	6/27/2002	10/1/2003	-13.9643
SC 11	ES-6	45	7/11/2002	10/1/2003	-13.4716
SC 11	ES-6	45	7/25/2002	10/1/2003	-13.3518
SC 11	ES-6	45	1/30/2004	7/26/2004	-15.5823
SC 11	ES-6	45	2/20/2004	7/28/2004	-16.1362
SC 11	ES-6	45	3/12/2004	7/30/2004	-15.8146

Lysimeter ID	Sample Location	Depth Below Land Surface (cm)	Sample Date	Run Date	$\delta^{18}O$ (‰)
SC 11	ES-6	45	3/26/2004	7/30/2004	-15.3699
SC 11	ES-6	45	4/9/2004	7/30/2004	-14.9505
SC 11	ES-6	45	5/7/2004	8/2/2004	-14.2549
SC 11	ES-6	45	5/28/2004	8/2/2004	-14.0123
SC 11	ES-6	45	6/25/2004	8/3/2004	-13.9766
SC 11	ES-6	45	3/10/2005	4/26/2005	-13.1256
SC 11	ES-6	45	4/8/2005	4/28/2005	-11.8851
SC 12	ES-6	80	2/6/2001	2/4/2004	-14.0676
SC 12	ES-6	80	2/19/2001	2/4/2004	-14.1267
SC 12	ES-6	80	3/3/2001	12/19/2003	-13.5442
SC 12	ES-6	80	3/21/2001	2/5/2004	-14.0972
SC 12	ES-6	80	4/9/2001	2/5/2004	-14.2152
SC 12	ES-6	80	4/16/2001	2/6/2004	-14.0305
SC 12	ES-6	80	5/3/2001	2/6/2004	-14.0576
SC 12	ES-6	80	5/17/2001	2/7/2004	-13.8282
SC 12	ES-6	80	5/31/2001	2/7/2004	-14.0516
SC 12	ES-6	80	6/14/2001	2/7/2004	-13.6292
SC 12	ES-6	80	1/7/2002	2/11/2004	-13.9346
SC 12	ES-6	80	2/15/2002	9/17/2003	-13.6628
SC 12	ES-6	80	3/15/2002	9/22/2003	-13.6916
SC 12	ES-6	80	4/5/2002	9/24/2003	-13.2143
SC 12	ES-6	80	4/19/2002	9/25/2003	-14.5685
SC 12	ES-6	80	5/3/2002	9/25/2003	-14.3900
SC 12	ES-6	80	5/16/2002	9/26/2003	-14.6055
SC 12	ES-6	80	5/30/2002	9/27/2003	-14.5594
SC 12	ES-6	80	6/13/2002	9/30/2003	-13.9752
SC 12	ES-6	80	6/27/2002	10/1/2003	-14.0001
SC 12	ES-6	80	7/11/2002	10/1/2003	-13.7077
SC 12	ES-6	80	1/30/2004	7/26/2004	-13.7386
SC 12	ES-6	80	2/20/2004	7/28/2004	-14.0366
SC 12	ES-6	80	3/12/2004	7/30/2004	-14.3620
SC 12	ES-6	80	3/26/2004	7/30/2004	-13.9388
SC 12	ES-6	80	4/9/2004	7/30/2004	-14.0014
SC 12	ES-6	80	5/7/2004	8/2/2004	-14.0610
SC 12	ES-6	80	5/28/2004	8/2/2004	-14.0503
SC 12	ES-6	80	2/11/2005	4/25/2005	-14.3830
SC 12	ES-6	80	3/10/2005	4/26/2005	-13.6583

Lysimeter ID	Sample Location	Depth Below Land Surface (cm)	Sample Date	Run Date	$\delta^{18}O$ (‰)
SC 12	ES-6	80	4/8/2005	4/28/2005	-12.8664
SC 14	ES-6	45	2/6/2001	2/4/2004	-14.0636
SC 14	ES-6	45	2/19/2001	2/4/2004	-14.6564
SC 14	ES-6	45	3/3/2001	12/19/2003	-14.7005
SC 14	ES-6	45	3/21/2001	2/5/2004	-14.7601
SC 14	ES-6	45	4/16/2001	2/6/2004	-14.5670
SC 14	ES-6	45	5/3/2001	2/6/2004	-13.6639
SC 14	ES-6	45	5/17/2001	2/7/2004	-14.0358
SC 14	ES-6	45	5/31/2001	2/7/2004	-14.1526
SC 14	ES-6	45	6/14/2001	2/7/2004	-12.6561
SC 14	ES-6	45	1/7/2002	2/11/2004	-14.2990
SC 14	ES-6	45	3/15/2002	9/22/2003	-14.7087
SC 14	ES-6	45	4/5/2002	9/24/2003	-14.5950
SC 14	ES-6	45	4/19/2002	9/25/2003	-15.1440
SC 14	ES-6	45	5/3/2002	9/25/2003	-14.7015
SC 14	ES-6	45	5/16/2002	9/26/2003	-14.9369
SC 14	ES-6	45	5/30/2002	9/27/2003	-13.1522
SC 14	ES-6	45	6/13/2002	9/30/2003	-12.3995
SC 14	ES-6	45	6/27/2002	10/1/2003	-12.3068
SC 14	ES-6	45	7/11/2002	10/1/2003	-12.3263
SC 14	ES-6	45	1/30/2004	7/26/2004	-15.0483
SC 14	ES-6	45	2/20/2004	7/28/2004	-15.5926
SC 14	ES-6	45	3/12/2004	7/30/2004	-15.5533
SC 14	ES-6	45	3/26/2004	7/30/2004	-15.0223
SC 14	ES-6	45	4/9/2004	7/30/2004	-14.2193
SC 14	ES-6	45	5/7/2004	8/2/2004	-12.7909
SC 14	ES-6	45	5/28/2004	8/2/2004	-12.8833
SC 14	ES-6	45	6/25/2004	8/3/2004	-13.1880
SC 14	ES-6	45	12/13/2004	4/23/2005	-13.1364
SC 14	ES-6	45	2/11/2005	4/25/2005	-13.1198
SC 14	ES-6	45	3/10/2005	4/26/2005	-12.1372
SC 14	ES-6	45	4/8/2005	4/28/2005	-11.8679
SC 15	ES-6	80	2/6/2001	2/4/2004	-14.1600
SC 15	ES-6	80	2/19/2001	2/4/2004	-13.9749
SC 15	ES-6	80	3/3/2001	2/4/2004	-13.9137
SC 15	ES-6	80	3/21/2001	2/5/2004	-14.0172
SC 15	ES-6	80	4/9/2001	8/3/2004	-14.1707

Lysimeter ID	Sample Location	Depth Below Land Surface (cm)	Sample Date	Run Date	$\delta^{18}O$ (‰)
SC 15	ES-6	80	4/16/2001	2/6/2004	-14.1312
SC 15	ES-6	80	5/3/2001	2/6/2004	-14.2234
SC 15	ES-6	80	5/17/2001	2/7/2004	-14.1724
SC 15	ES-6	80	5/31/2001	2/7/2004	-14.6548
SC 15	ES-6	80	6/14/2001	2/7/2004	-12.3313
SC 15	ES-6	80	1/7/2002	2/11/2004	-13.6220
SC 15	ES-6	80	3/15/2002	9/22/2003	-13.1336
SC 15	ES-6	80	4/5/2002	9/24/2003	-13.7724
SC 15	ES-6	80	4/19/2002	9/25/2003	-14.5192
SC 15	ES-6	80	5/3/2002	9/25/2003	-14.5272
SC 15	ES-6	80	5/16/2002	9/26/2003	-15.0562
SC 15	ES-6	80	5/30/2002	9/27/2003	-15.3733
SC 15	ES-6	80	6/13/2002	9/30/2003	-14.7585
SC 15	ES-6	80	6/27/2002	10/1/2003	-14.4589
SC 15	ES-6	80	7/25/2002	10/1/2003	-14.5394
SC 15	ES-6	80	1/30/2004	7/26/2004	-14.4470
SC 15	ES-6	80	2/20/2004	7/28/2004	-14.5401
SC 15	ES-6	80	3/12/2004	7/30/2004	-15.2607
SC 15	ES-6	80	3/26/2004	7/30/2004	-15.2514
SC 15	ES-6	80	4/9/2004	7/30/2004	-15.1950
SC 15	ES-6	80	5/7/2004	8/2/2004	-15.0842
SC 15	ES-6	80	5/28/2004	8/2/2004	-14.5369
SC 15	ES-6	80	6/25/2004	8/3/2004	-14.6210
SC 15	ES-6	80	7/23/2004	8/3/2004	-14.7431
SC 15	ES-6	80	2/11/2005	4/25/2005	-14.0895
SC 15	ES-6	80	3/10/2005	4/26/2005	-13.4056
SC 15	ES-6	80	4/8/2005	4/28/2005	-12.8534
SC 16	ES-6	25	2/19/2001	2/4/2004	-15.4168
SC 16	ES-6	25	3/3/2001	2/5/2004	-15.3865
SC 16	ES-6	25	3/21/2001	2/5/2004	-14.8411
SC 16	ES-6	25	4/9/2001	8/3/2004	-15.1378
SC 16	ES-6	25	4/16/2001	2/6/2004	-15.2957
SC 16	ES-6	25	5/3/2001	2/6/2004	-14.3707
SC 16	ES-6	25	5/17/2001	2/7/2004	-14.4412
SC 16	ES-6	25	5/31/2001	2/7/2004	-14.3023
SC 16	ES-6	25	6/14/2001	2/7/2004	-13.6415
SC 16	ES-6	25	3/15/2002	9/22/2003	-14.5489

Lysimeter ID	Sample Location	Depth Below Land Surface (cm)	Sample Date	Run Date	$\delta^{18}O$ (‰)
SC 16	ES-6	25	4/19/2002	9/25/2003	-14.8382
SC 16	ES-6	25	5/3/2002	9/25/2003	-15.0387
SC 16	ES-6	25	5/16/2002	9/26/2003	-15.2404
SC 16	ES-6	25	5/30/2002	9/27/2003	-15.1076
SC 16	ES-6	25	6/13/2002	9/30/2003	-14.2576
SC 16	ES-6	25	6/27/2002	10/1/2003	-13.8985
SC 16	ES-6	25	7/11/2002	10/1/2003	-12.9595
SC 16	ES-6	25	1/30/2004	7/26/2004	-18.4076
SC 16	ES-6	25	2/20/2004	7/28/2004	-16.1969
SC 16	ES-6	25	3/12/2004	7/30/2004	-15.5783
SC 16	ES-6	25	3/26/2004	7/30/2004	-14.4061
SC 16	ES-6	25	4/9/2004	7/30/2004	-15.5477
SC 16	ES-6	25	5/7/2004	8/2/2004	-14.9961
SC 16	ES-6	25	5/28/2004	8/2/2004	-14.2747
SC 16	ES-6	25	4/8/2005	4/28/2005	-11.2382
SC 17	ES-6	45	2/6/2001	2/4/2004	-14.3041
SC 17	ES-6	45	2/19/2001	2/4/2004	-14.7236
SC 17	ES-6	45	3/3/2001	2/5/2004	-14.9064
SC 17	ES-6	45	3/21/2001	2/5/2004	-14.5067
SC 17	ES-6	45	4/9/2001	8/3/2004	-14.3105
SC 17	ES-6	45	4/16/2001	2/6/2004	-14.2390
SC 17	ES-6	45	5/3/2001	2/6/2004	-13.6927
SC 17	ES-6	45	5/17/2001	2/7/2004	-13.4977
SC 17	ES-6	45	5/31/2001	2/7/2004	-13.5965
SC 17	ES-6	45	6/14/2001	2/7/2004	-11.9289
SC 17	ES-6	45	1/7/2002	2/11/2004	-15.0771
SC 17	ES-6	45	2/15/2002	9/17/2003	-14.8677
SC 17	ES-6	45	4/19/2002	9/25/2003	-12.6749
SC 17	ES-6	45	5/3/2002	9/25/2003	-14.6568
SC 17	ES-6	45	5/16/2002	9/26/2003	-15.3219
SC 17	ES-6	45	5/30/2002	9/27/2003	-13.7526
SC 17	ES-6	45	6/13/2002	9/30/2003	-12.5435
SC 17	ES-6	45	6/27/2002	10/1/2003	-12.9137
SC 17	ES-6	45	7/11/2002	10/1/2003	-12.8742
SC 17	ES-6	45	1/30/2004	7/26/2004	-15.9672
SC 17	ES-6	45	2/20/2004	7/28/2004	-15.2624
SC 17	ES-6	45	3/12/2004	7/30/2004	-15.5050

Lysimeter ID	Sample Location	Depth Below Land Surface (cm)	Sample Date	Run Date	$\delta^{18}O$ (‰)
SC 17	ES-6	45	3/26/2004	7/30/2004	-15.5184
SC 17	ES-6	45	4/9/2004	7/30/2004	-13.3997
SC 17	ES-6	45	5/7/2004	8/2/2004	-12.9847
SC 17	ES-6	45	5/28/2004	8/2/2004	-12.5683
SC 17	ES-6	45	2/11/2005	4/25/2005	-12.8936
SC 17	ES-6	45	4/8/2005	4/28/2005	-11.8236
SC 18	ES-6	80	2/6/2001	2/4/2004	-13.6417
SC 18	ES-6	80	2/19/2001	2/4/2004	-13.6056
SC 18	ES-6	80	3/3/2001	2/5/2004	-13.7876
SC 18	ES-6	80	3/21/2001	2/5/2004	-13.6316
SC 18	ES-6	80	4/9/2001	8/3/2004	-14.1591
SC 18	ES-6	80	4/12/2001	8/3/2004	-12.8525
SC 18	ES-6	80	4/16/2001	2/6/2004	-14.2873
SC 18	ES-6	80	5/3/2001	2/6/2004	-14.0683
SC 18	ES-6	80	5/17/2001	2/7/2004	-14.0099
SC 18	ES-6	80	5/31/2001	2/7/2004	-14.2328
SC 18	ES-6	80	6/14/2001	2/7/2004	-12.7580
SC 18	ES-6	80	1/7/2002	2/11/2004	-14.1902
SC 18	ES-6	80	3/15/2002	9/22/2003	-13.5289
SC 18	ES-6	80	4/5/2002	9/24/2003	-14.3527
SC 18	ES-6	80	4/19/2002	9/25/2003	-15.3241
SC 18	ES-6	80	5/3/2002	9/25/2003	-15.3489
SC 18	ES-6	80	5/16/2002	9/26/2003	-14.7647
SC 18	ES-6	80	5/30/2002	9/27/2003	-15.2793
SC 18	ES-6	80	6/13/2002	9/30/2003	-15.1251
SC 18	ES-6	80	6/27/2002	10/1/2003	-14.1969
SC 18	ES-6	80	7/9/2002	10/1/2003	-14.1101
SC 18	ES-6	80	7/11/2002	10/1/2003	-14.9839
SC 18	ES-6	80	7/25/2002	10/1/2003	-14.0561
SC 18	ES-6	80	1/30/2004	7/26/2004	-14.4023
SC 18	ES-6	80	2/20/2004	7/28/2004	-14.1257
SC 18	ES-6	80	4/9/2004	7/30/2004	-14.8207
SC 18	ES-6	80	5/7/2004	8/2/2004	-14.5165
SC 18	ES-6	80	5/28/2004	8/2/2004	-13.7218
SC 18	ES-6	80	6/25/2004	8/3/2004	-14.2432
SC 18	ES-6	80	7/23/2004	8/3/2004	-14.3427
SC 18	ES-6	80	2/11/2005	4/25/2005	-13.5475

Lysimeter ID	Sample Location	Depth Below Land Surface (cm)	Sample Date	Run Date	$\delta^{18}O$ (‰)
SC 18	ES-6	80	3/10/2005	4/26/2005	-12.8534
SC 18	ES-6	80	4/8/2005	4/28/2005	-12.0841
P 1	TD-12	23	12/22/2001	2/10/2004	-9.4208
P 1	TD-12	23	12/23/2001	2/10/2004	-11.2546
P 1	TD-12	23	2/14/2002	9/17/2003	-14.4835
P 1	TD-12	23	4/5/2002	9/22/2003	-15.1656
P 1	TD-12	23	1/30/2004	7/26/2004	-16.1401
P 1	TD-12	23	2/20/2004	7/27/2004	-17.1836
P 2	TD-12	42	12/22/2001	2/10/2004	-12.0760
P 2	TD-12	42	2/14/2002	9/17/2003	-11.9211
P 2	TD-12	42	4/5/2002	9/22/2003	-16.0277
P 2	TD-12	42	1/30/2004	7/26/2004	-13.2755
P 2	TD-12	42	2/20/2004	7/27/2004	-15.8442
P 3	TD-12	78	12/23/2001	2/10/2004	-11.8683
P 3	TD-12	78	4/5/2002	9/22/2003	-14.0838
P 3	TD-12	78	4/19/2002	9/24/2003	-13.6835
P 3	TD-12	78	1/30/2004	7/26/2004	-13.4963
P 3	TD-12	78	2/20/2004	7/27/2004	-13.7039
P 3	TD-12	78	2/11/2005	4/25/2005	-14.4227
P 3	TD-12	78	4/8/2005	4/28/2005	-11.7766
P 4	TD-12	21	12/23/2001	2/10/2004	-9.3064
P 4	TD-12	21	2/14/2002	9/17/2003	-14.6832
P 4	TD-12	21	4/5/2002	9/22/2003	-15.7934
P 4	TD-12	21	4/19/2002	9/24/2003	-15.7668
P 4	TD-12	21	1/30/2004	7/26/2004	-14.3227
P 4	TD-12	21	2/11/2005	4/25/2005	-13.1727
P 5	TD-12	44	2/14/2002	9/17/2003	-14.7112
P 5	TD-12	44	4/5/2002	9/22/2003	-14.8505
P 5	TD-12	44	1/30/2004	7/26/2004	-14.1024
P 5	TD-12	44	2/20/2004	7/27/2004	-17.1038
P 6	TD-12	80	12/23/2001	2/10/2004	-13.8502
P 6	TD-12	80	2/14/2002	9/17/2003	-13.6373
P 6	TD-12	80	4/5/2002	9/22/2003	-13.1354
P 6	TD-12	80	1/30/2004	7/26/2004	-13.8994
P 6	TD-12	80	2/20/2004	7/27/2004	-13.8317
P 7	TD-12	23	12/23/2001	2/10/2004	-12.3732
P 7	TD-12	23	2/14/2002	9/17/2003	-15.1946

Lysimeter ID	Sample Location	Depth Below Land Surface (cm)	Sample Date	Run Date	$\delta^{18}O$ (‰)
P 7	TD-12	23	4/5/2002	9/22/2003	-15.4171
P 7	TD-12	23	1/30/2004	7/26/2004	-14.1179
P 8	TD-12	41	2/14/2002	9/17/2003	-10.2487
P 8	TD-12	41	4/5/2002	9/22/2003	-14.8550
P 8	TD-12	41	1/30/2004	7/26/2004	-14.5955
P 8	TD-12	41	2/20/2004	7/27/2004	-17.5731
P 9	TD-12	78	2/14/2002	9/17/2003	-14.7671
P 9	TD-12	78	4/5/2002	9/22/2003	-14.8335
P 9	TD-12	78	2/20/2004	7/27/2004	-13.3415
P 9	TD-12	78	12/13/2004	4/23/2005	-14.2547
P 9	TD-12	78	2/11/2005	4/25/2005	-14.7455
P 9	TD-12	78	4/8/2005	4/28/2005	-13.7123
P 10	TD-12	18	4/5/2002	9/22/2003	-15.3433
P 10	TD-12	18	2/20/2004	7/27/2004	-15.3028
P 10	TD-12	18	12/13/2004	4/23/2005	-13.6196
P 11	TD-12	44	2/20/2004	7/28/2004	-13.5245
P 11	TD-12	44	4/8/2005	4/28/2005	-12.5465
P 12	TD-12	77	2/14/2002	9/17/2003	-13.5752
P 12	TD-12	77	4/5/2002	9/22/2003	-14.3249
P 12	TD-12	77	2/20/2004	7/28/2004	-13.7795
P 12	TD-12	77	2/11/2005	4/25/2005	-14.4842
SC 3	TD-12	90	10/27/2000	8/3/2004	-14.3666
SC 3	TD-12	90	12/8/2000	8/3/2004	-14.1059
SC 3	TD-12	90	2/3/2001	2/4/2004	-14.1902
SC 3	TD-12	90	3/21/2001	2/5/2004	-14.3220
SC 3	TD-12	90	4/8/2001	2/5/2004	-13.8637
SC 3	TD-12	90	5/4/2001	2/7/2004	-14.2016
SC 3	TD-12	90	5/21/2001	2/7/2004	-14.1114
SC 3	TD-12	90	5/31/2001	2/7/2004	-14.3564
SC 3	TD-12	90	6/14/2001	2/7/2004	-13.6209
SC 3	TD-12	90	7/12/2001	2/10/2004	-10.7613
SC 3	TD-12	90	12/22/2001	2/10/2004	-14.0915
SC 3	TD-12	90	1/7/2002	2/10/2004	-14.0655
SC 3	TD-12	90	1/9/2002	2/11/2004	-14.0614
SC 3	TD-12	90	2/15/2002	9/17/2003	-13.3172
SC 3	TD-12	90	3/15/2002	9/22/2003	-13.1098
SC 3	TD-12	90	4/5/2002	9/22/2003	-13.4381

Lysimeter ID	Sample Location	Depth Below Land Surface (cm)	Sample Date	Run Date	$\delta^{18}O$ (‰)
SC 3	TD-12	90	4/19/2002	9/24/2003	-13.7923
SC 3	TD-12	90	5/3/2002	9/25/2003	-12.8330
SC 3	TD-12	90	5/16/2002	9/26/2003	-14.1247
SC 3	TD-12	90	5/30/2002	9/27/2003	-13.0154
SC 3	TD-12	90	6/13/2002	9/30/2003	-14.3217
SC 3	TD-12	90	6/27/2002	10/1/2003	-13.6273
SC 3	TD-12	90	7/11/2002	10/1/2003	-13.6573
SC 3	TD-12	90	7/25/2002	10/1/2003	-13.9657
SC 3	TD-12	90	1/30/2004	7/26/2004	-13.8322
SC 3	TD-12	90	2/20/2004	7/28/2004	-14.3214
SC 3	TD-12	90	3/12/2004	7/30/2004	-14.0244
SC 3	TD-12	90	3/26/2004	7/30/2004	-13.7454
SC 3	TD-12	90	4/9/2004	7/30/2004	-14.0856
SC 3	TD-12	90	5/7/2004	8/2/2004	-13.9477
SC 3	TD-12	90	5/28/2004	8/2/2004	-14.4562
SC 3	TD-12	90	6/25/2004	8/3/2004	-14.7852
SC 5	TD-12	40	2/19/2001	2/4/2004	-14.0745
SC 5	TD-12	40	3/3/2001	2/4/2004	-14.0462
SC 5	TD-12	40	3/21/2001	2/5/2004	-14.0985
SC 5	TD-12	40	4/8/2001	2/5/2004	-13.8592
SC 5	TD-12	40	5/4/2001	2/7/2004	-13.8721
SC 5	TD-12	40	5/21/2001	2/7/2004	-13.8106
SC 5	TD-12	40	12/23/2001	2/10/2004	-12.5829
SC 5	TD-12	40	1/7/2002	2/10/2004	-13.4396
SC 5	TD-12	40	2/15/2002	9/17/2003	-14.3475
SC 5	TD-12	40	3/15/2002	9/22/2003	-14.6449
SC 5	TD-12	40	4/5/2002	9/22/2003	-15.5387
SC 5	TD-12	40	4/19/2002	9/24/2003	-15.6541
SC 5	TD-12	40	5/3/2002	9/25/2003	-14.6697
SC 5	TD-12	40	5/16/2002	9/26/2003	-15.8933
SC 5	TD-12	40	5/30/2002	9/27/2003	-14.7258
SC 5	TD-12	40	6/13/2002	9/30/2003	-15.8596
SC 5	TD-12	40	1/30/2004	7/26/2004	-15.9012
SC 5	TD-12	40	2/20/2004	7/28/2004	-15.6546
SC 5	TD-12	40	3/12/2004	7/30/2004	-16.7986
SC 5	TD-12	40	3/26/2004	7/30/2004	-16.6656
SC 5	TD-12	40	4/9/2004	7/30/2004	-16.7404

Lysimeter ID	Sample Location	Depth Below Land Surface (cm)	Sample Date	Run Date	$\delta^{18}O$ (‰)
SC 5	TD-12	40	5/7/2004	8/2/2004	-16.5518
SC 5	TD-12	40	1/12/2005	4/25/2005	-13.8769
SC 5	TD-12	40	2/11/2005	4/25/2005	-12.6537
SC 5	TD-12	40	3/10/2005	4/26/2005	-13.1702
SC 5	TD-12	40	4/8/2005	4/28/2005	-12.8235
SC 6	TD-12	88	2/15/2002	9/17/2003	-12.9993
SC 6	TD-12	88	3/15/2002	9/22/2003	-12.7757
SC 6	TD-12	88	1/30/2004	7/26/2004	-13.6032
SC 6	TD-12	88	2/20/2004	7/28/2004	-13.7647
SC 6	TD-12	88	12/13/2004	4/23/2005	-14.1934
SC 6	TD-12	88	2/11/2005	4/25/2005	-14.3967
SC 7	TD-12	32	3/15/2002	9/22/2003	-13.1343
SC 8	TD-12	44	3/21/2001	2/5/2004	-12.9236
SC 8	TD-12	44	1/7/2002	2/11/2004	-10.8543
SC 8	TD-12	44	4/19/2002	9/24/2003	-15.7690
SC 8	TD-12	44	5/3/2002	9/25/2003	-15.5443
SC 8	TD-12	44	5/16/2002	9/26/2003	-16.0375
SC 8	TD-12	44	5/30/2002	9/27/2003	-14.9052
SC 8	TD-12	44	6/13/2002	9/30/2003	-13.6664
SC 8	TD-12	44	1/30/2004	7/26/2004	-12.9123
SC 8	TD-12	44	2/20/2004	7/28/2004	-16.1593
SC 9	TD-12	84	10/27/2000	8/3/2004	-14.1709
SC 9	TD-12	84	4/16/2001	2/6/2004	-14.0472
SC 9	TD-12	84	5/4/2001	2/7/2004	-14.0280
SC 9	TD-12	84	5/21/2001	2/7/2004	-14.0257
SC 9	TD-12	84	5/30/2001	2/7/2004	-13.9811
SC 9	TD-12	84	6/14/2001	2/7/2004	-14.2032
SC 9	TD-12	84	7/12/2001	2/10/2004	-12.1552
SC 9	TD-12	84	2/15/2002	9/17/2003	-13.3651
SC 9	TD-12	84	4/5/2002	9/22/2003	-13.3744
SC 9	TD-12	84	4/19/2002	9/24/2003	-13.5724
SC 9	TD-12	84	5/16/2002	9/26/2003	-14.1335
SC 9	TD-12	84	5/30/2002	9/27/2003	-13.1323
SC 9	TD-12	84	6/13/2002	9/30/2003	-14.0307
SC 9	TD-12	84	6/27/2002	10/1/2003	-13.8302
SC 9	TD-12	84	7/11/2002	10/1/2003	-14.1388
SC 9	TD-12	84	2/20/2004	7/28/2004	-14.4588

Lysimeter ID	Sample Location	Depth Below Land Surface (cm)	Sample Date	Run Date	$\delta^{18}O$ (‰)
SC 9	TD-12	84	3/12/2004	7/30/2004	-14.3101
SC 9	TD-12	84	3/26/2004	7/30/2004	-14.0156
SC 9	TD-12	84	4/9/2004	7/30/2004	-14.5403
SC 9	TD-12	84	5/7/2004	8/2/2004	-14.3717
SC 9	TD-12	84	5/28/2004	8/2/2004	-14.5694
SC 9	TD-12	84	6/25/2004	8/3/2004	-15.1506
SC 9	TD-12	84	12/13/2004	4/23/2005	-14.2201
SC 9	TD-12	84	2/11/2005	4/25/2005	-14.7824
SC 9	TD-12	84	3/10/2005	4/26/2005	-13.4622
SC 9	TD-12	84	4/8/2005	4/28/2005	-13.7933
SS 1	TD-12	30	3/21/2001	2/5/2004	-15.0362
SS 1	TD-12	30	3/1/2002	9/17/2003	-15.7603
SS 1	TD-12	30	3/15/2002	9/22/2003	-14.1140
SS 1	TD-12	30	1/30/2004	7/26/2004	-16.9883
SS 1	TD-12	30	2/20/2004	7/28/2004	-17.0708
SS 2	TD-12	43	3/3/2001	2/4/2004	-14.0593
SS 2	TD-12	43	3/21/2001	2/5/2004	-13.7486
SS 2	TD-12	43	4/16/2001	8/3/2004	-13.3708
SS 2	TD-12	43	5/4/2001	2/6/2004	-13.5694
SS 2	TD-12	43	5/17/2001	2/7/2004	-13.5517
SS 2	TD-12	43	5/31/2001	2/7/2004	-13.6680
SS 2	TD-12	43	2/14/2002	9/17/2003	-12.1311
SS 2	TD-12	43	3/15/2002	9/22/2003	-14.3037
SS 2	TD-12	43	4/5/2002	9/22/2003	-15.1359
SS 2	TD-12	43	4/19/2002	9/24/2003	-15.6515
SS 2	TD-12	43	5/3/2002	9/25/2003	-15.1798
SS 2	TD-12	43	5/16/2002	9/26/2003	-15.6143
SS 2	TD-12	43	5/30/2002	9/27/2003	-14.6163
SS 2	TD-12	43	6/13/2002	9/27/2003	-14.5891
SS 2	TD-12	43	6/27/2002	10/1/2003	-14.6845
SS 2	TD-12	43	1/30/2004	7/26/2004	-13.0716
SS 2	TD-12	43	2/20/2004	7/28/2004	-14.3222
SS 2	TD-12	43	3/12/2004	7/29/2004	-15.6361
SS 2	TD-12	43	3/26/2004	7/30/2004	-15.6219
SS 2	TD-12	43	4/9/2004	7/30/2004	-16.0039
SS 2	TD-12	43	5/28/2004	8/2/2004	-16.0005
SS 2	TD-12	43	2/11/2005	4/25/2005	-14.2445

Lysimeter ID	Sample Location	Depth Below Land Surface (cm)	Sample Date	Run Date	$\delta^{18}O$ (‰)
SS 2	TD-12	43	4/8/2005	4/28/2005	-12.5047
SS 4	TD-12	23	5/4/2001	2/7/2004	-15.2048
SS 4	TD-12	23	5/17/2001	2/7/2004	-14.9103
SS 4	TD-12	23	12/22/2001	2/10/2004	-14.9091
SS 4	TD-12	23	2/14/2002	9/17/2003	-15.1607
SS 4	TD-12	23	3/1/2002	9/17/2003	-16.0114
SS 4	TD-12	23	3/15/2002	9/22/2003	-14.5867
SS 4	TD-12	23	4/5/2002	9/22/2003	-15.6332
SS 4	TD-12	23	4/19/2002	9/24/2003	-15.7271
SS 4	TD-12	23	5/3/2002	9/25/2003	-14.3254
SS 4	TD-12	23	5/16/2002	9/26/2003	-15.9860
SS 4	TD-12	23	5/30/2002	9/27/2003	-14.6825
SS 4	TD-12	23	6/13/2002	9/27/2003	-14.7611
SS 4	TD-12	23	6/27/2002	10/1/2003	-12.9929
SS 4	TD-12	23	1/30/2004	7/26/2004	-16.6865
SS 4	TD-12	23	2/20/2004	7/28/2004	-17.1243
SS 4	TD-12	23	3/12/2004	7/29/2004	-17.4433
SS 4	TD-12	23	3/26/2004	7/30/2004	-17.3548
SS 4	TD-12	23	2/11/2005	4/25/2005	-15.9564
SS 4	TD-12	23	3/10/2005	4/26/2005	-14.6049
SS 4	TD-12	23	4/8/2005	4/28/2005	-13.5052
SS 5	TD-12	45	3/21/2001	2/5/2004	-13.1823
SS 5	TD-12	45	4/8/2001	2/5/2004	-13.0421
SS 5	TD-12	45	5/4/2001	2/7/2004	-12.9939
SS 5	TD-12	45	5/17/2001	2/7/2004	-13.0044
SS 5	TD-12	45	2/14/2002	9/17/2003	-14.1926
SS 5	TD-12	45	3/1/2002	9/17/2003	-14.6857
SS 5	TD-12	45	3/15/2002	9/22/2003	-14.7924
SS 5	TD-12	45	4/5/2002	9/22/2003	-15.5223
SS 5	TD-12	45	4/19/2002	9/24/2003	-15.0984
SS 5	TD-12	45	5/3/2002	9/25/2003	-14.8631
SS 5	TD-12	45	5/16/2002	9/26/2003	-16.0645
SS 5	TD-12	45	5/30/2002	9/27/2003	-14.7553
SS 5	TD-12	45	6/13/2002	9/27/2003	-14.7860
SS 5	TD-12	45	6/27/2002	10/1/2003	-14.4443
SS 5	TD-12	45	1/30/2004	7/26/2004	-13.6218
SS 5	TD-12	45	2/20/2004	7/28/2004	-14.7173

Lysimeter ID	Sample Location	Depth Below Land Surface (cm)	Sample Date	Run Date	$\delta^{18}O$ (‰)
SS 5	TD-12	45	3/12/2004	7/29/2004	-16.1560
SS 5	TD-12	45	3/26/2004	7/30/2004	-16.1787
SS 5	TD-12	45	4/9/2004	7/30/2004	-16.2552
SS 5	TD-12	45	5/7/2004	8/2/2004	-14.9473
SS 5	TD-12	45	12/13/2004	4/23/2005	-12.9578
SS 5	TD-12	45	2/11/2005	4/25/2005	-13.3028
SS 7	TD-12	30	3/3/2001	2/4/2004	-12.9080
SS 7	TD-12	30	3/21/2001	2/5/2004	-13.1351
SS 7	TD-12	30	5/4/2001	2/7/2004	-13.5444
SS 7	TD-12	30	5/17/2001	2/7/2004	-13.7618
SS 7	TD-12	30	12/22/2001	2/10/2004	-11.4953
SS 7	TD-12	30	2/14/2002	9/17/2003	-13.5878
SS 7	TD-12	30	3/1/2002	9/17/2003	-13.6953
SS 7	TD-12	30	3/15/2002	9/22/2003	-14.0564
SS 7	TD-12	30	4/5/2002	9/22/2003	-15.3648
SS 7	TD-12	30	4/19/2002	9/24/2003	-15.6752
SS 7	TD-12	30	5/3/2002	9/25/2003	-14.5082
SS 7	TD-12	30	5/16/2002	9/26/2003	-13.7654
SS 7	TD-12	30	1/30/2004	7/26/2004	-13.6218
SS 7	TD-12	30	2/20/2004	7/28/2004	-15.0226
SS 7	TD-12	30	3/12/2004	7/30/2004	-16.2945
SS 7	TD-12	30	2/11/2005	4/25/2005	-15.7259
SS 7	TD-12	30	4/8/2005	4/28/2005	-12.8225
SS 8	TD-12	46	3/21/2001	2/5/2004	-12.8943
SS 8	TD-12	46	5/4/2001	2/7/2004	-12.5470
SS 8	TD-12	46	5/17/2001	2/7/2004	-12.7963
SS 8	TD-12	46	2/14/2002	9/17/2003	-11.0379
SS 8	TD-12	46	3/15/2002	9/22/2003	-13.0816
SS 8	TD-12	46	4/5/2002	9/22/2003	-15.0392
SS 8	TD-12	46	4/19/2002	9/24/2003	-14.0589
SS 8	TD-12	46	5/16/2002	9/26/2003	-15.4426
SS 8	TD-12	46	5/30/2002	9/27/2003	-14.2270
SS 8	TD-12	46	6/13/2002	9/30/2003	-15.0731
SS 8	TD-12	46	6/27/2002	10/1/2003	-14.1455
SS 8	TD-12	46	2/20/2004	7/28/2004	-13.9974
SS 8	TD-12	46	3/12/2004	7/30/2004	-15.3194
SS 8	TD-12	46	3/26/2004	7/30/2004	-14.9757

Lysimeter ID	Sample Location	Depth Below Land Surface (cm)	Sample Date	Run Date	$\delta^{18}O$ (‰)
SS 8	TD-12	46	4/9/2004	7/30/2004	-16.4750
SS 8	TD-12	46	5/7/2004	8/2/2004	-16.3644
SS 8	TD-12	46	5/28/2004	8/2/2004	-16.5599
SS 8	TD-12	46	12/13/2004	4/23/2005	-14.4463
SS 8	TD-12	46	2/11/2005	4/25/2005	-13.9857
SS 8	TD-12	46	3/10/2005	4/26/2005	-13.1629
SS 8	TD-12	46	4/8/2005	4/28/2005	-12.5179

APPENDIX H: Discharge data for Missouri Flat Creek sampling locations

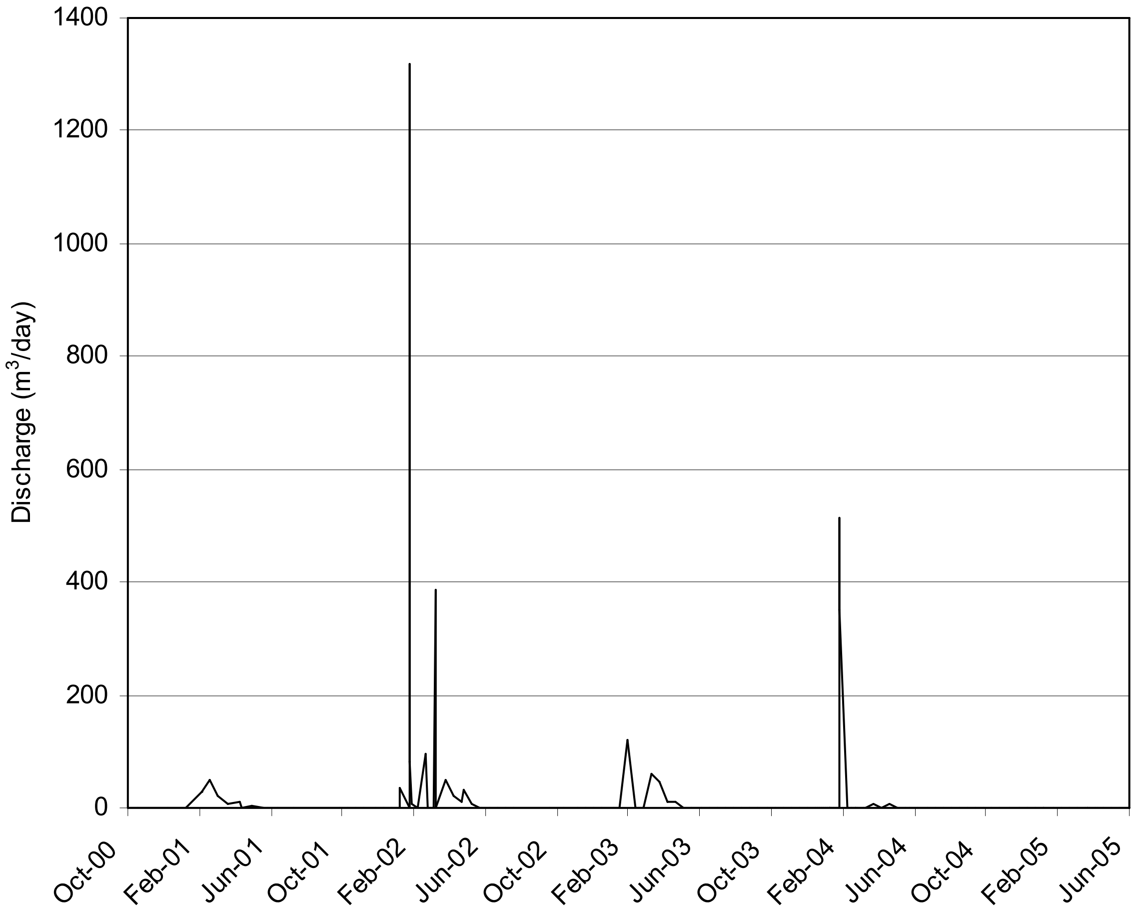

Figure H1: ES-6 hydrograph

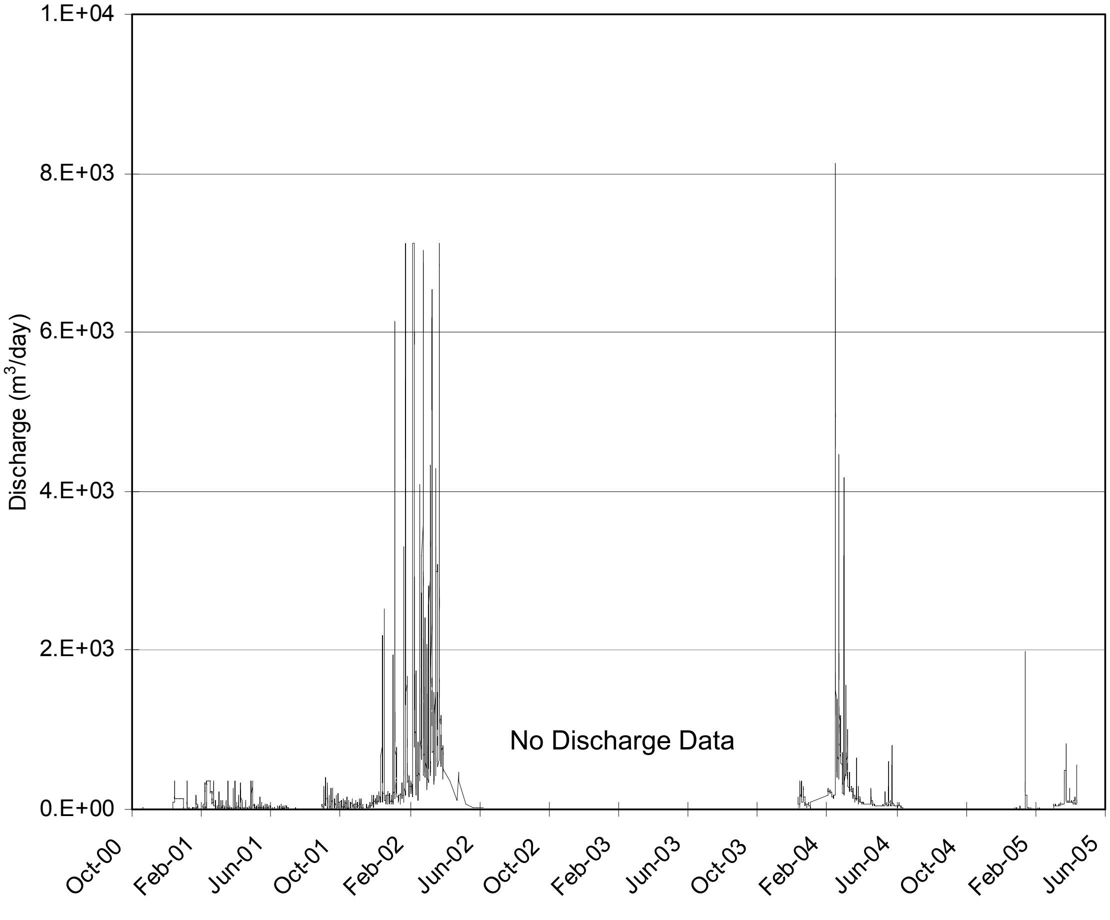

Figure H2: ES-106 hydrograph

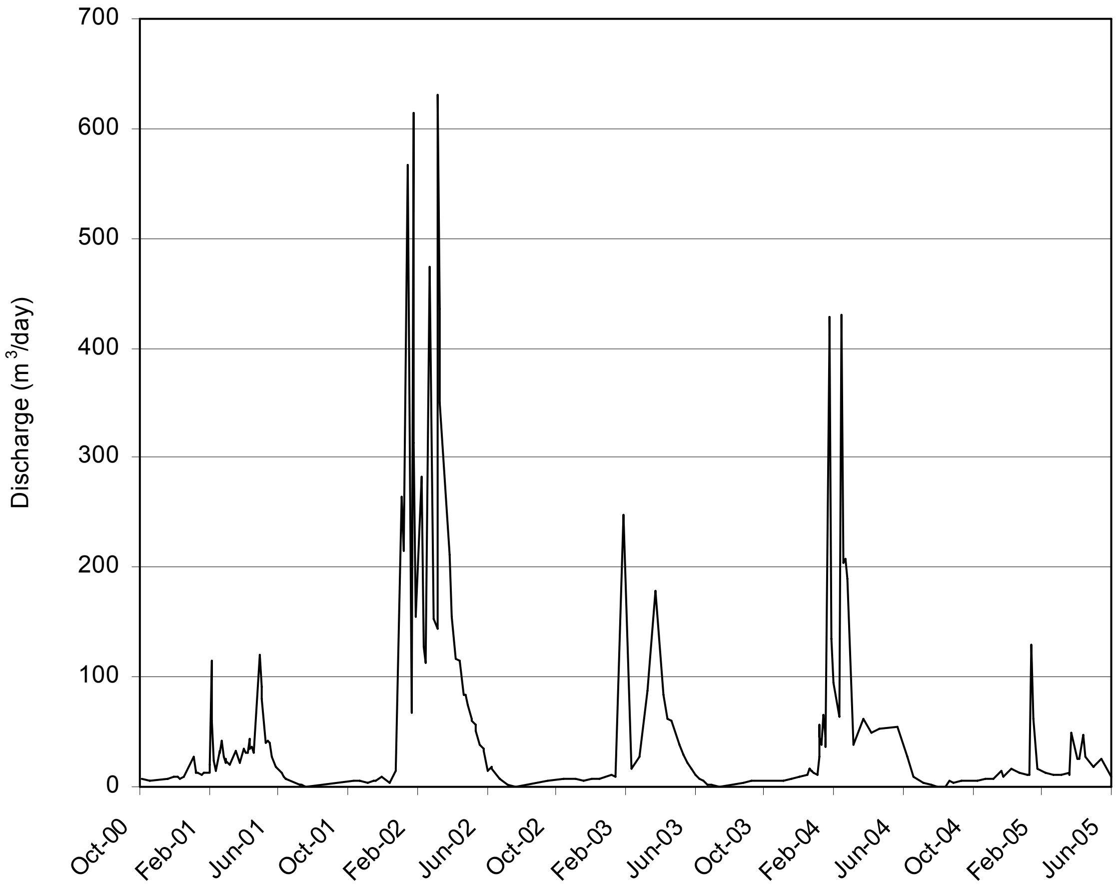

Figure H3: TD-12 hydrograph

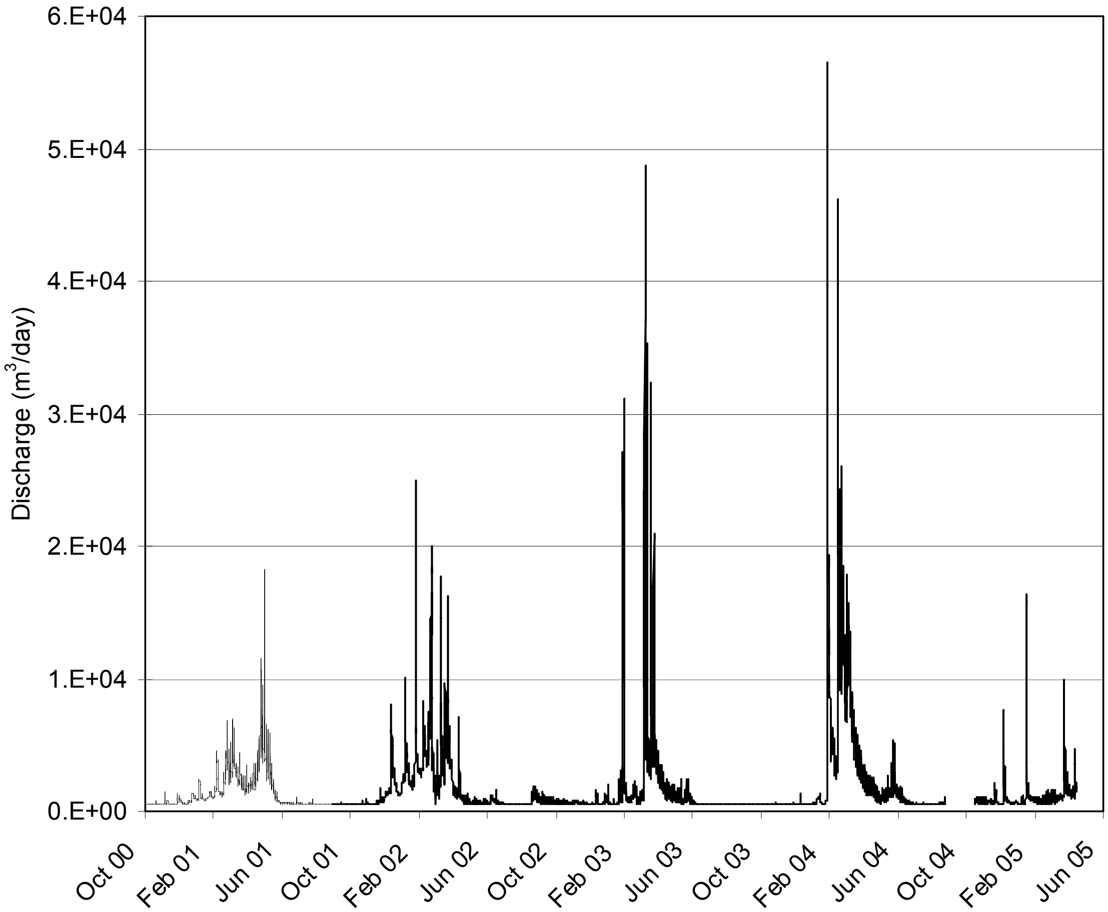

Figure H4: MFC-660 hydrograph

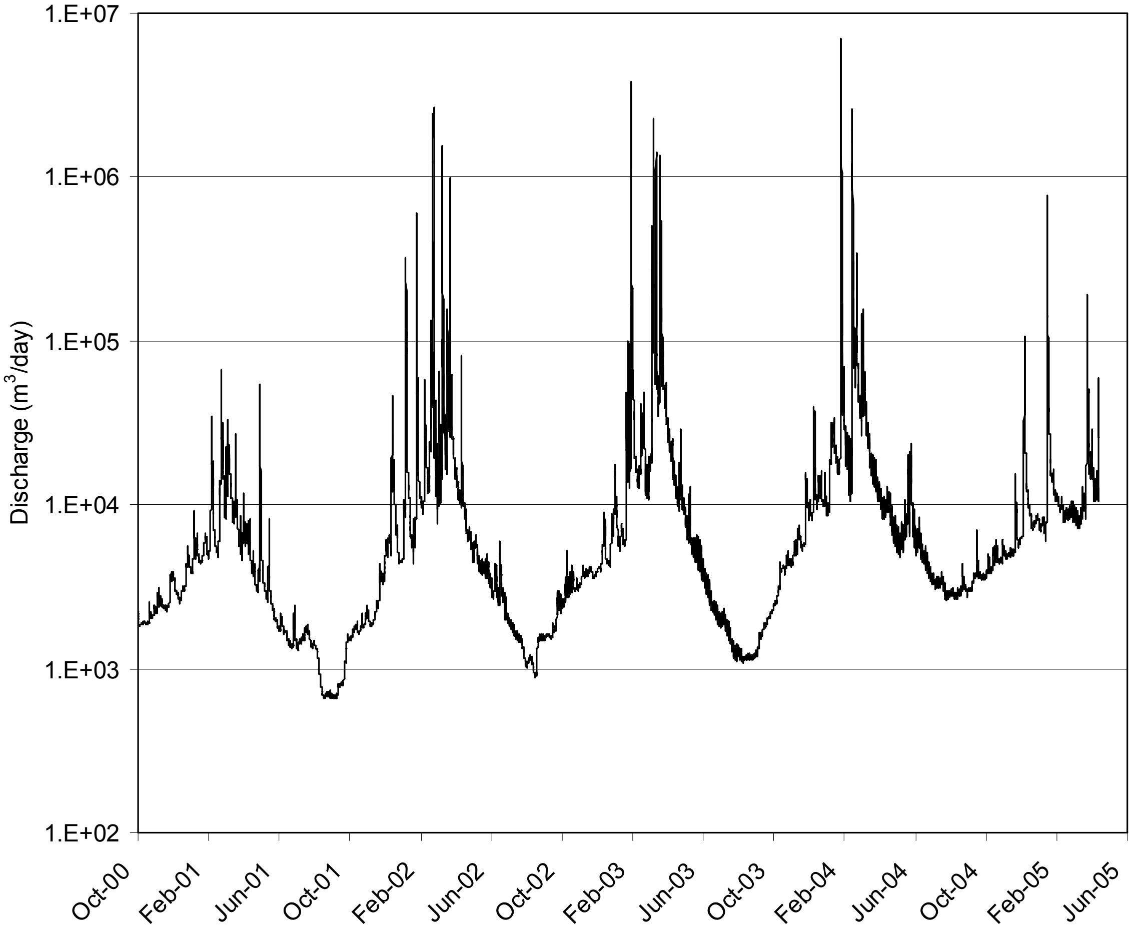

Figure H5: MFC-4700 hydrograph

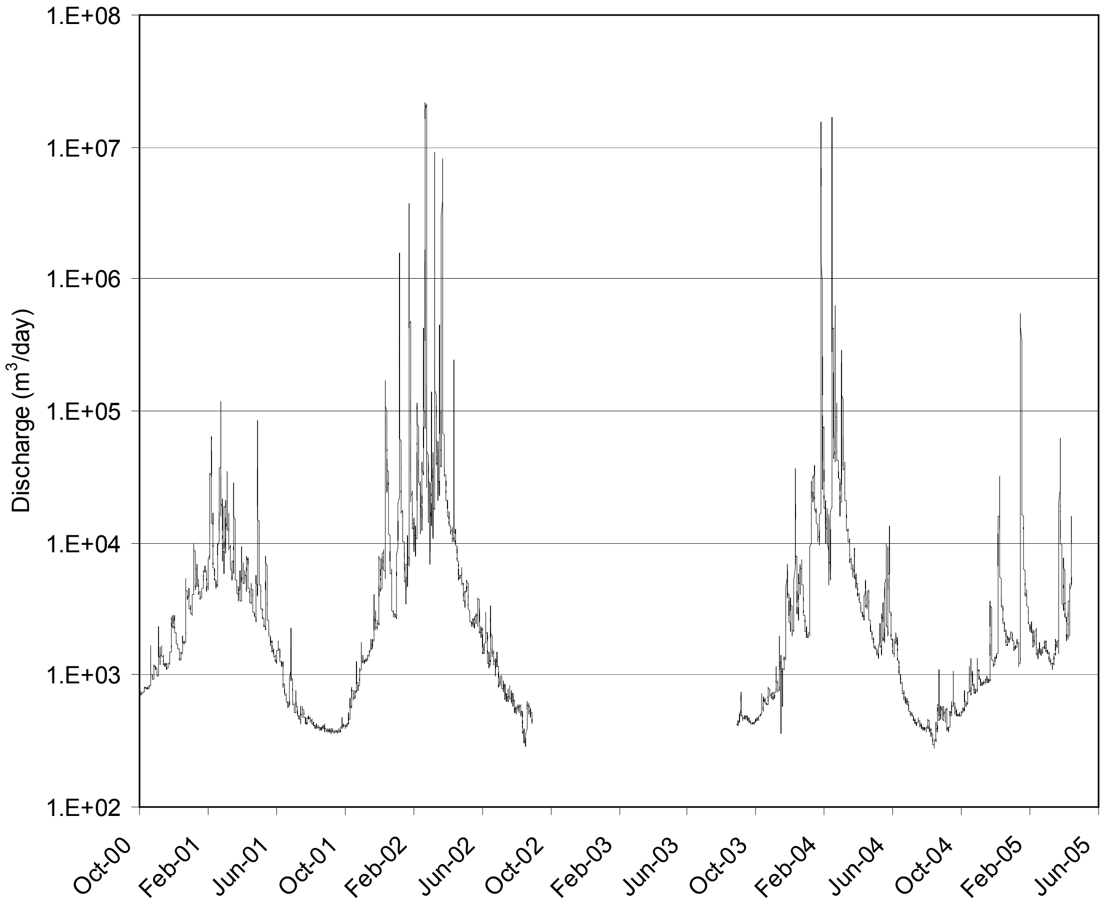

Figure H6: MFC-5700 hydrograph

APPENDIX I: EC data for Missouri Flat Creek sampling locations

Two corrections were applied to the raw EC data (not shown) and are discussed in section 2.4. The meter corrected EC adjusts for the differences in true and observed EC values due to meter calibrations. The EC correction adjusts for the effect of dissolved nitrate salts on EC. The nitrate corrected EC is the accurate EC value.

Sample Location	Sample Date	Meter Corrected EC (uS/cm)	EC Correction	Nitrate Corrected EC (uS/cm)
ES-6	2/5/2001	414.09	23.15	390.93
ES-6	2/6/2001	446.49	331.86	114.63
ES-6	2/19/2001	427.80	348.11	79.69
ES-6	3/3/2001	394.15	267.80	126.35
ES-6	3/20/2001	394.15	259.08	135.07
ES-6	4/12/2001	431.53	244.57	186.96
ES-6	5/2/2001	382.94	302.21	80.73
ES-6	1/7/2002	102.95	45.11	57.83
ES-6	1/9/2002	162.27	80.15	82.12
ES-6	1/24/2002	168.50	57.32	111.18
ES-6	1/25/2002	79.32	42.34	36.98
ES-6	1/26/2002	106.95	42.18	64.77
ES-6	1/27/2002	129.13	50.11	79.02
ES-6	1/29/2002	180.84	70.01	110.83
ES-6	2/8/2002	136.11	57.72	78.39
ES-6	2/22/2002	132.74	56.93	75.82
ES-6	3/8/2002	177.85	61.05	116.80
ES-6	3/11/2002	125.52	49.63	75.88
ES-6	3/29/2002	153.92	25.93	127.99
ES-6	4/12/2002	204.51	7.85	196.66
ES-6	4/26/2002	222.21	1.35	220.85
ES-6	4/27/2002	216.47	1.67	214.80
ES-6	5/10/2002	273.29	5.71	267.58
ES-6	1/31/2003	247.13	62.95	184.17
ES-6	2/14/2003	439.01	54.14	384.86
ES-6	3/14/2003	376.71	180.89	195.82
ES-6	3/28/2003	432.78	82.02	350.76
ES-6	4/11/2003	391.66	136.39	255.27
ES-6	4/25/2003	316.90	105.01	211.89
ES-6	1/29/2004	140.25	-	-
ES-6	1/29/2004	147.78	-	-
ES-6	1/30/2004	162.00	99.74	62.26

Sample Location	Sample Date	Meter Corrected EC (uS/cm)	EC Correction	Nitrate Corrected EC (uS/cm)
ES-6	2/24/2004	190.43	103.30	87.13
ES-6	2/26/2004	184.33	99.97	84.35
ES-6	2/27/2004	183.08	-	-
ES-6	3/12/2004	144.70	39.33	105.38
ES-6	3/26/2004	228.44	17.45	210.99
ES-6	4/9/2004	274.54	15.94	258.60
ES-6	4/23/2004	295.72	-	-
ES-6	5/28/2004	314.41	3.73	310.68
ES-6	3/27/2005	347.22	250.99	96.23
ES-106	2/3/2001	311.92	135.17	176.75
ES-106	2/19/2001	255.85	109.25	146.60
ES-106	3/2/2001	188.44	90.46	97.98
ES-106	3/20/2001	372.97	96.09	276.88
ES-106	4/9/2001	375.46	112.82	262.65
ES-106	5/2/2001	402.88	212.23	190.65
ES-106	5/17/2001	445.24	113.21	332.03
ES-106	1/9/2002	144.58	34.33	110.25
ES-106	1/24/2002	172.99	34.89	138.10
ES-106	1/25/2002	77.82	28.94	48.88
ES-106	1/26/2002	124.39	47.49	76.90
ES-106	1/27/2002	156.67	64.22	92.45
ES-106	1/29/2002	199.53	63.59	135.94
ES-106	2/22/2002	156.79	72.86	83.93
ES-106	2/24/2002	158.04	62.00	96.04
ES-106	3/8/2002	209.87	98.47	111.40
ES-106	3/11/2002	127.14	45.99	81.15
ES-106	3/12/2002	170.62	56.29	114.33
ES-106	3/29/2002	187.19	-0.15	187.34
ES-106	4/12/2002	220.71	18.40	202.31
ES-106	4/26/2002	262.08	10.47	251.61
ES-106	4/27/2002	233.42	4.84	228.58
ES-106	5/10/2002	282.01	13.80	268.21
ES-106	5/24/2002	274.54	1.99	272.55
ES-106	5/28/2002	294.47	0.88	293.59
ES-106	6/11/2002	272.05	0.24	271.80
ES-106	1/31/2003	233.42	65.70	167.72
ES-106	2/14/2003	339.33	102.46	236.87

Sample Location	Sample Date	Meter Corrected EC (uS/cm)	EC Correction	Nitrate Corrected EC (uS/cm)
ES-106	2/28/2003	358.02	90.65	267.37
ES-106	3/14/2003	339.33	141.96	197.37
ES-106	3/28/2003	321.89	171.51	150.37
ES-106	4/11/2003	330.61	123.05	207.56
ES-106	4/25/2003	328.12	79.16	248.95
ES-106	5/9/2003	326.87	125.74	201.13
ES-106	5/23/2003	320.64	87.49	233.15
ES-106	12/19/2003	330.92	114.56	216.36
ES-106	12/22/2003	242.27	68.66	173.62
ES-106	12/25/2003	233.08	59.46	173.61
ES-106	1/11/2004	282.41	-	-
ES-106	1/12/2004	150.29	43.13	107.16
ES-106	1/16/2004	175.38	50.74	124.63
ES-106	1/19/2004	207.15	-	-
ES-106	1/29/2004	111.32	55.66	55.66
ES-106	1/29/2004	131.56	66.68	64.88
ES-106	1/30/2004	216.35	148.41	67.94
ES-106	2/13/2004	428.76	264.55	164.21
ES-106	2/24/2004	230.93	119.08	111.85
ES-106	2/26/2004	270.80	155.23	115.57
ES-106	2/27/2004	269.55	145.32	124.23
ES-106	3/26/2004	284.51	92.12	192.38
ES-106	4/9/2004	386.68	171.88	214.80
ES-106	4/23/2004	346.81	124.31	222.49
ES-106	5/7/2004	396.65	147.78	248.87
ES-106	5/21/2004	358.02	50.11	307.91
ES-106	5/28/2004	374.22	50.90	323.32
ES-106	6/11/2004	391.66	72.15	319.51
ES-106	12/13/2004	512.15	238.94	273.20
TD-12	10/6/2000	338.08	33.54	304.54
TD-12	12/7/2000	325.62	43.45	282.17
TD-12	1/9/2001	324.38	62.48	261.90
TD-12	2/2/2001	320.64	54.07	266.57
TD-12	2/6/2001	426.55	175.60	250.95
TD-12	2/19/2001	354.28	127.88	226.40
TD-12	3/2/2001	341.82	108.85	232.97
TD-12	3/20/2001	330.61	191.46	139.15

Sample Location	Sample Date	Meter Corrected EC (uS/cm)	EC Correction	Nitrate Corrected EC (uS/cm)
TD-12	4/9/2001	341.82	102.11	239.71
TD-12	4/16/2001	323.13	110.60	212.53
TD-12	5/2/2001	380.45	176.24	204.21
TD-12	5/21/2001	350.54	191.62	158.93
TD-12	5/30/2001	321.89	105.28	216.60
TD-12	6/14/2001	334.35	85.31	249.04
TD-12	7/11/2001	321.89	46.70	275.19
TD-12	9/27/2001	287.00	31.32	255.68
TD-12	10/13/2001	298.21	25.06	273.15
TD-12	10/24/2001	284.51	17.13	267.38
TD-12	11/7/2001	280.77	32.11	248.65
TD-12	11/30/2001	335.59	74.37	261.22
TD-12	12/14/2001	426.55	220.00	206.55
TD-12	12/27/2001	323.13	105.13	218.00
TD-12	1/9/2002	351.79	228.00	123.79
TD-12	1/24/2002	331.85	160.94	170.92
TD-12	1/25/2002	326.87	211.75	115.12
TD-12	1/26/2002	351.79	242.75	109.04
TD-12	1/27/2002	350.54	-	-
TD-12	1/29/2002	351.79	217.14	134.65
TD-12	2/8/2002	325.62	205.25	120.37
TD-12	2/22/2002	291.98	199.70	92.28
TD-12	2/24/2002	318.15	209.53	108.61
TD-12	3/8/2002	315.66	171.24	144.41
TD-12	3/11/2002	295.72	172.51	123.21
TD-12	3/12/2002	306.93	190.74	116.19
TD-12	3/29/2002	334.35	165.85	168.49
TD-12	4/12/2002	329.36	56.69	272.67
TD-12	4/26/2002	329.36	121.62	207.75
TD-12	4/27/2002	328.12	85.86	242.25
TD-12	5/10/2002	323.13	127.80	195.33
TD-12	5/24/2002	360.51	109.80	250.71
TD-12	5/28/2002	349.30	108.30	241.00
TD-12	6/11/2002	356.77	94.66	262.11
TD-12	6/25/2002	311.92	56.21	255.70
TD-12	7/9/2002	303.20	60.65	242.54
TD-12	9/20/2002	304.44	27.95	276.49

Sample Location	Sample Date	Meter Corrected EC (uS/cm)	EC Correction	Nitrate Corrected EC (uS/cm)
TD-12	10/16/2002	275.78	29.92	245.86
TD-12	11/8/2002	295.72	29.90	265.82
TD-12	11/20/2002	287.00	30.11	256.88
TD-12	12/4/2002	288.24	30.10	258.14
TD-12	12/19/2002	294.47	36.17	258.31
TD-12	1/10/2003	298.21	1.93	296.28
TD-12	1/17/2003	268.31	31.95	236.36
TD-12	1/31/2003	411.60	101.61	309.99
TD-12	2/14/2003	311.92	79.76	232.16
TD-12	2/28/2003	330.61	60.90	269.71
TD-12	3/14/2003	333.10	104.01	229.09
TD-12	3/28/2003	321.89	63.83	258.06
TD-12	4/11/2003	324.38	127.98	196.39
TD-12	4/25/2003	314.41	116.98	197.43
TD-12	5/9/2003	320.64	93.28	227.36
TD-12	5/23/2003	313.16	83.01	230.16
TD-12	6/6/2003	331.85	77.69	254.17
TD-12	6/20/2003	315.66	85.40	230.26
TD-12	7/4/2003	303.20	33.58	269.62
TD-12	8/1/2003	1.98	9.27	-7.29
TD-12	8/15/2003	288.24	17.74	270.51
TD-12	8/29/2003	299.46	26.11	273.35
TD-12	9/12/2003	290.74	28.06	262.67
TD-12	9/27/2003	290.74	29.12	261.62
TD-12	10/13/2003	290.74	30.47	260.27
TD-12	10/24/2003	289.49	33.09	256.40
TD-12	11/7/2003	283.26	30.79	252.47
TD-12	11/21/2003	276.56	33.15	243.41
TD-12	12/5/2003	275.72	38.63	237.10
TD-12	12/19/2003	288.27	53.91	234.35
TD-12	12/22/2003	297.47	58.12	239.35
TD-12	12/25/2003	299.14	59.94	239.20
TD-12	12/28/2003	283.25	52.57	230.68
TD-12	12/31/2003	292.45	52.17	240.28
TD-12	1/5/2004	295.79	41.71	254.09
TD-12	1/9/2004	321.72	88.32	233.40
TD-12	1/10/2004	300.81	132.71	168.10

Sample Location	Sample Date	Meter Corrected EC (uS/cm)	EC Correction	Nitrate Corrected EC (uS/cm)
TD-12	1/11/2004	306.67	100.61	206.06
TD-12	1/12/2004	299.14	121.46	177.68
TD-12	1/16/2004	326.74	112.50	214.24
TD-12	1/19/2004	315.86	106.79	209.07
TD-12	1/29/2004	257.33	158.64	98.69
TD-12	1/29/2004	248.96	156.97	91.99
TD-12	1/30/2004	238.93	149.84	89.09
TD-12	2/13/2004	315.86	136.12	179.74
TD-12	2/24/2004	304.44	146.90	157.54
TD-12	2/26/2004	294.47	144.84	149.63
TD-12	2/27/2004	294.47	144.84	149.63
TD-12	3/12/2004	285.75	133.82	151.93
TD-12	3/26/2004	309.43	121.06	188.36
TD-12	4/9/2004	320.64	127.96	192.68
TD-12	4/23/2004	339.33	141.12	198.21
TD-12	5/7/2004	340.58	105.60	234.97
TD-12	5/21/2004	334.35	93.95	240.40
TD-12	5/28/2004	336.84	98.31	238.53
TD-12	6/11/2004	331.85	95.06	236.79
TD-12	6/25/2004	311.92	76.03	235.89
TD-12	7/9/2004	305.69	61.05	244.64
TD-12	7/23/2004	304.44	39.72	264.72
TD-12	9/3/2004	295.72	28.86	266.86
TD-12	9/17/2004	288.24	28.94	259.30
TD-12	10/1/2004	294.47	30.84	263.63
TD-12	10/15/2004	305.69	31.00	274.68
TD-12	10/29/2004	305.69	31.16	274.53
TD-12	11/12/2004	252.18	30.77	221.42
TD-12	11/29/2004	272.80	33.06	239.74
TD-12	12/13/2004	280.14	52.01	228.13
TD-12	12/27/2004	273.50	38.61	234.88
TD-12	1/11/2005	267.91	37.27	230.64
TD-12	1/12/2005	266.51	36.79	229.72
TD-12	1/28/2005	267.91	56.29	211.62
TD-12	2/11/2005	252.53	49.79	202.74
TD-12	2/25/2005	271.75	37.19	234.56
TD-12	3/10/2005	243.80	36.16	207.64

Sample Location	Sample Date	Meter Corrected EC (uS/cm)	EC Correction	Nitrate Corrected EC (uS/cm)
TD-12	3/23/2005	268.96	39.09	229.87
TD-12	3/25/2005	272.45	34.49	237.96
TD-12	3/27/2005	326.96	92.44	234.52
TD-12	3/29/2005	-	123.84	-123.84
TD-12	4/8/2005	299.01	-	-
TD-12	4/12/2005	285.73	-	-
TD-12	4/22/2005	283.98	-	-
TD-12	5/6/2005	287.47	-	-
TD-12	5/20/2005	319.62	-	-
TD-12	6/7/2005	308.44	-	-
MFC-660	10/6/2000	339.33	26.80	312.53
MFC-660	12/7/2000	341.82	34.17	307.65
MFC-660	1/9/2001	323.13	72.70	250.43
MFC-660	2/2/2001	273.29	52.65	220.65
MFC-660	2/19/2001	255.85	89.35	166.50
MFC-660	3/2/2001	323.13	150.31	172.82
MFC-660	3/20/2001	420.32	237.12	183.20
MFC-660	4/9/2001	384.19	135.65	248.54
MFC-660	4/16/2001	396.65	123.52	273.13
MFC-660	5/2/2001	346.68	125.98	220.70
MFC-660	5/21/2001	321.89	84.99	236.89
MFC-660	5/30/2001	326.87	85.39	241.48
MFC-660	6/15/2001	306.93	66.76	240.18
MFC-660	9/27/2001	295.72	36.39	259.33
MFC-660	10/13/2001	304.44	11.10	293.34
MFC-660	10/24/2001	306.93	7.54	299.40
MFC-660	11/7/2001	314.41	24.82	289.59
MFC-660	11/30/2001	356.77	139.45	217.32
MFC-660	12/14/2001	328.12	240.85	87.27
MFC-660	12/27/2001	384.19	215.08	169.10
MFC-660	1/9/2002	311.92	199.15	112.77
MFC-660	1/24/2002	326.87	169.58	157.29
MFC-660	1/25/2002	380.45	320.68	59.77
MFC-660	1/26/2002	299.46	192.25	107.21
MFC-660	1/27/2002	287.00	178.54	108.46
MFC-660	1/29/2002	344.31	214.37	129.94
MFC-660	2/8/2002	212.74	87.45	125.29

Sample Location	Sample Date	Meter Corrected EC (uS/cm)	EC Correction	Nitrate Corrected EC (uS/cm)
MFC-660	2/22/2002	204.76	97.52	107.25
MFC-660	2/24/2002	239.65	133.67	105.98
MFC-660	3/8/2002	269.55	111.79	157.77
MFC-660	3/12/2002	213.36	76.67	136.69
MFC-660	3/29/2002	290.74	137.39	153.34
MFC-660	4/12/2002	309.43	61.76	247.66
MFC-660	4/26/2002	323.13	51.46	271.67
MFC-660	4/27/2002	314.41	24.34	290.07
MFC-660	5/10/2002	329.36	90.86	238.50
MFC-660	5/24/2002	349.30	69.85	279.45
MFC-660	5/28/2002	331.85	54.71	277.15
MFC-660	6/11/2002	348.05	48.92	299.13
MFC-660	6/25/2002	324.38	47.18	277.20
MFC-660	7/9/2002	304.44	44.08	260.36
MFC-660	7/23/2002	287.00	31.00	255.99
MFC-660	9/20/2002	295.72	36.11	259.61
MFC-660	10/16/2002	316.90	30.21	286.69
MFC-660	11/8/2002	400.38	23.60	376.78
MFC-660	11/20/2002	313.16	26.81	286.35
MFC-660	12/4/2002	311.92	28.15	283.76
MFC-660	12/19/2002	299.46	29.82	269.63
MFC-660	1/10/2003	308.18	32.88	275.30
MFC-660	1/17/2003	306.93	36.14	270.79
MFC-660	1/31/2003	215.35	72.81	142.54
MFC-660	2/14/2003	335.59	79.03	256.56
MFC-660	2/28/2003	303.20	80.83	222.36
MFC-660	3/14/2003	291.98	81.07	210.91
MFC-660	3/28/2003	318.15	57.67	260.48
MFC-660	4/11/2003	330.61	134.28	196.33
MFC-660	4/25/2003	335.59	109.34	226.25
MFC-660	5/9/2003	341.82	89.41	252.41
MFC-660	5/23/2003	348.05	72.86	275.20
MFC-660	6/6/2003	355.53	64.94	290.59
MFC-660	6/20/2003	331.85	56.56	275.29
MFC-660	7/4/2003	282.01	31.68	250.33
MFC-660	7/18/2003	248.37	9.65	238.72
MFC-660	8/1/2003	265.82	30.36	235.46

Sample Location	Sample Date	Meter Corrected EC (uS/cm)	EC Correction	Nitrate Corrected EC (uS/cm)
MFC-660	8/15/2003	289.49	27.90	261.59
MFC-660	8/29/2003	282.01	29.23	252.78
MFC-660	9/12/2003	283.26	29.18	254.08
MFC-660	9/27/2003	277.03	31.63	245.40
MFC-660	10/13/2003	275.78	26.69	249.09
MFC-660	10/24/2003	294.47	28.87	265.61
MFC-660	11/7/2003	295.72	29.07	266.65
MFC-660	11/21/2003	281.58	20.29	261.29
MFC-660	12/5/2003	274.05	32.05	242.00
MFC-660	12/19/2003	295.79	61.76	234.03
MFC-660	1/5/2004	284.09	36.08	248.01
MFC-660	1/16/2004	260.67	-	-
MFC-660	1/29/2004	161.16	79.84	81.32
MFC-660	1/29/2004	256.49	129.70	126.79
MFC-660	1/30/2004	206.32	181.55	24.77
MFC-660	2/13/2004	464.72	268.83	195.88
MFC-660	2/24/2004	274.54	143.10	131.44
MFC-660	2/26/2004	260.83	146.43	114.40
MFC-660	2/27/2004	275.78	146.51	129.27
MFC-660	3/12/2004	289.49	141.83	147.66
MFC-660	3/26/2004	329.36	113.61	215.75
MFC-660	4/9/2004	385.43	159.91	225.53
MFC-660	4/23/2004	371.73	137.23	234.49
MFC-660	5/7/2004	328.12	81.74	246.38
MFC-660	5/21/2004	351.79	52.65	299.14
MFC-660	5/28/2004	344.31	67.71	276.61
MFC-660	6/11/2004	349.30	60.89	288.41
MFC-660	6/25/2004	318.15	58.83	259.32
MFC-660	7/9/2004	299.46	42.89	256.56
MFC-660	7/23/2004	305.69	27.91	277.78
MFC-660	8/6/2004	340.58	24.50	316.07
MFC-660	8/20/2004	284.51	27.99	256.51
MFC-660	9/3/2004	298.21	26.96	271.25
MFC-660	9/17/2004	301.95	29.34	272.61
MFC-660	10/1/2004	298.21	30.69	267.53
MFC-660	10/15/2004	316.90	25.22	291.69
MFC-660	10/29/2004	303.20	23.87	279.33

Sample Location	Sample Date	Meter Corrected EC (uS/cm)	EC Correction	Nitrate Corrected EC (uS/cm)
MFC-660	11/12/2004	263.02	22.12	240.89
MFC-660	11/29/2004	274.90	26.25	248.65
MFC-660	12/13/2004	268.96	57.24	211.71
MFC-660	12/27/2004	272.10	31.88	240.23
MFC-660	1/11/2005	269.31	30.37	238.94
MFC-660	1/12/2005	260.57	28.47	232.10
MFC-660	1/28/2005	272.80	53.76	219.04
MFC-660	2/11/2005	266.51	35.20	231.31
MFC-660	2/25/2005	268.96	33.94	235.02
MFC-660	3/10/2005	254.28	28.86	225.42
MFC-660	3/23/2005	271.40	20.06	251.34
MFC-660	3/25/2005	278.04	26.25	251.79
MFC-660	3/27/2005	288.52	87.69	200.84
MFC-660	3/29/2005	301.45	96.88	204.57
MFC-660	4/8/2005	303.90	-	-
MFC-660	4/12/2005	296.21	-	-
MFC-660	4/22/2005	305.64	-	-
MFC-660	5/6/2005	301.10	-	-
MFC-660	5/20/2005	345.13	-	-
MFC-660	6/7/2005	19.65	-	-
MFC-4700	12/7/2000	308.18	20.62	287.56
MFC-4700	1/9/2001	306.93	76.82	230.11
MFC-4700	2/19/2001	290.74	55.58	235.16
MFC-4700	3/2/2001	324.38	104.65	219.73
MFC-4700	3/20/2001	287.00	81.58	205.42
MFC-4700	4/9/2001	301.95	41.15	260.80
MFC-4700	4/16/2001	314.41	30.21	284.20
MFC-4700	5/2/2001	303.20	37.58	265.61
MFC-4700	5/21/2001	328.12	5.24	322.88
MFC-4700	5/30/2001	341.82	3.81	338.01
MFC-4700	6/15/2001	324.38	0.80	323.58
MFC-4700	7/11/2001	324.38	0.48	323.90
MFC-4700	9/27/2001	358.02	0.48	357.54
MFC-4700	10/13/2001	348.05	0.40	347.65
MFC-4700	10/24/2001	325.62	0.32	325.30
MFC-4700	11/7/2001	328.12	-0.15	328.27
MFC-4700	11/30/2001	268.31	20.62	247.69

Sample Location	Sample Date	Meter Corrected EC (uS/cm)	EC Correction	Nitrate Corrected EC (uS/cm)
MFC-4700	12/14/2001	290.74	129.78	160.95
MFC-4700	1/9/2002	267.06	132.00	135.06
MFC-4700	1/25/2002	204.14	44.24	159.90
MFC-4700	1/26/2002	219.71	101.08	118.63
MFC-4700	1/27/2002	252.11	123.84	128.27
MFC-4700	1/29/2002	303.20	122.49	180.71
MFC-4700	2/8/2002	237.16	98.39	138.77
MFC-4700	2/22/2002	172.12	3.34	168.78
MFC-4700	2/24/2002	189.19	86.34	102.85
MFC-4700	3/8/2002	264.57	-	-
MFC-4700	3/11/2002	134.86	52.72	82.14
MFC-4700	3/29/2002	229.68	74.05	155.63
MFC-4700	4/12/2002	268.31	46.70	221.61
MFC-4700	4/26/2002	293.23	48.13	245.10
MFC-4700	4/27/2002	304.44	33.14	271.30
MFC-4700	5/10/2002	303.20	22.84	280.36
MFC-4700	5/24/2002	318.15	9.76	308.39
MFC-4700	5/28/2002	320.64	6.19	314.45
MFC-4700	6/11/2002	314.41	3.34	311.07
MFC-4700	6/25/2002	343.07	2.15	340.92
MFC-4700	7/9/2002	329.36	0.09	329.28
MFC-4700	7/23/2002	321.89	0.01	321.88
MFC-4700	9/20/2002	364.25	-	-
MFC-4700	10/16/2002	316.90	1.43	315.47
MFC-4700	11/8/2002	329.36	4.90	324.46
MFC-4700	11/20/2002	341.82	1.80	340.03
MFC-4700	12/4/2002	316.90	6.70	310.20
MFC-4700	12/19/2002	294.47	8.41	286.06
MFC-4700	1/10/2003	301.95	28.39	273.55
MFC-4700	1/17/2003	267.06	28.31	238.75
MFC-4700	1/31/2003	143.96	50.19	93.77
MFC-4700	2/14/2003	284.51	61.94	222.56
MFC-4700	2/28/2003	269.55	64.05	205.50
MFC-4700	3/14/2003	229.68	55.96	173.72
MFC-4700	3/28/2003	244.63	81.81	162.82
MFC-4700	4/11/2003	288.24	66.86	221.38
MFC-4700	4/25/2003	284.51	44.63	239.88

Sample Location	Sample Date	Meter Corrected EC (uS/cm)	EC Correction	Nitrate Corrected EC (uS/cm)
MFC-4700	5/9/2003	309.43	24.00	285.42
MFC-4700	5/23/2003	305.69	8.27	297.41
MFC-4700	6/6/2003	320.64	3.90	316.74
MFC-4700	6/20/2003	333.10	3.32	329.78
MFC-4700	7/4/2003	311.92	0.50	311.42
MFC-4700	7/18/2003	354.28	-	-
MFC-4700	8/1/2003	406.61	-0.13	406.75
MFC-4700	8/15/2003	437.76	-	-
MFC-4700	8/29/2003	397.89	-0.10	397.99
MFC-4700	9/12/2003	390.42	-	-
MFC-4700	9/27/2003	382.94	-	-
MFC-4700	10/13/2003	338.08	-	-
MFC-4700	10/24/2003	366.74	-	-
MFC-4700	11/7/2003	380.45	5.84	374.60
MFC-4700	11/21/2003	309.17	3.41	305.77
MFC-4700	12/5/2003	262.34	14.35	248.00
MFC-4700	12/19/2003	291.61	39.01	252.60
MFC-4700	1/5/2004	307.50	20.70	286.80
MFC-4700	1/16/2004	281.58	74.13	207.45
MFC-4700	1/29/2004	216.35	101.08	115.27
MFC-4700	1/29/2004	180.39	85.15	95.24
MFC-4700	1/30/2004	189.59	113.61	75.98
MFC-4700	2/13/2004	342.62	96.96	245.66
MFC-4700	2/24/2004	267.06	124.23	142.83
MFC-4700	2/26/2004	259.59	125.02	134.56
MFC-4700	2/27/2004	259.59	125.10	134.48
MFC-4700	3/12/2004	279.52	109.57	169.96
MFC-4700	3/26/2004	319.39	76.82	242.57
MFC-4700	4/9/2004	329.36	46.86	282.50
MFC-4700	4/23/2004	313.16	23.15	290.01
MFC-4700	5/7/2004	345.56	6.67	338.89
MFC-4700	5/21/2004	318.15	1.83	316.32
MFC-4700	5/28/2004	242.14	9.76	232.38
MFC-4700	6/11/2004	330.61	3.89	326.72
MFC-4700	6/25/2004	309.43	1.43	307.99
MFC-4700	7/9/2004	277.03	0.16	276.86
MFC-4700	7/23/2004	324.38	-0.07	324.45

Sample Location	Sample Date	Meter Corrected EC (uS/cm)	EC Correction	Nitrate Corrected EC (uS/cm)
MFC-4700	8/6/2004	349.30	-	-
MFC-4700	8/20/2004	384.19	-	-
MFC-4700	9/3/2004	405.37	-	-
MFC-4700	9/17/2004	350.54	0.01	350.54
MFC-4700	10/1/2004	345.56	0.01	345.55
MFC-4700	10/15/2004	351.79	0.09	351.70
MFC-4700	10/29/2004	331.85	0.96	330.90
MFC-4700	11/12/2004	280.49	1.67	278.82
MFC-4700	11/29/2004	276.64	13.80	262.84
MFC-4700	12/13/2004	313.68	134.30	179.38
MFC-4700	12/27/2004	309.14	34.89	274.25
MFC-4700	1/12/2005	280.14	21.01	259.12
MFC-4700	1/28/2005	279.09	55.66	223.43
MFC-4700	2/11/2005	288.87	32.59	256.28
MFC-4700	2/25/2005	263.72	15.62	248.09
MFC-4700	3/10/2005	264.41	2.62	261.79
MFC-4700	3/25/2005	287.82	2.94	284.89
MFC-4700	3/27/2005	283.63	4.05	279.58
MFC-4700	4/8/2005	297.96	-	-
MFC-4700	4/22/2005	294.81	-	-
MFC-4700	5/6/2005	319.62	-	-
MFC-4700	5/20/2005	273.85	-	-
MFC-4700	6/7/2005	296.56	-	-
MFC-5700	12/7/2000	359.27	23.31	335.95
MFC-5700	1/9/2001	350.54	75.48	275.07
MFC-5700	2/2/2001	316.90	44.08	272.82
MFC-5700	3/2/2001	311.92	44.32	267.60
MFC-5700	4/9/2001	330.61	38.30	292.31
MFC-5700	5/2/2001	300.70	39.41	261.30
MFC-5700	5/30/2001	374.22	10.31	363.90
MFC-5700	7/11/2001	421.57	8.81	412.76
MFC-5700	10/13/2001	461.44	43.37	418.07
MFC-5700	10/24/2001	391.66	6.19	385.47
MFC-5700	11/30/2001	315.66	20.70	294.96
MFC-5700	12/14/2001	331.85	145.32	186.53
MFC-5700	1/9/2002	252.11	-0.15	252.26
MFC-5700	1/24/2002	309.43	91.73	217.70

Sample Location	Sample Date	Meter Corrected EC (uS/cm)	EC Correction	Nitrate Corrected EC (uS/cm)
MFC-5700	1/26/2002	233.42	108.22	125.20
MFC-5700	1/27/2002	267.06	-0.15	267.21
MFC-5700	1/29/2002	311.92	-0.15	312.07
MFC-5700	2/8/2002	248.37	95.45	152.92
MFC-5700	2/22/2002	177.72	87.21	90.51
MFC-5700	3/8/2002	285.75	104.81	180.94
MFC-5700	3/11/2002	156.29	71.99	84.30
MFC-5700	3/29/2002	268.31	91.33	176.97
MFC-5700	4/12/2002	300.70	153.56	147.14
MFC-5700	4/26/2002	319.39	36.95	282.44
MFC-5700	4/27/2002	324.38	37.11	287.27
MFC-5700	5/10/2002	351.79	27.99	323.80
MFC-5700	5/24/2002	351.79	19.43	332.36
MFC-5700	5/28/2002	346.81	12.85	333.96
MFC-5700	6/11/2002	339.33	9.68	329.65
MFC-5700	6/25/2002	361.76	11.10	350.65
MFC-5700	7/9/2002	414.09	13.09	401.00
MFC-5700	7/23/2002	452.72	6.03	446.68
MFC-5700	9/20/2002	526.23	0.11	526.12
MFC-5700	10/16/2002	391.66	10.68	380.98
MFC-5700	11/8/2002	345.56	12.78	332.78
MFC-5700	11/20/2002	355.53	9.02	346.51
MFC-5700	12/4/2002	341.82	2.55	339.27
MFC-5700	12/19/2002	321.89	11.43	310.46
MFC-5700	1/10/2003	318.15	39.57	278.58
MFC-5700	1/17/2003	318.15	30.63	287.52
MFC-5700	1/31/2003	197.29	47.36	149.92
MFC-5700	2/14/2003	326.87	45.28	281.59
MFC-5700	2/28/2003	296.97	47.36	249.61
MFC-5700	3/14/2003	270.80	55.78	215.01
MFC-5700	3/28/2003	265.82	77.41	188.41
MFC-5700	4/11/2003	288.24	66.96	221.28
MFC-5700	4/25/2003	311.92	47.11	264.81
MFC-5700	5/9/2003	340.58	32.40	308.17
MFC-5700	5/23/2003	331.85	16.41	315.45
MFC-5700	6/6/2003	358.02	9.64	348.38
MFC-5700	6/20/2003	364.25	11.78	352.47

Sample Location	Sample Date	Meter Corrected EC (uS/cm)	EC Correction	Nitrate Corrected EC (uS/cm)
MFC-5700	7/4/2003	391.66	11.43	380.23
MFC-5700	7/18/2003	424.06	3.56	420.50
MFC-5700	8/1/2003	426.55	0.26	426.29
MFC-5700	8/15/2003	424.06	-0.12	424.18
MFC-5700	8/29/2003	457.70	-	-
MFC-5700	9/12/2003	396.65	23.01	373.63
MFC-5700	9/27/2003	493.83	5.00	488.84
MFC-5700	10/13/2003	465.18	5.48	459.69
MFC-5700	10/24/2003	400.38	6.08	394.30
MFC-5700	11/7/2003	386.68	12.04	374.64
MFC-5700	11/21/2003	330.92	8.73	322.19
MFC-5700	12/5/2003	285.76	20.18	265.58
MFC-5700	12/19/2003	335.10	105.13	229.97
MFC-5700	1/5/2004	362.69	71.28	291.42
MFC-5700	1/16/2004	303.32	96.80	206.52
MFC-5700	1/29/2004	211.33	91.17	120.16
MFC-5700	1/29/2004	197.12	88.48	108.64
MFC-5700	1/30/2004	194.61	133.67	60.94
MFC-5700	2/13/2004	348.48	124.23	224.25
MFC-5700	2/24/2004	287.00	123.12	163.88
MFC-5700	2/26/2004	260.83	123.20	137.63
MFC-5700	2/27/2004	265.82	121.30	144.52
MFC-5700	3/12/2004	298.21	101.72	196.49
MFC-5700	3/26/2004	331.85	76.11	255.74
MFC-5700	4/9/2004	341.82	55.10	286.72
MFC-5700	4/23/2004	353.04	40.36	312.68
MFC-5700	5/7/2004	359.27	18.64	340.63
MFC-5700	5/21/2004	336.84	13.09	323.75
MFC-5700	5/28/2004	298.21	10.47	287.74
MFC-5700	6/11/2004	354.28	11.90	342.38
MFC-5700	6/25/2004	390.42	10.63	379.79
MFC-5700	7/9/2004	448.98	10.39	438.59
MFC-5700	7/23/2004	491.34	5.16	486.18
MFC-5700	8/6/2004	536.20	-	-
MFC-5700	8/20/2004	561.12	-	-
MFC-5700	9/3/2004	333.10	7.85	325.24
MFC-5700	9/17/2004	495.08	20.22	474.86

Sample Location	Sample Date	Meter Corrected EC (uS/cm)	EC Correction	Nitrate Corrected EC (uS/cm)
MFC-5700	10/1/2004	440.26	11.03	429.23
MFC-5700	10/15/2004	399.14	17.37	381.77
MFC-5700	10/29/2004	365.50	15.15	350.35
MFC-5700	11/12/2004	314.38	8.33	306.05
MFC-5700	11/29/2004	292.72	10.31	282.40
MFC-5700	12/13/2004	294.46	77.86	216.61
MFC-5700	12/27/2004	308.09	40.04	268.05
MFC-5700	1/12/2005	297.61	23.15	274.45
MFC-5700	1/28/2005	293.07	56.29	236.77
MFC-5700	2/11/2005	294.46	32.67	261.80
MFC-5700	2/25/2005	294.81	20.86	273.96
MFC-5700	3/10/2005	281.54	9.99	271.54
MFC-5700	3/25/2005	301.10	6.51	294.60
MFC-5700	3/27/2005	314.03	26.09	287.94
MFC-5700	4/8/2005	300.75	-	-
MFC-5700	4/22/2005	318.92	-	-
MFC-5700	5/6/2005	358.75	-	-
MFC-5700	5/20/2005	297.26	-	-
MFC-5700	6/7/2005	345.13	-	-