

**Spatial and Temporal Trends in Greenhouse Gas Fluxes from a Temperate Floodplain
along a Stream-Riparian-Upland Gradient**

Breanne Leigh Ensor

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Durelle T. Scott, Chair
W. Cully Hession
Erich T. Hester
Brian D. Strahm
R. Quinn Thomas

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ABSTRACT

Increased floodplain and wetland restoration activity has raised concerns about potential impacts on the release of greenhouse gases (GHGs) to the atmosphere due to restored connectivity between aquatic and terrestrial ecosystems. Research has shown GHG fluxes from hydrologically active landscapes such as floodplains and wetlands vary spatially and temporally in response to primary controls including soil moisture, soil temperature, and available nutrients. In this study, we performed a semimonthly sampling campaign measuring GHG (CO_2 , CH_4 , and N_2O) fluxes from six locations within a third-order stream floodplain. Site locations were based on dominant landscape positions and hydrologic activity along a topographic gradient including a constructed inset floodplain at the stream margin, the natural levee, an active slough, the general vegetated floodplain, a convergence zone fed by groundwater, and the upland area. Flux measurements were compared to abiotic controls on GHG production to determine the most significant factors affecting GHG flux from the floodplain. We found correlations between CO_2 flux and soil temperature, organic matter content, and soil moisture, CH_4 flux and pH, bulk density, inundation period length, soil temperature, and organic matter content. But minimal correlations between N_2O flux and the measured variables. Spatially, our results demonstrate that constructed inset floodplains have higher global warming potential in the form of CH_4 than any other site and for all other GHGs, potentially offsetting the positive benefits incurred by enhanced connectivity. However, at the reach scale, total CO_2 flux from the soil remains the greater influence on climate since the area covered by these inset floodplains is comparatively much smaller than the rest of the floodplain.

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GENERAL AUDIENCE ABSTRACT

The restoration of floodplains has become a common addition to stream restoration projects in the United States and Europe. The goal of floodplain restoration is to remove levees restricting water flow to the stream channel and to increase flooding frequency in the adjacent floodplain or construct small floodplains near the stream bank. This improves the floodplain and stream ecosystems and reduces the risk of flooding upstream. However, with the alteration of the floodplain soil environment as the floodplain is inundated more frequently, floodplain restoration creates conditions for potential increases in greenhouse gas (GHG) production in comparison to the original state of the floodplain. In this study, we performed a semimonthly sampling campaign measuring GHG (CO_2 , CH_4 , and N_2O) fluxes from six locations within a stream floodplain. Site locations were based on dominant landscape positions and hydrologic activity including a constructed inset floodplain at the stream bank, the natural levee, a wetland area fed by stream and groundwater, the general vegetated floodplain, a depression area fed by groundwater, and the upland area. Flux measurements were compared to physical controls on GHG production to determine the most significant factors affecting GHG flux from the floodplain. We found correlations between CO_2 flux and soil temperature, organic matter content, and soil moisture, CH_4 flux and pH, bulk density, inundation period length, soil temperature, and organic matter content. But minimal correlations between N_2O flux and the measured variables. Spatially, our results demonstrate that constructed inset floodplains have higher global warming potential in the form of CH_4 than any other site and for all other GHGs, potentially offsetting the positive benefits floodplain restoration. However, at the reach scale, total CO_2 flux from the soil remains the greater influence on climate since the area covered by these inset floodplains is comparatively much smaller than the rest of the floodplain. These findings can be used by restoration specialists to minimize the impact their floodplain restoration designs may have on GHG emissions.

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List of Abbreviations

CH ₄	Methane
CO ₂	Carbon Dioxide
DOC	Dissolved Organic Carbon
GHG	Greenhouse Gas
GHGs	Greenhouse Gases
NH ₃	Ammonia
NH ₄ ⁺	Ammonium
N ₂	Nitrogen Gas
NO	Nitric Oxide
N ₂ O	Nitrous Oxide
NO ₂ ⁻	Nitrite
NO ₃ ⁻	Nitrate
PO ₄ ³⁻	Phosphate
R ²	Correlation Coefficient
SRP	Soluble Reactive Phosphorus
StREAM Lab	Stream Research, Education, And Management Lab
TDN	Total Dissolved Nitrogen
V _h	Headspace Volume
WFPS	Water-Filled Pore Space

1 Introduction

1.1 Literature Review

1.1.1 Introduction

Over the course of human development, land use changes, material production and energy consumption have caused sufficient damage to the landscape and Earth's natural resources including riverine systems and their floodplains (Foley et al. 2005). Frequent damming of rivers for hydropower and irrigation have severely altered the hydrologic regime of water bodies from the massive Mississippi River to small northeastern tributaries (McCully 2001), thus reducing function within the stream and its surroundings. In response to river degradation and subsequent flooding events, engineers and scientists have begun to initiate remediation strategies to restore hydrologic dynamics, nutrient cycling, sediment transport, and floodplain biodiversity to their original states (Tockner and Stanford 2002). Strategies include removing restricting levees along the stream bank, reshaping channels, and creating depressional areas within the floodplain all with the goal of reconnecting the stream channel to the floodplain hydrologically to improve sediment, nutrient and water retention in the floodplain (Roni et al. 2002). However, floodplains also provide the ideal set of conditions for biogeochemical cycling, microbial activity, and the production of greenhouse gases (GHGs) (CO_2 , CH_4 , and N_2O) from the soil (Reddy and DeLanune 2008). Alterations in hydrologic activity and nutrient availability may increase greenhouse gas production within the floodplain soil, causing concern for the impact that these restoration projects may have on climate change (Audet et al. 2013a).

The soil microbial community interactions with vegetation and the soil matrix largely mediates carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) fluxes from soils. The diversity of this community dictates the magnitude of these three gases being released or taken up by the soil. Most microbes release CO_2 while producing energy through respiration, yet others, such as methanogens and nitrosomes, release N_2O and CH_4 through processes including denitrification, nitrification, and methanogenesis. In terms of climate concerns, N_2O and CH_4 are 289 and 72 times more potent as greenhouse gases (GHGs) in the atmosphere over a 20-year timescale than CO_2 (IPCC 2014). Therefore, conditions that stimulate the growth of the soil microbial community and the dominance of denitrifying and methanogenic bacteria have negative impacts on the climate.

This review examines how floodplains function to improve water quality through nutrient retention leading to hotspots and hot-moments in biogeochemical cycling and GHG production. It will then examine the major controlling factors on the production of CO₂, CH₄, and N₂O within the floodplain soil environment. While many studies have shown the effect of individual controls on GHG production, few have performed encompassing investigations on the collective influence of these factors. A more complete knowledge of how these coupled factors govern the production of GHGs in floodplain soils throughout the seasons is needed to better advise restoration practitioners on mitigating GHG flux from floodplains while maximizing the benefits of stream-floodplain connectivity.

1.1.2 Biogeochemical Cycling in Floodplains with High Stream Connectivity

While streams and rivers are not much affected by high nutrient loading, increased nutrient inputs via activities including agriculture and farming over a large area such as the Mississippi River basin have caused zones of hypoxia in coastal waters leading to eutrophication and the disruption of marine ecosystems (Rabalais et al. 2009). Restoration practitioners focus on restoring and creating wetlands and floodplains near high nutrient streams because they act as effective processing centers for nitrogen and nutrient laden sediment. Extensive research has proven that these natural systems have a significant impact on water quality, especially in terms of overabundant nutrients in systems (Vought et al. 1994, Craft and Casey 2000, Johnston 1991, Noe and Hupp 2009, Roley et al. 2012). The microbial and vegetative communities suited for survival in highly saturated soils quickly convert ammonium (NH₄⁺), the primary form of nitrogen in fertilizer, to nitrate (NO₃⁻) through nitrification at the oxidized surface soil layer and eventually to nitric oxide (NO), nitrous oxide (N₂O) or nitrogen gas (N₂) through denitrification in aerobic conditions deeper in the soil (Mitsch and Gosselink 2000). Scott et al (2014) observed significant retention of NO₃⁻ coupled with exports NH₄⁺ in the natural Atchafalaya River floodplain during a large flood event. Further studies on the same basin showed nitrogen and organic matter removal even during the seasonal flooding period (Jones et al. 2014). Floodplains and wetlands remove phosphorus and suspended sediment from floodwater via sorption and sedimentation. Aluminum and iron compounds in the soil attract dissolved phosphorus when the water is rich in phosphorus (Richardson 1985) especially under anaerobic conditions (Kemp et al. 1982). Interactions between floodwater and sediments also remove dissolved organic matter (Chow et al. 2013). In turbid floodwaters, phosphorus spirals through patterns of mobilization

and immobilization with suspended sediment and can be removed via sedimentation. Sedimentation occurs when a channel floods its floodplain as velocity is decreased when the channel's hydraulic radius and stream gradient decrease and roughness coefficient increases after bankfull flow is reached (Johnston 1991).

The rate of biogeochemical cycling in floodplain environments is mediated by many factors, but the most influential is hydrology (Hill 1996). Compared to channels, floodplains and wetlands slow flood waters significantly, allowing for increased reaction time for these processes to occur and removal of nutrients from the surface water (Tockner et al. 1999). Large floodplains connected to low order streams such as the Amazon River which have lengthy seasonal flood pulses have greater widespread biogeochemical processing rates than high order streams with smaller floodplains (Noe et al. 2007). Small floodplains typically experience short and frequent inundation periods, creating spatial and temporal variability in biogeochemical cycling across the landscape (Kreiling et al. 2013, Jones et al. 2015). NO_3^- also enters surface water via subsurface groundwater flow from upland agricultural areas. This form of nitrogen may be absorbed by plants if it encounters active root zones or removed to the atmosphere via microbial denitrification (Mitsch et al. 2001). However, some groundwater may travel much deeper than vegetation roots extend and bypass most removal pathways (Correll et al. 1994).

While floodplain restoration improves water quality, induced changes in potential for biogeochemical cycling may alter the global warming footprint of floodplains. Recent studies have shown increased potential for incomplete denitrification and release of N_2O to the atmosphere from floodplains due to hydrologic reconnection of the river and floodplain (Kaushal et al. 2008, Roley et al. 2012). However, others have shown that denitrification hotspots are highly spatially and temporally variable and have not seen any significant large scale effects of restoration on denitrification efficiency within two years of restoration (Orr et al. 2007, Audet et al. 2013). Increased inundation frequency and period have shown to increase CH_4 efflux from soils (Badiou et al. 2011, Audet et al. 2013). On the other hand, increased productivity of vegetation and soil microbes due to nutrient accumulation enhances carbon sequestration and burial of the system thus counterbalancing carbon emissions (CO_2 and CH_4) (Zehetner et al. 2009, Samaritani et al. 2011). The production of these GHGs by the dynamic soil microbial community biodiversity is controlled by several abiotic factors that may be altered through floodplain restoration including temperature, soil moisture, and available nutrients.

1.1.3 The Influence of Temperature on Biogeochemical Cycling

Microbial activity is mediated by enzymatic functioning rates that increase as temperature increases, climaxing at the optimum functioning temperature. Research has shown that soil temperature has a very strong seasonal correlation with CO₂ production where warmer temperatures in the summer result in larger effluxes of CO₂ from the soil (Pulliam 1993, Updegraff et al. 2001, Conant et al. 2004, Elaiasson et al. 2005, Morse et al. 2012). This raises concern for warming temperatures relative to the feedback between global temperature and CO₂ in the atmosphere. As CO₂ increases in the atmosphere, global temperatures increase, forcing greater respiration and the release of carbon from what could be carbon sinks. Pulliam (1993) found that CH₄ flux magnitude is mediated by climate since fluxes in a southeastern floodplain swamp were only significant at flooded sites when temperatures were above 15°C. However, other studies show that temperature and CH₄ production do not have a strong predictive correlation (Yavitt et al. 1990, Whiting and Chanton 1993, Hirota et al. 2004). Air and soil temperatures over the course of the year influence nitrification and denitrification rates with maximum N₂O production during warm temperatures in July and August (Maag and Vinther 1996, Hernandez and Mitsch 2006, Stres et al. 2008, Song et al. 2009). Yet, Stres et al. (2008) found higher production of N₂O under a certain combination of conditions such as cold and highly saturated conditions. However, this response in N₂O production to temperature is not as strong as other microbial processes such as the reduction of O₂ during respiration.

1.1.4 The Influence of Soil Moisture on Biogeochemical Cycling

The microbial community utilizes a wide variety of naturally occurring compounds as sources of electron acceptors in reduction-oxidation reactions for energy conversion. The species makeup of the community is separated into microhabitats differing in time and space depending on the heterogeneous availability of the most commonly used electron acceptors (Nannipieri et al. 2003). The electron tower shows the amount of free energy gained through the conversion of a redox pair from calculations based upon atomic configuration (Marcus 1956). The redox pairs common to floodplain environments are O₂/H₂O, Fe⁺³/Fe⁺², NO₃⁻/N₂ (NO₃⁻/N₂O), NO₃⁻/NO₂⁻, SO₄⁻²/H₂S, CO₂/acetate, and CO₂/CH₄ with O₂ providing the most and CO₂ providing the least energy per reaction (Liss and Baker 1994). In redox reactions, electrons are transferred from the oxidizing agent to the reducing agent, increasing the oxidation state of the oxidized atom and storing energy in the cell as adenosine triphosphate (ATP). Most microbes utilize O₂ as terminal

electron acceptors but some specialized species, including methanogens and other obligate anaerobes, can utilize other compounds for the energy conversion. Soil moisture controls the potential for certain redox reactions by dominating the concentration of available free oxygen in the soil. As concentrations of the greatest energy bearing electron acceptors decreases such as free oxygen in anoxic conditions, the microbial community shifts to utilizing the next best electron acceptor on the tower until soil dynamics change and better electron acceptors, particularly oxygen, are reintroduced to the system. Therefore, CO₂, CH₄, and N₂O production in soils largely depends on the availability of oxygen and the processing of other available electron acceptors in the soil.

Many studies have found a significant reduction in CO₂ production as soil moisture increases (Linn and Doran 1984, Davidson et al. 2000, Batson et al. 2014). Moore and Knowles (1989) also documented a strong correlation between water table height and CO₂ emissions from soil. When the water table height exceeds the soil surface, diffusion of O₂ and CO₂ through the water column restricts emission rates. In relation to precipitation, Xu et al. (2004) showed a rapid response in respiring microbes to precipitation events with spikes in CO₂ flux within hours of the start of rainfall. However, even though soil moisture is shown to influence respiration rates, CO₂ emissions still follow temporal soil temperature patterns regardless of the degree of saturation in the soil (Pulliam 1993, Yu et al. 2008, Creed et al. 2013, Jacinthe et al. 2015). Yet, CO₂ flux may not vary as much spatially when soil moisture is low and relatively uniform (Morse et al. 2012).

As oxygen concentrations diminish in the soil, denitrifying bacteria begin to dominate the microbial community by utilizing NO₃⁻ as an electron acceptor. Microbes performing denitrification under anoxic conditions reduce NO₂⁻ and NO₃⁻ to N₂ while creating energy. Nitrous oxide (N₂O) and nitrogen oxide (NO) are released as intermediary products of denitrification when nitrous oxide and nitrogen oxide reductases are repressed in the cell (Knowles 1982). Previous research indicates that the greatest production of N₂O through denitrification occurs at a water filled pore space (WFPS) of 60-70% (Linn and Doran 1984, Davidson et al. 1986, Parton et al. 1996). Soil water content greater than a WFPS of 70% or standing water would inhibit the diffusion of N₂O (Rabot et al. 2015) due to its low diffusivity (Hernandez and Mitsch 2006). Davidson et al. (2000) expresses NO, N₂O, and N₂ emissions as a function of WFPS where NO and N₂O are produced at a 1:1 ratio at a WFPS of 60% through nitrification and denitrification but once WFPS exceeds 80%, only N₂ is produced through

denitrification. Yet, Rowlings et al. (2015) found maximum N_2O production at a WFPS of 82-84% in the field and others found highest production at even 100% WFPS (Bollmann and Conrad 1998, Pihlatie et al. 2004). Field studies have shown that precipitation is also a strong influence in episodic production of N_2O that correspond with wetting and drying cycles of the soil (Rabot et al. 2015, Rowlings et al. 2015) or high nutrient content in rainwater (Mosier et al. 1981). Release of N_2O during such drying phases is attributed to the release of gaseous N_2O trapped in liquid (Rabot et al. 2015). Researchers suggest to control these wetting and drying events and nutrient supplies on floodplains in order to reduce the total annual N_2O emissions (Welti et al. 2012). On the other hand, Morse et al. (2012) discovered that more N_2O was produced in a dry agricultural site in comparison to intermittently wetted forested and restored wetlands indicating that soil moisture and hydrologic regime may not be the only driver in N_2O production.

Methanogens cannot live in the presence of oxygen (Daniels et al. 1983). Therefore, the microbial community may only include methanogens during complete soil reduction which typically occurs during conditions of high soil saturation. High water table heights lead to higher production of CH_4 (Moore and Knowles 1989, Updegraff et al. 2001, Hirota et al. 2004) and hydrologic connectivity during periods of high rainfall maximize production of CH_4 in the floodplain (Updegraff et al. 2001, Harms and Grimm 2008, Yu et al. 2008). Research from tropical floodplains show diurnal (Harrison et al. 2005) and seasonal trends in CH_4 flux with greater production during the wet season (Devol et al. 1990, Wassmann et al. 1992, Smith et al. 2000, Marani and Alvala 2007, Song et al. 2009). During precipitation events, CH_4 production will pulse shortly after infiltration begins and then sharply decline due to competition of resources (Harms and Grimm 2008). Areas having variations in such wetting and drying of soil produce significantly less CH_4 than those that are saturated for longer periods of time (Boon et al. 1997, Altor and Mitsch 2006, Sha et al. 2011). CH_4 emissions are reduced during the growing season due to oxygen transport to the soil through macrophyte roots even while the soils are inundated (Whiting and Chanton 1993, Bellisario et al. 1999, Van der Nat and Middelburg 2000, Hirota et al. 2004, Altor and Mitsch 2006). Alternatively, well drained soils can act as a CH_4 sink through methane oxidation (Hanson and Hanson 1996).

1.1.5 The Influence of Nutrient Retention and Soil Properties on Biogeochemical Cycling

Microbial functioning may also be temporally or spatially limited in available nutrients required for producing energy including carbon, nitrogen or phosphorus (Kayranli et al. 2010). Pulliam (1993) showed a positive correlation between soil organic content and CO₂ production spatially. However, limitations on other inputs such as oxygen, nitrogen, and phosphorus dominated the response in CO₂ production. For example, Yu et al. (2008) documented that areas of a floodplain containing high levels of organic matter but were continuously flooded emitted low fluxes of CO₂. Batson et al. (2014) determined a significant relationship between C:N and C:P and CO₂ production that was more influential than the organic content of the soil, while others have found relationships between C:N and NH₄⁺ and CO₂ production (Jacinthe et al. 2015).

CH₄ production is controlled by the presence of other electron acceptors in the soil such as oxygen or NO₃⁻ in addition to available carbon and acetate. Stadmark and Leonardson (2005) found that low concentrations of nitrate in combination with warm temperatures in constructed ponds designed for nutrient retention resulted in an increase in CH₄ production. They concluded that if retention ponds are not constructed for maximum nutrient retention, the ponds will act as sources of CH₄. Similarly, Updegraff et al. (2001) found a negative correlation between soil N availability and CH₄ flux.

The main nutrient used in the denitrification process and the main control on N₂O production is NO₃⁻ available to the microbial community in soils. In an experiment conducted by Scaroni et al. (2014), additions of NO₃⁻ to floodplain soils stimulated denitrifying bacteria and increased N₂O emissions. High levels of NO₃⁻ are typically found in subsurface hotspots of floodplains that have high hydrologic connectivity to the adjacent stream and receive nitrogen rich flows from uplands (McClain et al. 2003, Harms and Grimm 2008, Groffman et al. 2009, Harms et al. 2009, Vidon et al. 2010). Temporally, NO₃⁻ production is maximized at the beginning of the rainy season during the initial flush of prime soil decomposition (Birch 1958). Therefore, post-flood pulse conditions may be most favorable for denitrification due to the degree of soil saturation, shallow height of the water table, and the new influx of available nutrients (Hernandez and Mitsch 2006). Denitrification also requires an ample supply of dissolved carbon. Wet soils tend to have high levels of dissolved nitrogen and carbon, released

from slowly decomposing leaf litter, available for biological use (Baldwin and Mitchell 2000). Li et al. (2005) simulated increases in N_2O fluxes as soil organic carbon increased over time. The results indicated a concern for the effects of increased global carbon sequestration on N_2O emissions. These hot spots and hot moments of denitrification can vary depending on water source, vegetation, litter fall rates, and flood pulse which are controlled by the temporal variation in hydrology (Harms et al. 2009, Vidon et al. 2010). In the tropics, spikes in available C and N occur during summer monsoon seasons (Harms and Grimm 2008) when hydrological flowpaths mobilize nutrients accumulated during a dry period (McClain et al. 2003). These hydrological flowpaths appear as flood pulses from the stream channel during large precipitation events. On the other hand, some natural wetland systems can be sinks for N_2O if consumption of the gas exceeds production due to nutrient imbalances (Schlesinger 2013, Audet 2014). N_2O is readily taken up during nitrification and denitrification when flooded soils are limited in inorganic N (Chapuis-Lardy 2007).

1.1.6 Conclusion

Based on the ideal conditions for GHG production explored by previous research, floodplains contain spatially and temporally variable hot spots and hot-moments in the production of CO_2 , CH_4 , and N_2O . Alterations in hydrologic regime and nutrient retention in floodplains may change the variability of environmental conditions, leading to alterations in the biogeochemical activity of the microbial community. General temporal trends in GHG production follow seasonal variations in temperature via stimulation of enzymatic activity at warmer temperatures. Changes in the flood pulse and inundation period of a floodplain increases saturation frequency in the soil, varying the concentration of available electron acceptors for energy conversion and increases the potential for N_2O and CH_4 production but suppression in CO_2 production. Additional nutrient and sediment retention in the floodplain also increases the potential for GHG production by supplying the microbial community with more resources to metabolize. However, the collective effect of the natural variability of these environmental conditions versus the changes caused by restoration in the floodplain on GHG production is not well documented and more studies should observe the balance between the benefits of floodplain restoration and the potential for greater GHG production.

1.2 Research Objectives

The overall goal of this research was to determine the greatest controls on CO₂, CH₄, and N₂O flux from a low-order floodplain. We investigated the influence of abiotic controls related to an increased hydrologic regime on the production of GHGs. CO₂, CH₄, and N₂O fluxes were measured across several locations in a low-order Appalachian floodplain every two weeks for a one year period. GHG emissions were compared to measurements in soil moisture, soil temperature, and available soil nutrients. The specific objectives of this study were:

- (1) To determine temporal trends in soil CO₂, CH₄, and N₂O fluxes across a floodplain landscape gradient from stream to upland;
- (2) To determine spatial soil CO₂, CH₄, and N₂O flux trends along a soil moisture gradient within a floodplain;
- (3) To identify the influence of key controls on soil greenhouse gas flux in the floodplain.
- (4) Identify hotspots for greenhouse gas emissions in the floodplain at the reach scale for the use in floodplain restoration design.

1.3 Organization of Thesis

This document is organized around a journal article that will be submitted for publication in *Ecological Applications*. A comprehensive literature review proceeds the article, providing an overview of biogeochemical cycling and controls on greenhouse gas production in hydrologically active soils. Chapter 2 forms the core of the thesis, and is written as a stand-alone publication with a full abstract, introduction, methods, results, discussion, conclusions, and references. Supporting information for the thesis, including additional figures and analysis code, appear in the appendices.

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2 Spatial and Temporal Trends in Greenhouse Gas Fluxes from a Temperate Floodplain along a Stream-Riparian-Upland Gradient

In preparation for Ecological Applications

Breanne L. Ensor, Durelle T. Scott*, Erich T. Hester, Brian Strahm, R. Quinn Thomas, Nate Jones, Tyler Weiglein, W. Cully Hession

Corresponding Author*:

Durelle T. Scott
Department of Biological Systems Engineering
Virginia Polytechnic and State University
302-K HABB1
Blacksburg, VA 24061
Email: dscott@vt.edu

Other Authors:

Breanne L. Ensor
Department of Biological Systems Engineering
Virginia Polytechnic and State University
200-L Agnew Hall
Blacksburg, VA 24061

Erich T. Hester
Department of Civil and Environmental Engineering
Virginia Polytechnic and State University
220-D Patton Hall
Blacksburg, VA 24061

Brian D. Strahm
Department of Forest Resources and Environmental Conservation
Virginia Polytechnic and State University
228 Cheatham Hall
Blacksburg, VA 24061

R. Quinn Thomas
Department of Forest Resources and Environmental Conservation
Virginia Polytechnic and State University
310-B Cheatham Hall

Blacksburg, VA 24061
C. Nathaniel Jones
Department of Forest Resources and Environmental Conservation
Virginia Polytechnic and State University
309 Cheatham Hall
Blacksburg, VA 24061

Tyler L. Weiglein
Department of Forest Resources and Environmental Conservation
Virginia Polytechnic and State University
309 Cheatham Hall
Blacksburg, VA 24061

W. Cully Hession
Department of Biological Systems Engineering
Virginia Polytechnic and State University
204 Seitz Hall
Blacksburg, VA 24061

2.1 Introduction

2.1.1 Floodplains as Hotspots for Biogeochemical Cycling

In response to river degradation and subsequent flooding events, engineers and scientists have begun to initiate remediation strategies to restore hydrologic dynamics, nutrient cycling, sediment transport, and floodplain biodiversity to their original states (Tockner and Stanford 2002). Restoration practitioners focus on restoring and creating wetlands and floodplains near streams with high nutrient loading because they act as effective processing centers for nitrogen and nutrient laden sediment. Extensive research has demonstrated that these natural systems have a significant impact on water quality, especially in terms of overabundant nutrients in systems (Johnston 1991, Vought et al. 1994, Craft and Casey 2000, Noe and Hupp 2009, Roley et al. 2012). Increasing floodplain-channel connectivity is a common restoration strategy that reduces nutrient loading in streams by slowing water velocity and increasing the contact time of floodwater with reactive surfaces such as sediment and the microbial community (Mitsch and Jorgensen 2004, Hoffman and Baattrup-Pedersen 2007). Large floodplains connected to low order streams such as the Amazon River which have lengthy seasonal flood pulses have greater widespread biogeochemical processing rates than high order streams with smaller floodplains (Noe et al. 2007). Small floodplains typically experience short and frequent inundation periods, creating spatial and temporal variability in biogeochemical cycling across the landscape (Kreiling et al. 2013, Jones et al. 2015). However, the variability in redox conditions that promote NO_3^- removal also serve as prime locations for hotspots and hot-moments of biogeochemical cycling (Dahm et al. 1998, Ward et al. 1999, McClain et al. 2003, Harms and Grimm 2008), causing concern for the impact that these restoration projects may have on floodplain GHG production (Audet et al. 2013a). Some studies have determined that the additional loading of nutrients and sediment onto floodplain-like soils increases potential for incomplete denitrification and soil N_2O and CH_4 efflux (Freeman et al. 1997, Groffman et al. 2000, Whiting and Chanton 2001, Bridgman et al. 2006, Verhoeven et al. 2006). However, others have shown that denitrification hotspots are highly spatially and temporally variable and have not seen any significant large scale effects of restoration on denitrification efficiency within two years of restoration (Orr et al. 2007, Audet et al. 2013a).

Environmental conditions within floodplains that largely influence microbial processes and ultimately the balance between CO₂ generation versus N₂, N₂O, or CH₄ are electron acceptor availability and temperature. Delivery of nutrient rich water to floodplain surfaces results in diminished replenishment of O₂ to microsites within floodplain soils, setting up the cascade of alternative electron acceptors. Floodplain regions with high hydrologic exchange with the river (and low residence time) are likely to maintain oxic conditions. Spatial heterogeneity of hydrologic processes within such floodplains from variability in surface topography, subsurface soil types, and subsurface preferential flowpaths further affect solute transport and spatial heterogeneity of biogeochemical cycling (Jung et al. 2004, Hester et al. 2016). However, regions with higher hydrologic residence time will rapidly become O₂ limited (Tockner et al. 1999). Generally, floodplain environments are rich in organic carbon and are not substrate limited due to accumulation of vegetation material (Bayley 1995) making limitations in electron acceptors a greater influence on microbial activity. Soils with high soil organic content and greater concentrations of labile carbon sources produce greater CO₂ flux (Pulliam 1993). However, limitations on oxygen as an electron acceptor dominate the response in CO₂ production. For example, Yu et al. (2008) showed that areas containing high levels of organic matter but were continuously flooded had low emissions of CO₂ since low oxygen levels restricted respiration. Methanogens produce CH₄ in highly reduced conditions where most electron acceptors such as O₂, NO₃⁻, and SO₄²⁻, are absent from the environment. Therefore, low concentrations of NO₃⁻ in highly saturated soils in combination with warm temperatures result in large effluxes of CH₄ (Updegraff et al. 2001, Stadmark and Leonardson 2005). N₂O production in floodplain soils is controlled by the availability of nutrients directed by autochthonous, allochthonous and biological nutrient sources and hydrologic periods (Vidon et al. 2010). These sources are mobilized when hydrological flowpaths activate after dry periods via a flood pulse or precipitation event, reducing oxygen levels in the soil and making NO₃⁻ more available for energy conversion (McClain et al. 2003).

Soil moisture dictates which processes occur in floodplain soils by controlling concentrations of electron acceptors available to the microbial community. Spatial and temporal changes in the environment leading to changes in electron acceptor availability shifts the microbial community makeup and the types of gases released through the various metabolic processes (Nannipieri et al. 2003). Saturation conditions in the soil control the diffusion of

oxygen below the surface, decreasing the availability of O_2 for respiration as the soil wetness increases thus restricting CO_2 production (Linn and Doran 1984, Moore and Knowles 1989, Davidson et al. 2000, Batson et al. 2014). However, soil moisture does not dominate as a control of CO_2 production and emission trends remain linked to soil temperature patterns regardless of soil moisture (Pulliam 1993, Yu et al. 2008, Creed et al. 2013, Jacinthe et al. 2015). As the soil becomes anoxic, the community shifts to utilizing nitrate as a reducing source for denitrification, producing N_2O and NO through incomplete reactions, similar to flow in a “leaky pipe” (Firestone and Davidson 1989). Laboratory results indicate that the greatest production of N_2O through denitrification occurs at a water filled pore space (WFPS) of 60-70% (Linn and Doran 1984, Davidson et al. 1986, Parton et al. 1996). Yet, Rowlings et al. (2015) found maximum N_2O production at a WFPS of 82-84% in the field and others found high production at even 100% WFPS (Bollmann and Conrad 1998, Pihlatie et al. 2004). Furthermore, field studies have shown that precipitation is a stronger influence in episodic production of N_2O that correspond with wetting and drying cycles of the soil (Rabot et al. 2015, Rowlings et al. 2015). At highly anoxic conditions, where O_2 and NO_3 concentrations are minimal, methanogens dominate the microbial community and utilize CO_2 as an electron receptor for energy, producing CH_4 as a by-product. Studies have shown that areas having variations in wetting and drying of soil produce significantly less CH_4 than those that are saturated for longer periods of time (Boon et al. 1997, Altor and Mitsch, 2006, Sha et al. 2011). Research from tropical floodplains, show diurnal (Harrison et al. 2005) and seasonal trends in CH_4 flux with greater production during the wet season (Devol et al. 1990, Wassmann et al. 1992, Smith et al. 2000, Marani and Alvala 2007, Song et al. 2009). CH_4 emissions are also reduced during the growing season due to oxygen transport to the soil through macrophyte roots (Whiting and Chanton, 1993, Bellisario et al. 1999, Van der Nat and Middelburg 2000, Hirota et al. 2004, Altor and Mitsch 2006).

Soil temperature is another factor that affects rates of microbial respiration, where most microbial activity is suppressed when soil temperature is less than 20 °C and increases with warmer temperatures (Nedwell 1999). Previous studies have shown that soil temperature has a very strong seasonal correlation with soil CO_2 production where warmer temperatures in the summer result in the largest effluxes of CO_2 (Pulliam 1993, Updegraff et al. 2001, Conant et al. 2004, Elaiasson et al. 2005, Morse et al. 2012) and N_2O (Maag and Vinther 1996, Hernandez and Mitsch 2006, Stres et al. 2008, Song et al. 2009) from the soil. Other studies have shown mixed

results for methanogens and CH₄ flux. At a Southeastern floodplain swamp, Pulliam (1993) found that CH₄ flux magnitude was mediated by temperature since fluxes were only significant at flooded sites when temperatures were above 15°C. However, other studies show that temperature and CH₄ production do not have a strong predictive correlation (Yavitt et al. 1990, Whiting and Chanton 1993, Hirota et al. 2004). For N₂O production, previous studies suggest temperature is secondary to gradients in soil moisture (Stres et al. 2008).

Although many studies have shown the influence of each of these factors on GHG production from soil, few have investigated their conjunctive effect on GHG production in the floodplain. A more complete knowledge of how these coupled factors govern the production of GHGs in floodplain soils throughout the seasons would better advise restoration practitioners on mitigating GHG flux from floodplains while maximizing the benefits of stream-floodplain connectivity.

2.1.3 Purpose of Study

In this study, we quantified CO₂, CH₄, and N₂O fluxes from March 2015 to March 2016 from a low-order Appalachian floodplain across a landscape gradient from the stream to upland. Our objectives were to (1) determine spatial and temporal trends in soil CO₂, CH₄, and N₂O fluxes along a soil moisture gradient within a floodplain; (2) identify the influence of key controls on soil greenhouse gas flux in the floodplain; and (3) identify hotspots and hot moments for greenhouse gas emissions within floodplain environments. Our overall goal was to determine the most dominant controls on CO₂, CH₄, and N₂O flux from a low-order floodplain along a landscape gradient throughout the year. In addition to bimonthly GHG flux measurements, we recorded continuous soil temperature and moisture and bimonthly available soil nutrients measurements. This study contributes to the discussion on the impacts of increasing floodplain-channel connectivity on climate and indicates time periods and locations in the floodplain most susceptible to GHG production.

2.2 Methods

2.2.1 Site Description

Stroubles Creek is a third-order alluvial stream located within the Ridge and Valley physiographic province in Blacksburg, Virginia. The study floodplain is located downstream of

Virginia Tech's campus within the Stream Research, Education, and Management (StREAM) Lab (streamlab.bse.vt.edu). The 15 km² watershed is 84% urban and/or residential land resulting in rapid runoff from impervious surfaces contributing to short but elevated storm peaks.

Agriculture fields within the contributing area of the stream reach (13% of the watershed land use) are fertilized with swine/bovine manure bi-annually and contribute runoff via shallow subsurface flowpaths into the floodplain (**Figure 2-2-1**). Climate data collected at the NOAA Blacksburg weather station located approximately 3 km east of the study site shows an annual daily average temperature of 11.3°C (52.3°F) and an average annual precipitation of 85.6 cm. (Diamond et al. 2013). Stroubles Creek at the study site has an average discharge of 0.18 m³/s and an approximate bankfull depth of 0.7 m (Jones et al. 2015). In 2009 to 2010, the 0.87 km reach of Stroubles Creek near the study site was restored, which involved cattle exclusion from the stream and floodplain, cutting back steep banks, and constructing inset floodplains (-Thompson et al. 2012). The floodplain vegetation is heterogeneous with a recently planted woody riparian zone near the stream and herbaceous species throughout dominated by reed canary grass in predominantly wet areas. The soil is loamy clay with layers rich in organic content and intermittent subsurface clay lenses that create seasonal areas of standing water.

The study floodplain has a distinct wet season (October-April) where locations in the floodplain with subsurface clay layers are constantly inundated and the soils throughout the rest of the floodplain are highly saturated. The rest of the year (May-September), floodplain inundation decreases due to high evapotranspiration rates (Jones et al. 2015). During the study period, the floodplain experienced a maximum air temperature of 30.5°C in mid-June and a minimum air temperature of -14.9°C in February (**Figure 2-2-1**). Total rainfall over the study period was 113.5 cm based on data from the StREAM Lab weather station located within the study site (**Figure 2-2-2**).

Six sites were selected throughout the floodplain along a stream-riparian-upland gradient (upland-U, convergence-C, active floodplain-AF, slough-S, levee-L, inset floodplain-IF) (**Figure 2-2-2**) to capture temporal and spatial trends in greenhouse gas flux. Sites were chosen based on soil moisture conditions determined through seasonal aerial imaging, vegetation, and soil sensor data. The inset floodplain site is adjacent to the stream channel that was constructed during restoration (Thompson et al. 2012). The second site (L) is within several meters of the stream on the natural stream levee. The third site (S) is within one of the depressional sloughs that have

ponded water for the longest portion of the year. The next two sites are representative of generally wetter and drier regions of the main floodplain, where site four (C) is in a topographically convergent zone resulting in higher soil moisture. In contrast, the fifth site (AF) is at a similar elevation but has better infiltration and does not experience inundation except during flood events. Clay lenses below the soil surface at the convergence and slough reduce vertical infiltration and cause ponding at the surface during the wet season and precipitation events. The sixth site (U) is located outside of the 100-year floodplain on the hillslope. is located on an inset floodplain adjacent to the stream channel.

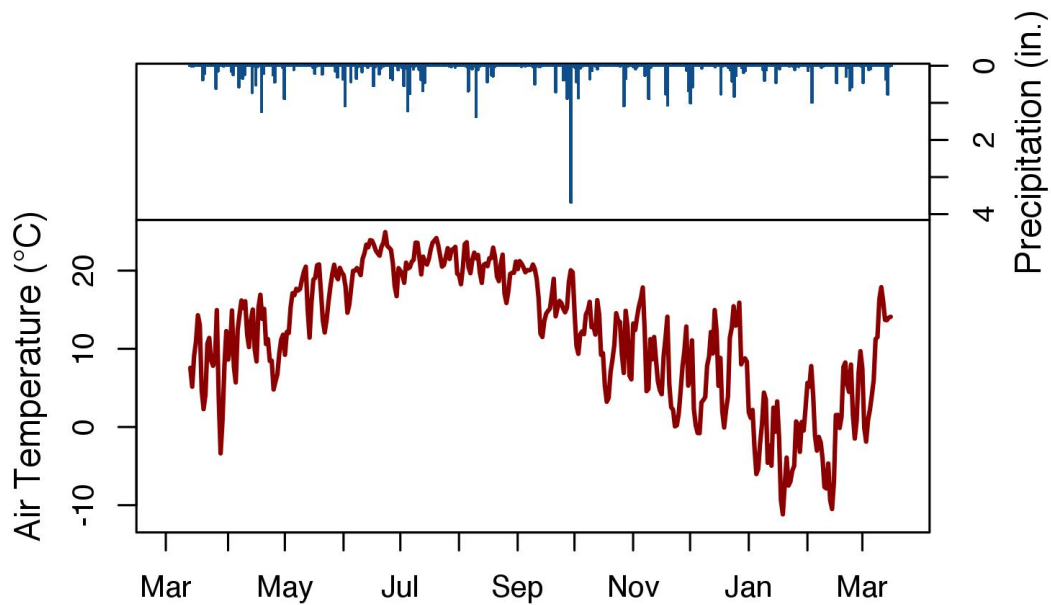


Figure 2-2-1. Daily average air temperature and daily precipitation totals from the StREAM Lab meteorological tower during the study period.

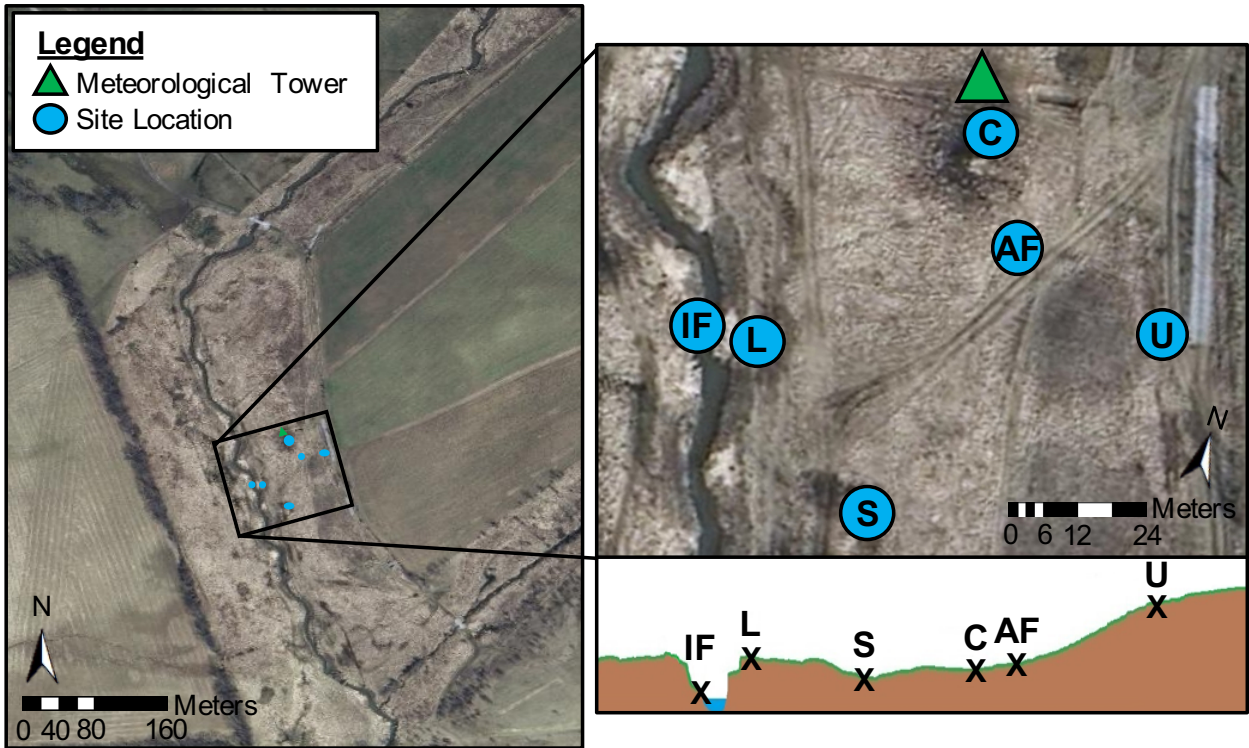


Figure 2-2-2. Map of VT StREAM Lab and enlargement of study area with relative elevation profile of the floodplain showing the location of all six sites (IF-inset floodplain, L-levee, S-slough, AF-active floodplain, C-convergence, U-upland), meteorological tower, and the spatial survey area. This stream reach lies 3 km southwest of the Virginia Tech campus.

2.2.2 Biweekly Field Measurements

A biweekly sampling campaign of greenhouse gas fluxes and their abiotic controls was completed once every other week between the hours of 0900 – 1300 over 12 months for a year (March 2015 – March 2016) for a total of 25 sampling days. Sampling was conducted during the same time of day to reduce diurnal trends in GHG flux. Access to the study area was limited over the sampling period, and boardwalks were placed during sampling campaigns to minimize soil disruption. CO_2 , CH_4 , and N_2O flux, soil moisture, soil temperature, rainfall, and available soil nutrients were measured to identify factors influencing greenhouse gas production in the floodplain. Four collars constructed from 25.3 cm inner diameter Sch. 40 PVC were installed at each of the six sites (**Figure 2-2-1**) one month prior to the initial measurement. Collars were inserted 10 cm below the soil surface, leaving about 5 cm of collar height above the surface to produce a reasonable amount of headspace volume (V_h) within the collar and a good seal with the soil, minimizing gas loss during sampling (**Figure 2-2-3**) (Brill 2013, Collier et al. 2014).

The presence of standing water and the depth of standing water were also recorded. When the water surface exceeded the collar height, a 20 cm extension collar was secured to the inserted collar. V_h ranged from 3.2 to 10.9 liters depending on water surface height and soil accumulation. Vegetation within collars was clipped to 1 cm before sampling to minimize CO_2 exchange via photosynthesis. CO_2 , CH_4 , and N_2O concentrations in the collar headspace were measured with a Picarro G2508 Cavity Ring-Down Laser Spectrometry Greenhouse Gas Analyzer (Picarro, Santa Clara, CA) using the unsteady state static chamber method similar to Keith and Wong (2006). For each measurement, a PVC cap with an outlet to the analyzer and vent was placed on the collar and sealed with a wide rubber band to the collar over a 5-minute period. Chamber GHG concentrations were assumed to be uniformly mixed and mainly driven by diffusion (Healy et al. 1996). One soil sample from a designated area within 2 meters of each site was collected on every sampling day (**Figure A-2**). To observe variability in available soil nutrients, in addition to one soil sample taken from each site, two replicate samples were collected from one designated area on a rotating basis every sampling day. About 1 kg of soil per sample was dug out with a spade to a depth of about 10 cm. Samples were placed in polyethylene bags and stored in a cooler. Soil was stored field-moist at 4°C upon returning from the field and nutrients were extracted within 24 hours of collection (Jones and Willett 2006).



Figure 2-2-3. Image depicting the four collars and solar panel station containing the data logger connected to the Decagon 5TM sensor installed at the Convergence site, and the StREAM Lab meteorological tower with rain gauge. The Decagon 5TM sensor location is marked by an orange field flag.

2.2.3 Continuous Monitoring

Soil volumetric water content and soil temperature at each site were measured continuously averaged over 15 minute intervals throughout the year using one Decagon 5TM Soil Moisture and Soil Temperature Sensor (Decagon, Pullman, WA) per site at a depth of 5 cm. Soil moisture was expressed as water filled pore space (WFPS) calculated as the ratio of the volumetric moisture content to the soil porosity (Blake and Hartge 1986). Soil porosity was calculated with bulk density estimated at each site. The rate of change between 5 days before the sampling day and the sampling day of the average 24-hr soil WFPS were calculated to define

drying or wetting periods before measurements. Precipitation was measured at the StREAM Lab meteorological station every 30 min with a TR-525USW Rainfall Sensor (**Figure 2-2-1**). Air temperature and pressure values were also recorded every 30 min by the StREAM Lab meteorological tower. The average air temperature and pressure over the sampling period for each sampling day was used in molar volume of air calculations for the gas concentration conversions.

Following the 12-month sampling campaign, the Decagon 5TM sensors were removed and calibrated and soil from inside all collars was collected for soil analysis. Bulk density was determined via percent weight of dry mass per volume of soil. Percent organic matter was measured by burning off all organics at 500°C for 5 hours and calculating the percent of mass lost. Soil samples were sent to the Virginia Tech Soil Testing Lab operated by the department of Crop and Soil Environmental Sciences for a routine soil fertility test that included soil pH.

2.2.4 Soil Extraction and Analysis for Available Nutrients

Nutrient extraction was performed as specified by Jones and Willett (2006). Soil samples were pulverized and mixed by hand to create a representative sample of the 10 cm soil profile. Soil samples were subsampled into 1:5 soil to water mixtures and mixed with a shaker table for one hour at 200 rpm. Mixtures were allowed to settle for 30 minutes before pipetting 45 mL of solution into centrifuge tubes. Samples were centrifuged for 10 minutes at 6000 rpm and were immediately filtered through a 0.45 µm filter and frozen in sterile 20 mL HDPE scintillation bottles (Fisher Scientific, Pittsburgh, PA) until nutrient analysis. Nitrate (NO₃⁻), ammonium (NH₄⁺), and soluble reactive phosphorus (SRP) were analyzed colorimetrically with a segmented flow analyzer (SEAL AA3) (SEAL Analytical, Mequon, WI). Dissolved organic carbon (DOC) and total dissolved nitrogen (TDN) were estimated using a Shimadzu TOC-Vcph analyzer (Shimadzu Scientific Instruments, Columbia, MD).

2.2.5 GHG Flux Calculations

Dry air GHG concentration data (CO₂, CH₄, and N₂O) (Keeling et al. 1976) taken by the Picarro GHG Analyzer were converted from molar fraction ppm to mol L⁻¹ using the temperature and pressure corrected molar volume of air calculated by the ideal gas law (Collier et al. 2014):

$$\left(\frac{V}{n}\right) = \frac{RT}{P}$$

where V/n is the molar volume of air in L mol^{-1} , R is the gas constant of $8.31447 \text{ L kPa K}^{-1} \text{ mol}^{-1}$, T is the average air temperature in K, and P is the average air pressure in kPa. Gas emissions for each collar were calculated by determining the change in concentration with respect to time ($\frac{\partial C}{\partial t}$) when the collar was capped and applying the general flux equation (Keith and Wong 2006, Collier et al. 2014):

$$F_{GHG} = \frac{V_h}{A} \frac{\partial C}{\partial t}$$

where F_{GHG} is the GHG flux from the soil within the collar in $\text{mol m}^{-2} \text{ s}^{-1}$, V_h is the calculated chamber headspace volume in liters, A is the calculated surface area of the soil confined by the collar in m^2 , and $\frac{\partial C}{\partial t}$ is the slope of the concentration vs. time relationship in $\text{mol L}^{-1} \text{ s}^{-1}$. The correlation coefficient (R^2) for CO_2 , CH_4 , and N_2O linear regressions ranged from 0.01 to 0.99. Low R^2 values occurred during periods of minimal flux ($\frac{\partial C}{\partial t} \sim 0$) when concentrations were near the detection limits for each respective gas (380 ppm for CO_2 , 1.5 ppm for CH_4 , and 0.3 for N_2O) (Figure 2-2-4).

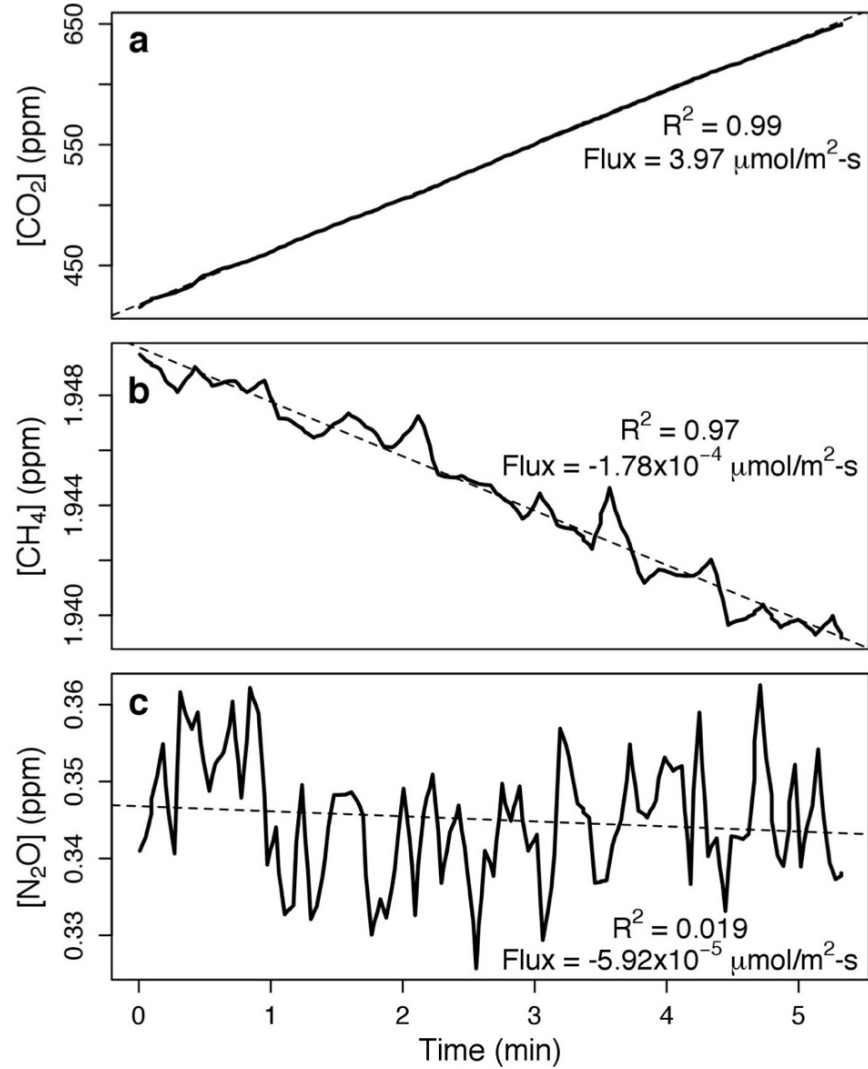


Figure 2-2-4. Sample gas concentration trends (solid line) with linear fit (dashed line) for a single collar measurement (upland collar #4; 6/4/2015) over 5 minutes for (a) CO_2 , (b) CH_4 , and (c) N_2O with R^2 and calculated flux values. Minimum instrument detection limits were 380, 1.5, and 0.3 ppm for CO_2 , CH_4 , and N_2O respectively and minimum concentrations measured during the study period were 365, 1.7, and 0.4 ppm for CO_2 , CH_4 , and N_2O respectively.

2.2.6 Statistical Analysis

Average daily GHG flux data were first tested for normality using a Shapiro test. The gas flux data sets ($n=25$ for each GHG) were identified as not normal and were log-transformed. Stepwise linear regressions were used to identify the key controls on soil greenhouse gas flux in the floodplain. All statistical tests were performed (R version 3.1.1) at a significance level of $\alpha = 0.05$.

2.2.7 Global Warming Potential and Scaling to the Stream Reach

The average annual flux values for each site were converted to global warming potential (GWP) in kg CO₂/ha-year. At a 20-year timescale, CH₄ and N₂O respectively are 72 and 289 times more potent than CO₂ in the atmosphere (IPCC 2014). A 20-year time scale was used to correlate with a scale by which floodplain landscapes may change. These GWP values were scaled to a 2.5 ha floodplain of a 210 m reach. Total area coverage of each site was estimated using the total wetness index (TWI) and a digitalized elevation model (DEM) normalized to the overall valley elevation. The TWI was calculated using the equation:

$$TWI = \ln \left(\frac{\alpha}{\tan(\beta)} \right)$$

where α is the upslope contributing area and β is the slope (Beven and Kirkby 1979). Each site type was classified by the TWI and normalized elevation measured at each site location in this study. A detailed account of the method used is provided in **Appendix C.3**.

2.3 Results

2.3.1 Seasonality and Spatial Heterogeneity of Soil Conditions in the Floodplain

Soil temperature followed a seasonal pattern with warmer temperatures in the summer (May – September) and colder temperatures in the winter (October – April) (**Figure 2-2-5a**). Although soil temperature did not vary much between sites, soil moisture was highly variable in degree of saturation and response to rainfall. Soil moisture trends showed a wet season (October – May) and dry season (June – September) (**Figure 2-2-5b**) throughout the study area. Generally, the winter months were wetter when water loss via evapotranspiration was minimal, and lowest following rain free periods in the summer when evapotranspiration is at a maximum. Standing water (highlighted in grey in **Figure 2-2-5b**) was present over 65% of the year at the convergence and slough sites and 40% of the year at the inset floodplain site during the wet period and periodically following rainfall/flooding events during the summer. Soil moisture within the drier sites also responded to rainfall events and never reached saturation excess with the exception of the single overbank flood event that inundated the entire floodplain (9/29/2015). The inset floodplain remained highly saturated (80% - 100% WFPS) for the entire study period and only showed responses to large rainfall events. Periods of standing water on the inset

floodplain were short and intermittent, and corresponded with increases in stream flow (**Figure 2-2-5b**).

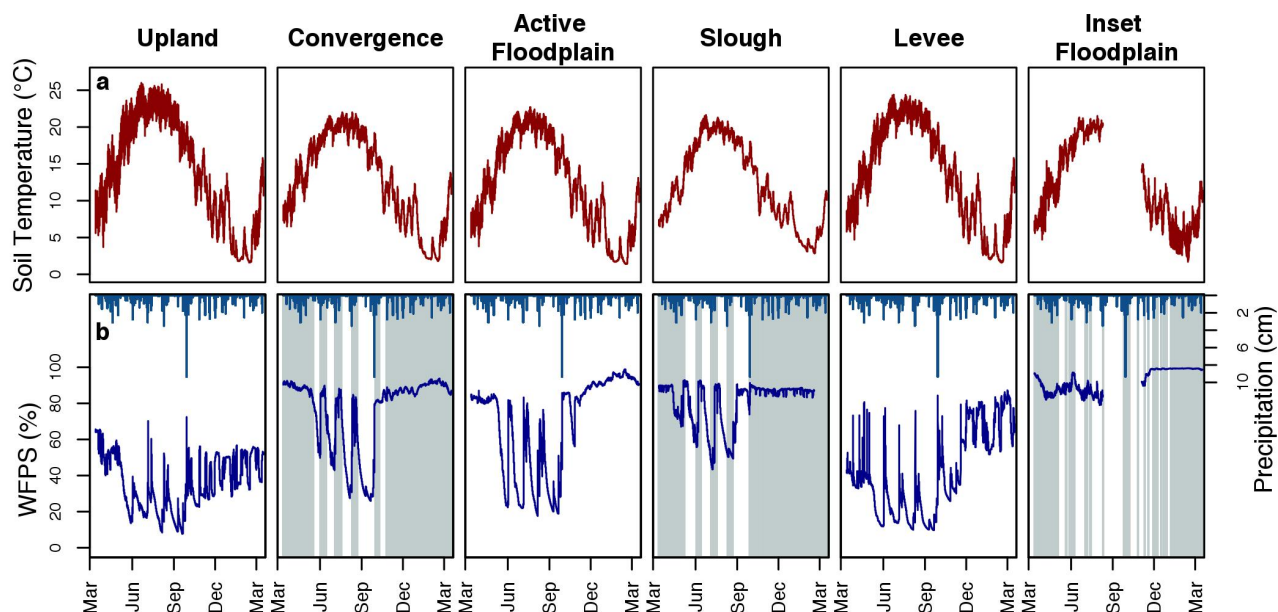


Figure 2-2-5. (a) Soil temperature (red) and, (b) soil water-filled pore space (dark blue), precipitation (light blue), and periods of inundation (grey shaded area), and for each site over the study period.

Available soil nutrients varied widely in temporal and spatial patterns over the study period (**Figure 2-2-6**). Overall NO_3^- , NH_3 , and DOC concentrations were the highest in the fall and ranged from 0.1 to 15.8, 0.0 to 64.6, and 0.0 to 51.3 mg/g soil respectively (**Table 2-2-1**) SRP concentrations ranged from 0.0 to 2.0 mg/g soil but did not have any discernable variation throughout the year. Increased nutrient availability during the fall (beginning in October) corresponds to the beginning of the wet season, leaf senescence, and the suppression of nutrient cycling in vegetation.

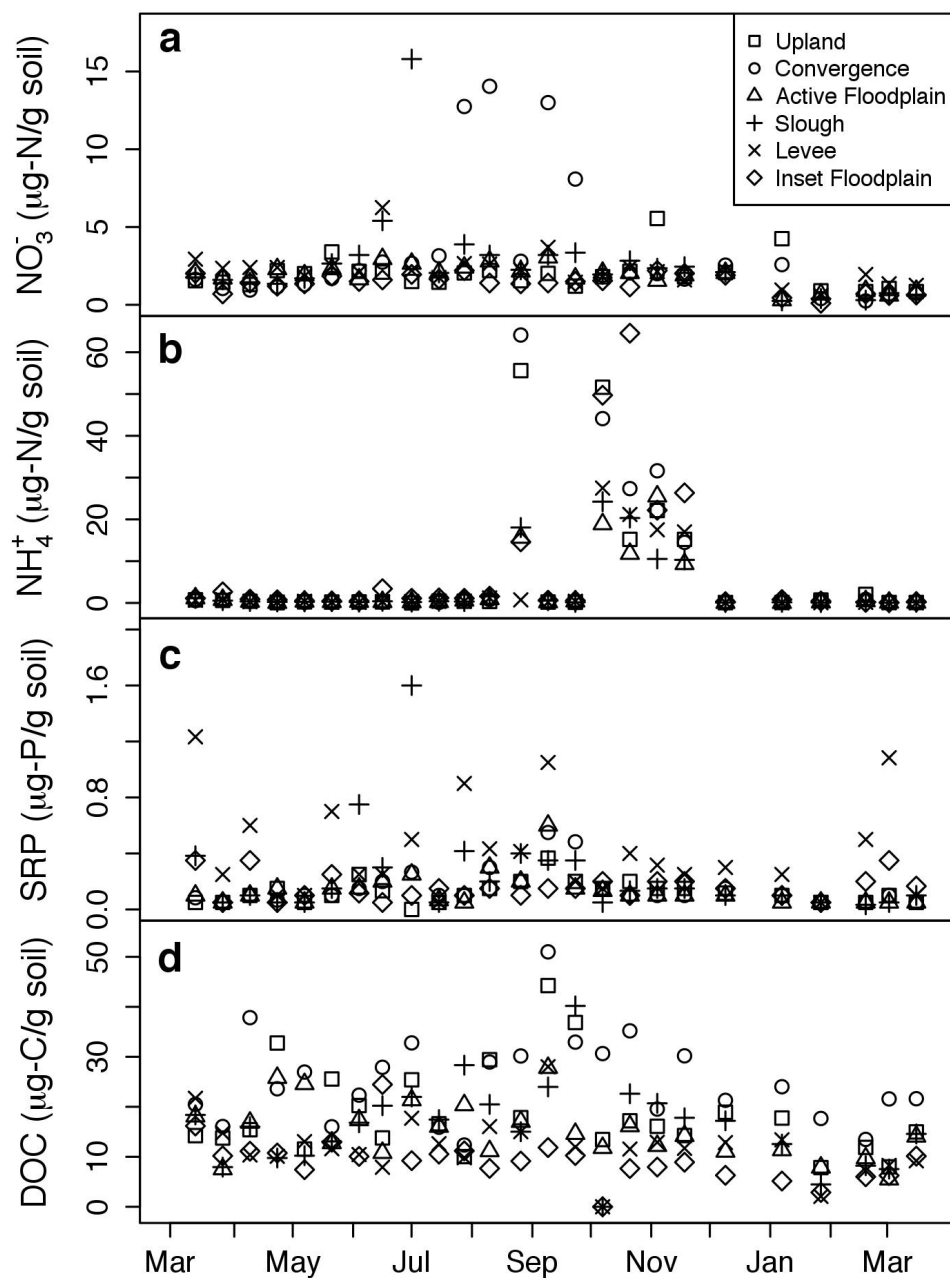


Figure 2-2-6. Available soil (a) NO_3^- -N, (b) NH_3 -N, (c) SRP, and (d) DOC concentration for each site over the study period.

Table 2-2-1. Minimum, maximum and average available nutrient concentrations (µg/g soil) per site for each season and annually.

	NO ₃ ⁻				NH ₄ ⁺				SRP				DOC			
	Spr	Sum	Fall	Win	Ann	Spr	Sum	Fall	Win	Ann	Spr	Sum	Fall	Win	Ann	Ann
Upland	Min	0.9	1.5	1.2	0.9	0.9	0.1	0.0	0.2	0.1	0.0	0.1	0.0	0.2	0.1	0.0
	Max	3.4	2.4	5.6	4.3	5.6	1.3	55.6	51.6	2.1	55.6	0.2	0.3	0.5	0.2	0.5
	Avg	1.7	1.9	2.3	1.9	1.9	0.5	6.4	13.1	0.5	4.9	0.1	0.1	0.2	0.1	0.1
Convergence	Min	0.8	2.1	1.7	0.3	0.3	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1
	Max	1.7	14.1	13.3	3.6	14.1	1.1	64.1	44.1	0.9	64.1	0.1	0.4	0.9	0.2	0.9
	Avg	1.3	5.1	5.6	1.7	3.3	0.4	7.5	14.8	0.4	5.5	0.1	0.2	0.3	0.1	0.2
Active Floodplain	Min	0.9	1.7	1.6	0.3	0.3	0.1	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1
	Max	2.8	3.0	3.1	2.1	3.1	1.9	15.6	25.5	0.5	25.5	0.2	0.3	0.6	0.1	0.6
	Avg	1.9	2.3	2.1	0.8	1.8	0.5	2.1	13.0	0.2	3.7	0.1	0.2	0.2	0.1	0.1
Slough	Min	0.7	2.1	2.0	0.3	0.3	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.0	0.0
	Max	2.7	15.8	3.4	2.1	15.8	2.4	18.1	24.7	0.4	24.7	0.5	1.6	0.4	0.1	1.6
	Avg	1.6	4.8	2.7	0.6	2.5	0.5	2.4	13.3	0.2	3.9	0.2	0.5	0.2	0.1	0.2
Levee	Min	1.3	1.8	1.5	0.6	0.6	0.1	0.2	0.2	0.1	0.1	0.1	0.1	0.2	0.1	0.1
	Max	3.7	6.3	3.7	2.2	6.3	1.2	1.9	27.5	0.2	27.5	2.0	0.9	1.1	1.7	2.0
	Avg	2.4	2.8	2.2	1.4	2.2	0.4	0.7	14.9	0.1	3.7	0.6	0.4	0.4	0.6	0.5
Inset Floodplain	Min	0.5	1.0	1.2	0.1	0.1	0.2	0.4	0.6	0.1	0.1	0.1	0.1	0.1	0.1	0.1
	Max	2.2	2.2	2.4	1.9	2.4	2.7	41.3	64.6	0.8	64.6	0.6	0.2	0.3	0.4	0.6
	Avg	1.3	1.6	1.7	0.8	1.4	0.9	4.9	27.1	0.4	8.0	0.2	0.1	0.2	0.2	0.2
Overall	Min	0.5	1.0	1.2	0.1	0.1	0.1	0.0	0.2	0.1	0.0	0.1	0.0	0.1	0.0	0.0
	Max	3.7	15.8	13.3	4.3	15.8	2.7	64.1	64.6	2.1	64.6	2.0	1.6	1.1	1.7	2.0
	Avg	1.7	3.0	2.8	1.2	2.2	0.5	4.0	16.0	0.3	5.0	0.2	0.2	0.2	0.2	0.2

Soil pH ranged from 6.21 to 7.81, soil bulk density from 0.64 to 0.92 g/cm³, organic matter content from 10 to 20%, and porosity from 0.65 to 0.76 across the sites (**Table 2-2-2**). The convergence, active floodplain, and slough soil had the lowest bulk density and highest organic matter content. The upland, levee, and inset floodplain had similar organic matter content, but the upland had higher bulk density meaning the upland also had the lowest porosity. The sites that were most frequently inundated (convergence, slough) had the lowest bulk density and pH.

Table 2-2-2. Average soil characteristics per site.

	Upland	Convergence	Active Floodplain	Slough	Levee	Inset Floodplain	Overall
pH	7.71	6.21	7.02	6.56	7.63	7.81	7.16
Bulk Density (g/cm ³)	0.924	0.67	0.69	0.64	0.87	0.77	0.76
% Organic Matter	11	16	20	15	11	10	14
Porosity	0.65	0.75	0.74	0.76	0.67	0.71	0.71

2.3.2 Temporal Greenhouse Gas Flux Patterns

Greenhouse gas fluxes varied spatially and temporally throughout the floodplain following a predictable seasonal pattern for CO₂ and CH₄. CO₂ flux peaked during the summer months (May-August) (**Figure 2-2-7a**) with a maximum daily average value of 10.1 µmol/m²-s on 6/16/2015 at the levee and a minimum daily average value of -0.0812 µmol/m²-s on 2/20/2016 at the upland. Measureable CH₄ fluxes were detected within the inset floodplain and the slough. CH₄ fluxes within the inset floodplain followed a similar pattern as CO₂ flux and peaked in August (**Figure 2-2-7b**) with a maximum daily average value of 1.26 µmol/m²-s on 8/10/2015. The highest daily average CH₄ flux value measured at the slough was 0.209 µmol/m²-s on 4/23/2015. This location also had the only observed CH₄ sink measurements with a minimum daily average flux of -0.561 µmol/m²-s on 5/7/2015. N₂O fluxes were generally near the detection limit of the instrument, where the maximum daily average flux was 0.00254

$\mu\text{mol}/\text{m}^2\text{-s}$ (**Figure 2-2-7c**). In contrast to CO_2 and CH_4 , N_2O fluxes did not follow a discernable seasonal pattern.

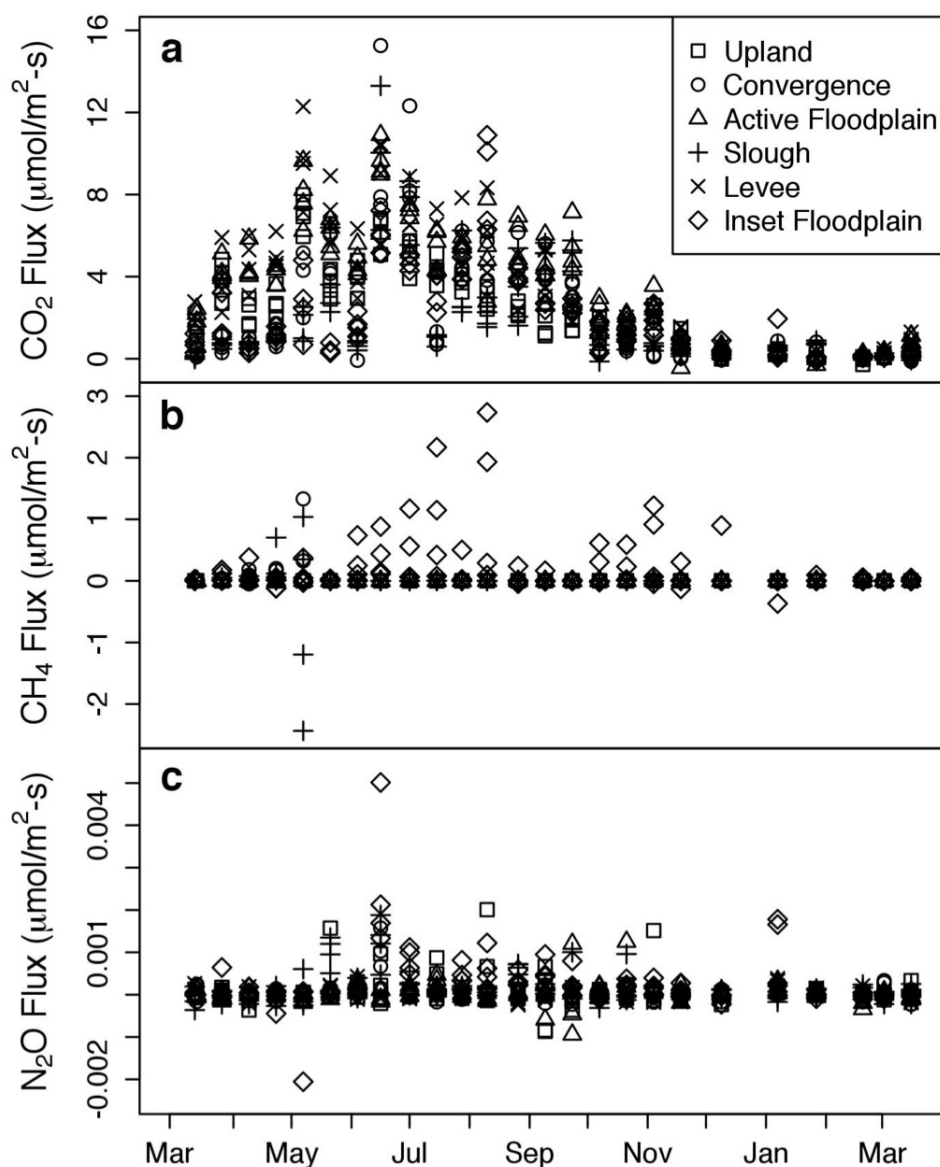


Figure 2-2-7. (a) CO_2 , (b) CH_4 , and (c) N_2O flux from all collars at each site in the floodplain over the entire study period.

2.3.3. Spatial Greenhouse Gas Flux Patterns

Sites that had fewer interactions with either groundwater or surface water (upland, active floodplain, levee) had greater CO_2 production during a floodpulse than the hydrologically active sites (convergence, slough, inset floodplain; **Figure 2-2-8a**). One likely mechanism for this is the suppression of CO_2 diffusion through the water column to the atmosphere. The inset floodplain

produced greater CH₄ flux values in comparison to any other site (**Figure 2-2-8b**). The upland, slough, and inset floodplain were the only sites that showed any variation in N₂O production throughout the study period (**Figure 2-2-8c**).

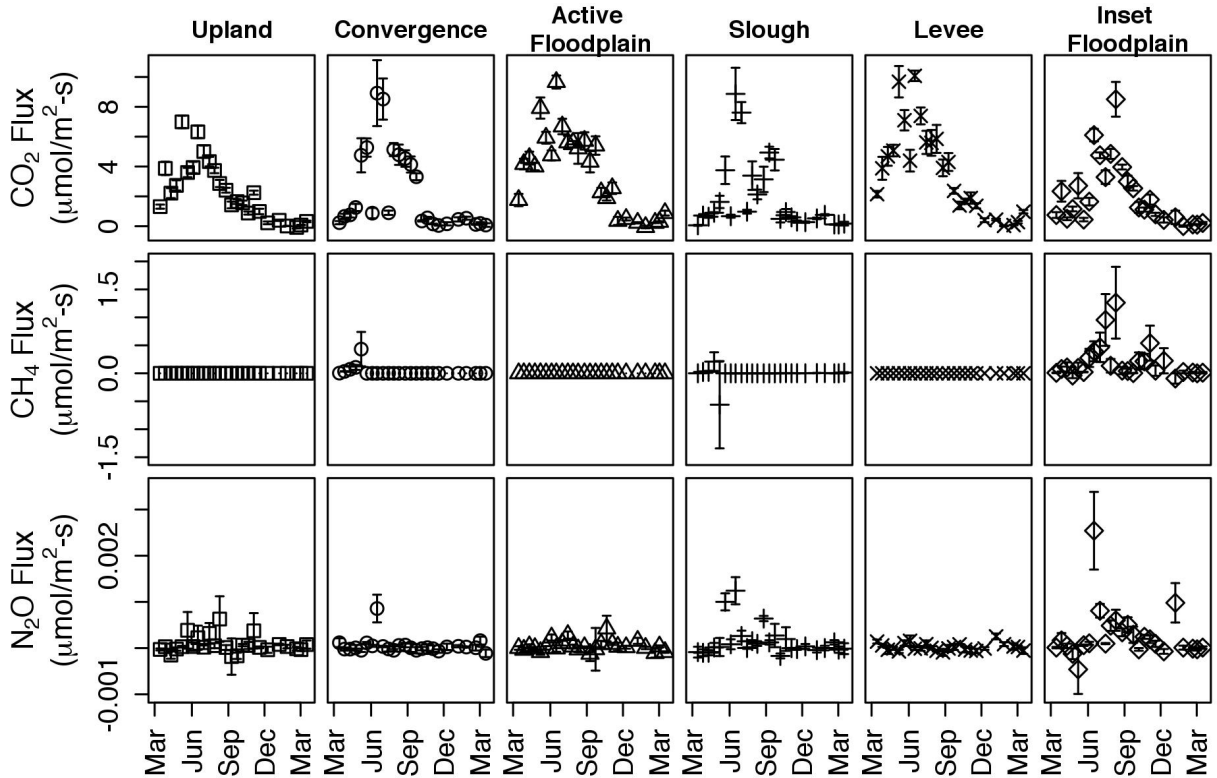


Figure 2-2-8. Daily average CO₂, CH₄, and N₂O flux over time per site with standard error.

2.2.4 GHG Flux Stepwise Linear Regression Models

The stepwise linear regression model was used to identify the primary variables contributing to the spatial and temporal variation in GHG fluxes. Temporally varying variables included soil temperature (*ST*), soil WFPS (*WFPS*), change in soil WFPS over the previous 5 days (*WFPS*₅), total daily precipitation (*P*₀), total precipitation of the previous day (*P*₋₁), standing water height (*h*_{H₂O}), number of days with standing water (*D*_{H₂O}), and soil available nutrients (*NO*₃⁻, *NH*₃, *SRP*, *DOC*). Additionally, static soil properties (bulk density (*ρ*_{*b*}), soil organic matter content (*OM*), and soil pH) were included. The resulting models for each gas are:

$$\ln(CO_2 \text{ Flux}) = 0.17ST - 0.048P_{-1} - 0.15h_{H_2O} + 6.2OM - 2.6 \quad (R^2 = 0.62)$$

$$\ln(CH_4 \text{ Flux}) = 0.24ST - 0.028WFPS - 0.12P_{-1} + 0.037D_{H_2O} + 0.049DOC - 23\rho_b + 5.2pH - 33 \quad (R^2 = 0.64)$$

$$\ln(N_2O \text{ Flux}) = 0.086ST + 0.015WFPS - 0.14h_{H_2O} - 12 \quad (R^2 = 0.11)$$

Significance of the factors on each GHG flux is assessed by the given p-value (**Table 2-2-3**).

Table 2-2-3. P-values for proposed controls on GHG production from stepwise linear model.

	ST	WFPS	P ₋₁	h _{H₂O}	D _{H₂O}	DOC	ρ _b	OM	pH
CO ₂	2x10 ⁻¹⁶	-	0.04	1x10 ⁻⁴	-	-	-	0.006	-
CH ₄	9x10 ⁻¹⁰	0.005	0.02	-	2x10 ⁻¹⁶	0.02	5x10 ⁻⁹	-	8x10 ⁻¹⁵
N ₂ O	0.001	0.009	-	0.02	-	-	-	-	-

2.4 Discussion

2.4.1 CO₂ Fluxes

CO₂ flux from the soil was highly correlated with soil temperature and variables representing hydrologic characteristics of the soil. Increasing soil temperatures influence metabolic processes by improving enzymatic and cell function (Hinshelwood 1946). This interaction between the microbial respiration and soil temperature has been well documented throughout the literature (Pulliam 1993, Updegraff et al. 2001, Conant et al. 2004, Elaiison et al. 2005, Morse et al. 2012). Temporal patterns in CO₂ flux that correspond to temperature may also be driven by availability to substrate during periods of active photosynthesis and in areas with greater organic matter content. However, we were not able to discern vegetative influence on CO₂ flux via photosynthesis or root respiration, and therefore our total CO₂ flux value will be offset by primary production on the floodplain especially during the growing season. Hydrologic characteristics including the change in WFPS over five days, precipitation from the previous day, and inundation height were all negatively correlated with CO₂ flux. Consumption and lack of replenishment of O₂ as saturation increases in the soil restricts CO₂ production by respiring microbes (Linn and Doran 1984, Davidson et al. 2000, Batson et al. 2014). Similarly, since CO₂ diffusion through standing water ($D = 1.92 \times 10^{-5} \text{ cm}^2/\text{s}$; Marrero and Mason 1972) is significantly

slower than through air ($D = 0.139 \text{ cm}^2/\text{s}$; Pritchard and Currie 2006), increasing inundation height suppressed CO_2 flux. CO_2 production is heavily linked to the percentage of organic matter in the soil especially near the soil surface (Schlesinger and Andrews 2000). Although the floodplain soils only varied 10% in organic matter content, small increases in organic matter still had a positive correlation with CO_2 production.

2.4.2 CH_4 Fluxes

CH_4 flux was strongly linked to redox conditions in the soil. Significant CH_4 fluxes were only observed at locations with inundation periods lasting at least 40% of the year with little recharge of O_2 (convergence, inset floodplain). However, standing water may not be the only indicator of CH_4 production in soils since the slough experienced similar sustained inundation periods and was a sink for CH_4 . This can be attributed to CH_4 uptake through the vascular system of emergent macrophytes from the water column and the subsequent diffusion of atmospheric CH_4 through the water surface (Villa and Mitsch 2014). High production of CH_4 at the inset floodplain especially in warm conditions with high organic matter sequestration suggests a potential deterrent for stream restoration practices. Introducing ponds, pools, or inset floodplains with prolonged inundation may increase overall CH_4 emissions from the floodplain. Soil pH affects many microbial species by limiting enzymatic activity. Wang et al. (1993) found that methanogens produced higher CH_4 at about neutral pH and that even a slight decrease in pH would significantly decrease CH_4 production. Bulk density is an indicator of diffusion of gases through the soil matrix. Studies have observed restriction of gas diffusion with increasing bulk density especially in terms of CH_4 (Dorr et al. 1993, Keller and Reiners 1994, Macdonald et al. 1996). While the sampled surface sediment at the inset floodplain site had newly exposed soil with low organic matter content, soil surrounding root zones deeper in the horizon showed evidence of higher organic content. This sediment, in permanently saturated conditions due to water table height, may be the location of high CH_4 production.

2.4.3 N_2O Fluxes

Low N_2O fluxes were observed throughout the floodplain over the course of the year. Yet, the IPCC (2014) attributes 20% of total N_2O flux to the atmosphere to be from soils under natural vegetation. Low and even negative N_2O flux from soils similar to our study has been observed in many studies (Jordan et al. 1998, Schiller and Hastie 1996, Pinto et al. 2006, Yates et al. 2006). N_2O reduction to N_2 via denitrification in microsite hotspots in the soil contributes to

low flux of N_2O especially during periods of low available NO_3^- (Chapuis-Lardy et al. 2006). However, many sources show short pulses of N_2O flux in response to rapidly changing environmental conditions such as wetting and drying cycles in coordination with precipitation events (Groffman and Tiedje 1988, Davidson et al. 1993, Ruser et al. 2006, Rowlings et al. 2015). This can be attributed rapid shifts in electron acceptor availability as the soil is saturated and dries out. The temporal resolution of our study was not detailed enough to observe these types of responses in N_2O flux. The highest N_2O flux values were observed at the inset floodplain site where the greatest levels of anoxia occurred. Yet, these values remained insignificant in comparison to observed CO_2 and CH_4 fluxes.

2.4.4 Average Annual GHG Fluxes and Global Warming Potential (GWP)

In the present study, the floodplain experienced positive annual fluxes for all measured GHGs. The levee and active floodplain produced the most annual CO_2 over the study period at approximately $1,410 \text{ g C/m}^2\text{-yr}$ (**Table 2-2-4**). These two sites were highly productive due to high availability of organic matter substrate in the soil matrix and were not restricted in O_2 concentrations by high soil moisture or inundation. Our average annual CO_2 flux values were slightly lower than other measured fluxes from floodplains but not from drier sites such as riparian buffers (Jacinthe et al. 2015) (**Table 2-2-5**). However, our CO_2 flux values are overestimates because we did not take into account CO_2 uptake via photosynthesis occurring in the floodplain especially during the growing season when CO_2 production peaked. In comparison, net primary productivity in similar floodplains ranges from 360 to $1,125 \text{ g C/m}^2\text{-yr}$ (Aselmann and Crutzen 1989). The inset floodplain produced substantially higher CH_4 flux than any other site at $78 \text{ g C/m}^2\text{-yr}$ (**Table 2-2-4**). Comparable wetlands produced much lower CH_4 flux (**Table 2-2-5**) (Audet et al. 2013b, Batson et al. 2014). This causes concern for the influence of the construction of inset floodplains as a restoration strategy on altering the floodplain's annual GWP. The floodplain produced very little annual N_2O flux in comparison to CO_2 and CH_4 over the entire year with a value of $0.03 \text{ g N/m}^2\text{-yr}$ (**Table 2-2-4**). Similar studies observed similar flux values with wide variability between sites (**Table 2-2-5**). However, as implied previously, standard observational campaigns do not sample frequently enough to detect perturbation driven pulses in N_2O flux. The overall average global warming potential (GWP) on a 20-year timescale observed for this study was $39,555 \text{ kg CO}_2\text{/ha-yr}$. Of the six sites, the inset floodplain produced the greatest average GWP from mostly CH_4 (**Figure 2-2-9**).

Table 2-2-4. Average annual flux measured at each site in g C/m²-yr for CO₂ and CH₄, and g N/m²-yr for N₂O.

	Upland	Convergence	Active Floodplain	Slough	Levee	Inset Floodplain	Average
CO ₂	927	895	1,413	758	1,412	833	804
CH ₄	-0.051	10	-0.088	-4.5	-0.052	80	10
N ₂ O	0.032	0.024	0.021	0.068	0.010	0.13	0.030

Table 2-2-5. Average annual flux from comparable studies in g C or g N/m²-yr.

Source	Location	CO ₂ (g C/m ² -yr)	CH ₄ (g C/m ² -yr)	N ₂ O (g N/m ² -yr)
This study	Floodplain Wetland; Virginia	804	10	0.03
Batson et al. 2014	Floodplain Wetland; Virginia	1,091	-0.3	0
Jacinthe et al. 2015	Riparian Buffer; Indiana, USA	495	92	...
Audet et al. 2013a	Restored Riparian Wetland; Denmark	1,199	-0.03	0.01
Morse et al. 2012	Forested Wetland; North Carolina, USA	...	14.5	0.45
Pulliam 1993	Floodplain Wetland; Georgia, USA	919	...	...
Hernandez and Mitsch 2006	Restored Riparian Marsh; Ohio, USA	...	...	0.03
Song et al. 2009	Seasonally Inundated Wetland; Northeastern China	880	4.4	0.11

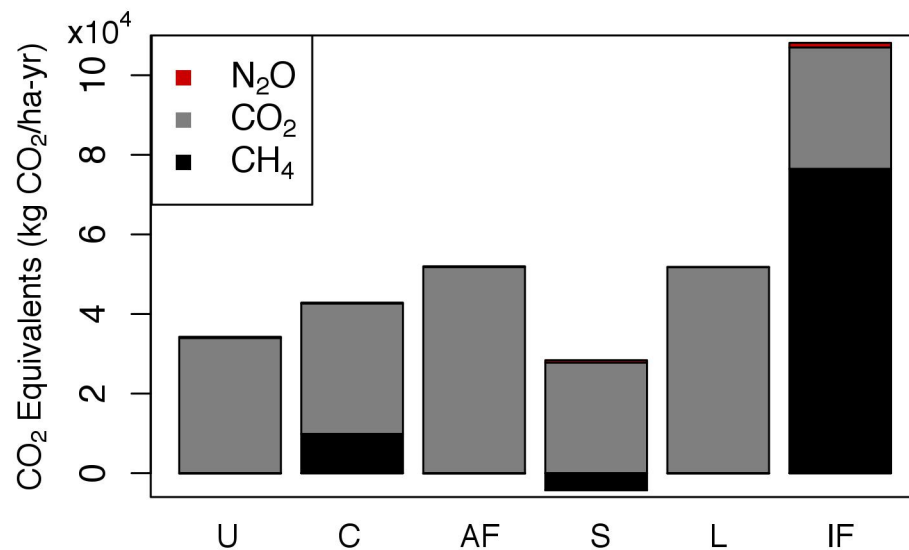


Figure 2-2-9. Cumulative global warming potential per site.

2.4.5 Floodplain GWP at the Reach Scale

Natural floodplain topography creates localized hotspots of active biogeochemistry largely driven by the degree of saturation in the soil (Harms and Grimm 2008). For this study, we chose six different locations in the floodplain that represented common soil moisture conditions along the stream to upland valley gradient to be able to characterize total annual GHG flux from the entire floodplain area. At the reach scale, a 208 m reach of Stroubles Creek with a floodplain of 3 ha consisted of mostly active floodplain with intermittent convergence and slough areas (**Figure 2-2-10**). This floodplain's total annual global warming footprint from soil was 131,398 kg CO₂/yr (**Table 2-2-6**). 97% of this total GWP was from CO₂ and the site type that contributed the greatest GWP was the active floodplain. As discussed above, the magnitude of CH₄ flux emitted by the inset floodplain site over the course of the year posed a concern for the climate. However, at the reach scale, the inset floodplain type covered a very small portion of the floodplain and contributed insignificant amounts of CH₄ to the overall GWP of the floodplain. An increase in floodplain connectivity would convert active floodplain areas to convergence or slough type conditions, decreasing the CO₂ flux but increasing the potential for CH₄ flux, especially during the wet season when evapotranspiration shuts down and inundation period is lengthened. Therefore, practitioners should be aware of potential alterations in GHG flux when restoring floodplain connectivity.

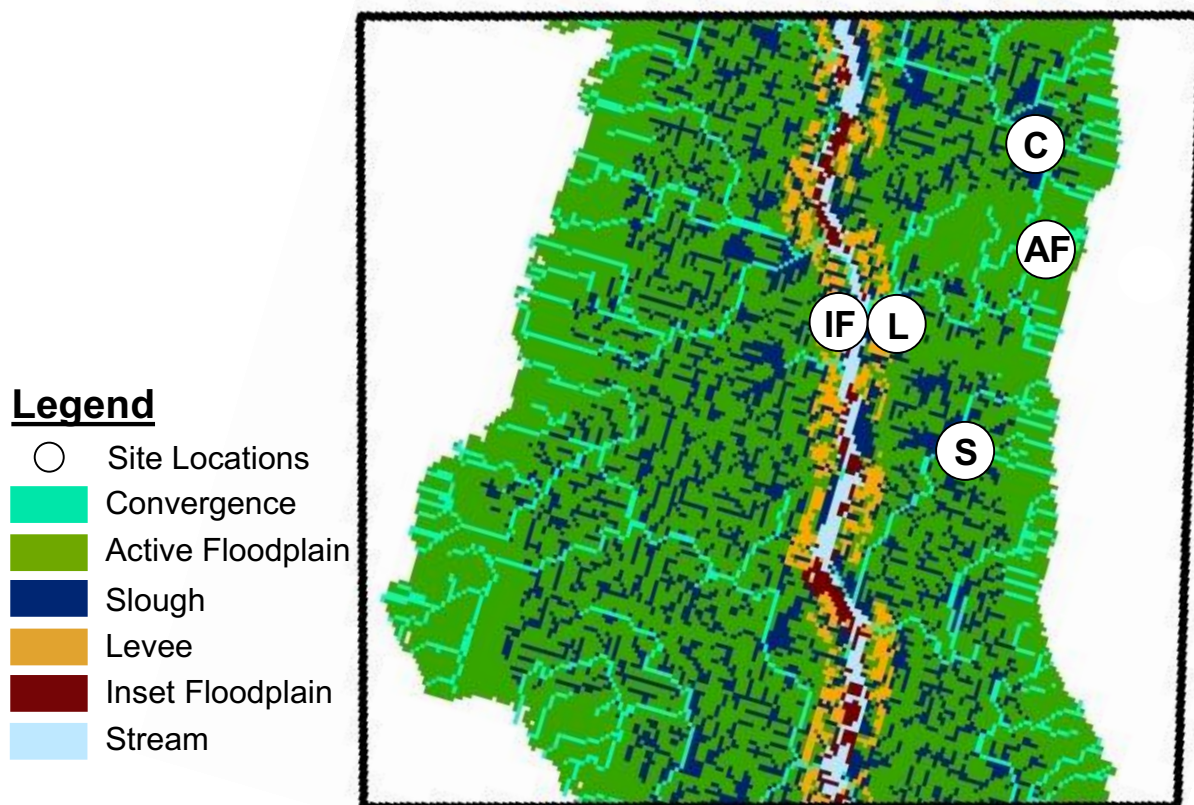


Figure 2-2-10. Estimated site type area coverage for a reach of Stroubles Creek.

Table 2-2-6. Site area, site GWP and areal GWP for all site types in the total floodplain area.

Site Type	Area (ha)	Percent Area	Site GWP (kg CO ₂ equivalents/ha-yr)			Areal GWP (kg CO ₂ equivalents/yr)			Total Areal GWP
			CO ₂	CH ₄	N ₂ O	CO ₂	CH ₄	N ₂ O	
Convergence	0.22	8.8%	32,779	9,862	215	7,156	2,153	47	9,355
Active Floodplain	1.6	65%	51,795	-84	190	83,903	-137	308	84,074
Slough	0.51	21%	27,773	-4,289	620	14,239	-2,199	318	12,358
Levee	0.10	4.0%	51,839	-50	103	5,189	-5	10	5,194
Inset Floodplain	0.034	1.4%	30,513	76,479	1147	1,031	2,585	39	3,655
Overall Floodplain	2.5	100%	194,608	81,923	2,266	111,509	2,398	721	114,628

2.5 Conclusions

Biogeochemical cycling over temporal and spatial scales are highly variable and dependent on many factors. While the effects of individual factors on GHG production are easy

to establish, especially in the lab setting, field studies that investigate the conjunctive effect of multiple influencers are less successful. This is due to the variability of all factors over not only time but space as well.

The greatest GHG production occurred during the peak of the summer when all plant and microbial activity was at its highest. During this time, the heterogeneity of the soil especially in terms of soil moisture was low. Control of stream-floodplain connectivity during warmer months, specifically by inundating the floodplain, would increase the spatial variability of factors that control GHG production and thus reduce overall GHG emissions. Increasing the connectivity of streams to their floodplains may reduce overall CO₂ emissions, but increase the potential for creating hotspots of CH₄ or N₂O production by altering soil moisture and inundation periods. Of the six selected sites for this study, the inset floodplain constructed as a stream restoration strategy produced considerable amounts of CH₄ compared to the other sites. Therefore, practitioners should use caution when installing frequent sequential inset floodplains in reaches with small floodplains to not alter the natural GHG production to negatively impact the local climate.

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Appendix A: Additional Site Characterization Tables and Figures

Figure A-1 shows the arrangement of collars for each site in relation to the stream with site latitude and longitude locations in **Table A-1**. Due to heterogeneity in soils, individual collars may have been located on micro hot spots within the sites themselves. Collars 1 and 3 at the inset floodplain site showed greater response in CH₄ than the other two. All other collars at the other sites did not show strikingly different patterns compared to their counterparts (**Figure A-2**).

Table A-1. Latitude and longitude locations for each site in degree decimal minutes.

Site	Latitude	Longitude
Upland	37°12.369 N	80°26.790 W
Convergence	37°12.384 N	80°26.813 W
Active Floodplain	37°12.371 N	80°26.807 W
Slough	37°12.342 N	80°26.811 W
Levee	37°12.355 N	80°26.830 W
Inset Floodplain	37°12.355 N	80°26.835 W

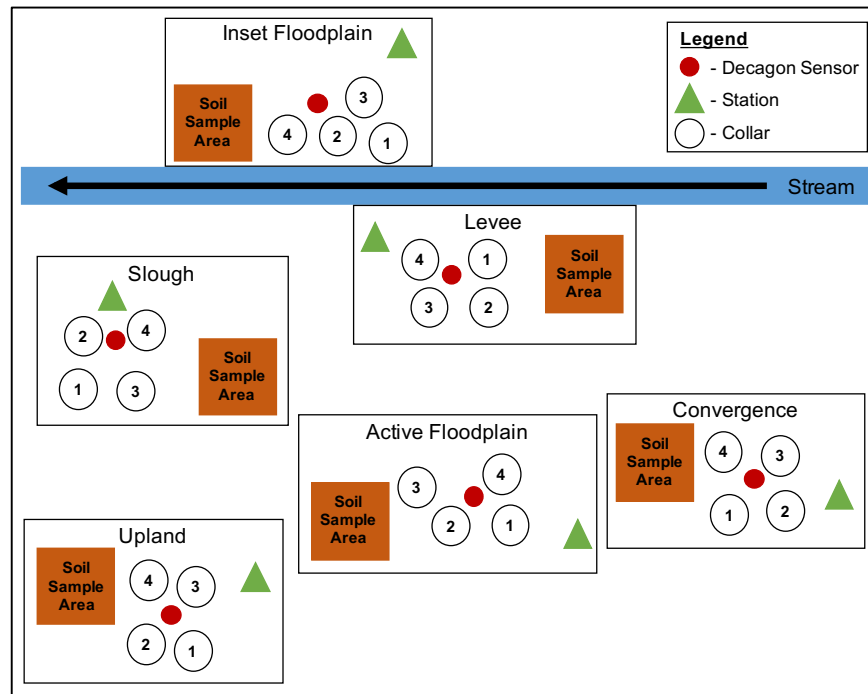


Figure A-1. Images showing locations of individual collars at each site (not to scale).

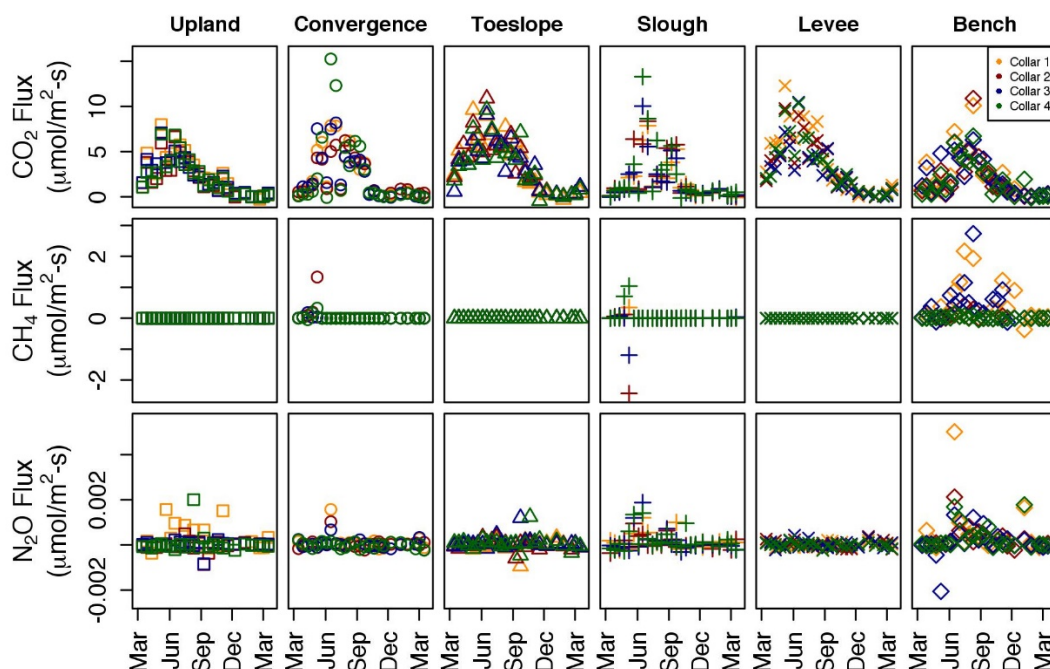


Figure A-2. GHG flux trends from each individual collar at each site over the study period.

At the end of the study period, soil from inside every collar was collected and sent to the Virginia Tech Soil Analysis Laboratory. Additional soil characteristics were measured but not used in the statistical analysis (**Table A-2**).

Table A-2. Additional average soil properties from soil inside collars at each site.

	pH	P (ppm)	K (ppm)	Ca (ppm)	Mg (ppm)	Zn (ppm)	Mn (ppm)	Cu (ppm)	Fe (ppm)	B (ppm)	CEC (meq/100g)
Upland	7.71	6	88	3305	975	1.1	19.8	0.1	7.7	1.7	24.725
Convergence	6.21	7	64	1914	293	3.7	21.6	0.7	120.0	1.2	13.525
Active Floodplain	7.02	7	87	2895	694	3.1	16.8	0.1	3.9	2.3	20.35
Slough	6.56	18	76	2428	477	10.6	33.2	1.0	42.7	1.9	16.75
Levee	7.64	18	59	3727	664	11.4	17.3	0.2	4.1	1.7	24.2
Inset Floodplain	7.81	1	35	4593	436	10.5	26.6	0.1	0.5	0.6	26.575

Appendix B: Instrumentation

B.1 Picarro G2508 Analyzer Operation

A Picarro G2508 Cavity Ring-Down Laser Spectrometry Greenhouse Gas Analyzer was used to measure greenhouse gas flux from the floodplain. This instrument utilizes cavity ring-down laser spectrometry technology to measure CO₂, CH₄, N₂O, NH₃, and water vapor. Sample air flows through a chamber lined with high reflectivity mirrors. A single-frequency laser fills the chamber with light and immediately shuts off. The light reflects off of the mirrors and decays at a set exponential rate to create the “ring-down” effect which is measured by a photodetector. The laser wavelength is adjusted to emit light within the absorption spectrum for each of the gases. When the chamber is filled with an absorbing gas, the light decays faster than in the empty chamber. The instrument uses these decay rates to calculate the concentrations of each gas in an air parcel (Busch and Busch 1997).

The particular instrument set up used for this study includes the analyzer, a multiplexor, and a pump strapped and attached to shelving within a transportable box (**Figure B-1**). When in the field, the transportable box was strapped to a utility cart for mobility. The instrument was powered in the field by a small gas generator. Nalgene tubing and Swagelok fittings were used to attach the cap to the multiplexor valve. For easy access in the field, a mobile tablet was used in place of a monitor, mouse, and keyboard. A wireless USB adapter was installed in the instrument to emit a wireless signal. The tablet used this signal and a personal hotspot created by a cellular device to connect to the instrument over a remote desktop application. To ensure a proper connection, the personal hotspot connection was created first and then the tablet was operated to connect to the cellular device. When the instrument was used in temperatures colder than the specified minimum operational temperature (10°C), the transportable box was lined with 0.5 inch insulation to keep the instrument heated and a desiccant chamber was attached to the intake valve during shutdown to reduce the humidity of the air entering the instrument and prevent condensation upon returning to the lab.



Figure B-1. Image of the Picarro G2508 with cap attachment installed in the transportable box and strapped to a utility cart. Shown with operating tablet in waterproof case.

Reference:

Busch, K. W., and M. A. Busch. 1999. Cavity ring-down spectroscopy: An ultratrace absorption measurement technique. American Chemical Society Symposium Series **720**.

B.2 Decagon Sensor Installation

This sensor installation procedure was based on sensors previously deployed by Chris Guth (Guth 2014). A data logger station was set up near the installed collars at five of the sites on 2 February 2015 (**Figure B-2a**). The three stations at the slough site were previously installed in 2013 (Guth 2014) which continue to collect data. Each station consisted of a protective box and solar panel attached to an aluminum pole which was pounded into the ground (**Figure B-2b**). CR200 Series data loggers (Campbell Scientific, Inc., Logan, UT) were used to collect data from

the Decagon 5TM sensors. The sensors were connected to the data logger as follows: red cable to the SDI port, white cable to the battery port, and the naked cable to a ground port. Each data logger was powered by a 12-volt battery connected to a solar panel drip charge (**Figure B-3**). The data loggers were programmed to collect data measurements every 30 seconds to be averaged over 15 minutes (**Figure B-4**).



Figure B-2. (a) Locations of all soil sensor stations in the floodplain. (b) Soil moisture station at the active floodplain site.

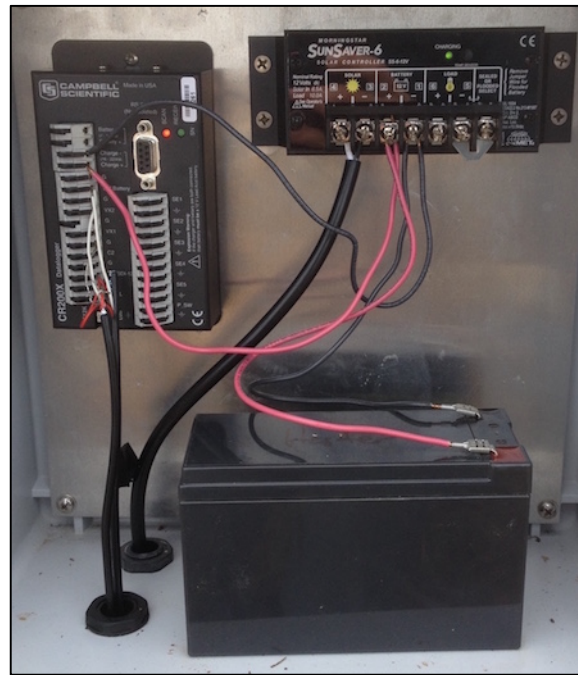


Figure B-3. Data logger set up inside protective box with battery and solar panel attachment.

```

'CR200 Series
'Decagon 5TM Soil Moisture/Temperature Sensors
'To measure Soil Moisture and Soil Temperature at 6 locations in the
'Stroubles Floodplain (Inset Floodplain, Levee, Slough, Active Floodplain, Convergence, Upland)
'Created by Breanne Ensor 2/5/2015

'Declare Variables and Units
Public BattV
Public Sensor0(2)

Alias Sensor0(1)=Moisture0
Alias Sensor0(2)=Temp0

Units BattV=Volts

'Define Data Tables
DataTable(AVG15min,True,-1)
    DataInterval(0,15,Min)
    Average(1,BattV,False)
    Average(1,Temp0,False)
    Average(1,Moisture0,False)
EndTable

'Main Program
BeginProg
    Scan(30,sec)
        'Default Datalogger Battery Voltage measurement BattV
        Battery(BattV)
        'Generic SDI-12 Sensor measurements Temp, Moisture, Result3,
        'Result4, Result5, Result6, Result7, Result8, and Result9
        SWBatt (1)
        SDI12Recorder(Sensor0(),"0M!",1,0)
        'Call Data Tables and Store Data
        CallTable(AVG15min)
    NextScan
EndProg

```

Figure B-4. Data logger program code for LoggerNet software.

The Decagon 5TM sensors (**Figure B-5**) were installed between 5 and 10 cm deep at each site. For each installation, a vertical hole was dug in the middle of the collars and the sensor was carefully inserted into the soil profile horizontally. The hole was refilled with original soil without compaction and the wire leading to the station was buried about 1 cm underground. The sensor location was marked with a field flag. Data for the slough site was collected by a Decagon GS3 sensor installed in March 2013 (Guth 2014).

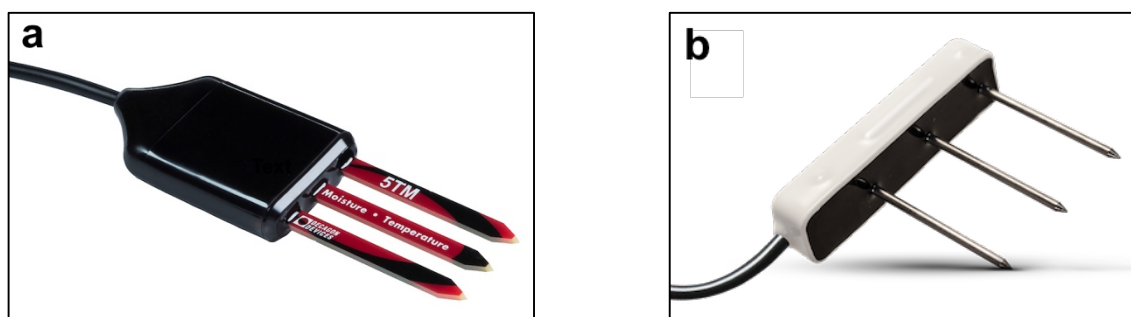


Figure B-5. (a) Decagon Devices 5TM Soil Moisture and Temperature sensor, and (b) Decagon Devices GS3 Soil Moisture, Temperature, and Electrical Conductivity sensor (Decagon Devices Inc.)

Reference:

Guth, C. R. 2014. Surface water and groundwater hydraulics, exchange, and transport during simulated overbank floods along a third-order stream in Southwest Virginia (Masters Thesis). Virginia Tech Electronic Theses and Dissertations Database.

B.3 Decagon 5TM and GS3 Soil Moisture Sensor Calibration

Post data collection, all six Decagon 5TM sensors were removed from the field to be calibrated on 2 April 2016. The following sensor calibration procedure was created following the calibration method recommended by Decagon. Soil moisture readings from all six sensors were recorded at the upland site for comparison (**Table B-1**). An approximately 1200 cm³ soil core was taken from each site to serve as the calibration medium. In the lab, the soil was removed from the cores and spread out to air dry for at least 48 hours. All rocks and large vegetative material was removed from the soil samples. The soil from each site was repacked into individual cores close to their original bulk densities with the sensor inserted into the top of the core such that the entire sensor was covered with soil. Volumetric soil samples and soil moisture readings were collected. The soil was removed from the cores and water was added to the soil to increase the volumetric water content. After thorough mixing, the soil was once again packed into the cores and volumetric soil samples and soil moisture readings were collected. The addition of water and collection of volumetric soil samples and soil moisture readings were repeated until soil water content reached well above full saturation. The volumetric soil samples were massed and dried in an oven at 60-70°C for 48 hours. The dry volumetric samples were massed and volumetric water content (VWC) (cm³/cm³) was calculated:

$$V_{water} = M_{wet} - M_{dry}$$

$$VWC = \frac{V_{water}}{V_{soil}}$$

where V_{water} was the volume of water in the volumetric soil sample, M_{wet} was the mass of the wet soil, M_{dry} was the mass of the dry soil, and V_{soil} was the volume of the container used to collect the volumetric soil samples.

The calculated VWC values were used in comparison to the recorded VWC valued in a quadratic calibration equation for each site except for the GS3 sensor at the slough (**Table B-2**). A quadratic equation was used to better estimate soil moisture at very high saturation. Each respective calibration equation was applied to the soil moisture data collected for each site for use in analysis.

Table B-1. Soil moisture readings at the upland site showing variations between sensors.

Original Sensor Location	Soil Moisture Reading (m ³ /m ³)
Upland	0.343
Convergence	0.392
Active Floodplain	0.371
Slough	*
Levee	0.354
Inset Floodplain	0.365

*Equipment malfunction

Table B-2. Calibration equations with R-squared values for each site.

	Calibration Equation	R ²
Upland	$y = -0.0691x^2 + 5.2451x - 44.106$	0.98
Convergence	$y = -0.0132x^2 + 2.1778x - 8.2317$	0.99
Active Floodplain	$y = -0.0147x^2 + 2.4914x - 13.768$	1
Slough (5TM)	$y = -0.0503x^2 + 3.6893x - 0.1325$	0.99
Slough (GS3)	$y = 0.0013x^3 - 0.122x^2 + 4.453x - 14.947$	0.99
Levee	$y = -0.0066x^2 + 1.9258x - 9.219$	0.99
Inset Floodplain	$y = -0.0606x^2 + 5.2982x - 45.236$	0.99

Appendix C: Additional Calculations

C.1 Flux Calculations

Table C-1 shows the range of concentration measured by the instrument, the slope estimated over the 5-minute period with the R^2 value from the linear regression and the flux calculated using the slope for each collar for each sampling day.

Table C-1. Minimum and maximum measured concentrations, estimated slope with R² value, and calculated flux from each collar for each sampling day.

		CO ₂					CH ₄					N ₂ O				
		Flux μmol/m ² -s	Slope μmol/L-s	R ² -	Min μmol/L	Max μmol/L	Flux μmol/m ² -s	Slope μmol/L-s	R ² -	Min μmol/L	Max μmol/L	Flux μmol/m ² -s	Slope μmol/L-s	R ² -	Min μmol/L	Max μmol/L
3/13/15	U1	1.52	0.0133	1.00	20.1	23.1	1.9E-05	1.7E-07	0.43	0.0854	0.0855	-3.2E-05	-2.8E-07	0.00	0.0140	0.0158
	U2	1.09	0.0095	1.00	20.4	22.9	3.5E-05	3.1E-07	0.65	0.0851	0.0852	-3.6E-05	-3.1E-07	0.01	0.0139	0.0156
	U3	1.58	0.0138	1.00	18.1	23.3	1.9E-05	1.7E-07	0.45	0.0853	0.0854	2.6E-05	2.3E-07	0.01	0.0136	0.0157
	U4	1.06	0.0093	1.00	18.3	20.6	2.0E-05	1.7E-07	0.32	0.0852	0.0853	-7.4E-05	-6.5E-07	0.03	0.0140	0.0157
	C1	0.21	0.0008	0.96	18.0	18.2	4.0E-03	1.5E-05	0.97	0.0850	0.0879	1.6E-04	5.9E-07	0.01	0.0141	0.0162
	C2	0.54	0.0020	0.96	18.0	18.3	1.6E-03	6.0E-06	0.97	0.0849	0.0859	-1.6E-04	-6.1E-07	0.01	0.0143	0.0160
	C3	0.10	0.0004	0.84	17.9	18.1	3.3E-03	1.2E-05	0.88	0.0849	0.0882	2.5E-04	9.3E-07	0.06	0.0135	0.0159
	C4	0.09	0.0003	0.76	18.0	18.1	5.4E-03	2.0E-05	0.95	0.0848	0.0885	2.3E-04	8.5E-07	0.03	0.0142	0.0160
	T1	2.43	0.0174	1.00	18.2	23.0	-1.3E-06	-9.2E-09	0.00	0.0848	0.0848	-3.6E-06	-2.6E-08	0.00	0.0144	0.0158
	T2	2.19	0.0191	1.00	18.0	23.7	-1.6E-06	-1.4E-08	0.01	0.0848	0.0848	-6.0E-05	-5.3E-07	0.02	0.0141	0.0158
	T3	0.58	0.0046	0.98	28.2	28.9	-1.6E-05	-1.2E-07	0.10	0.0848	0.0849	-3.7E-05	-2.9E-07	0.00	0.0138	0.0161
	T4	1.82	0.0130	0.99	18.5	22.0	-3.4E-06	-2.4E-08	0.01	0.0849	0.0850	1.1E-04	7.9E-07	0.03	0.0138	0.0164
	S1	0.04	0.0002	0.71	17.4	17.5	1.8E-04	9.5E-07	0.92	0.0824	0.0827	1.9E-04	1.0E-06	0.08	0.0136	0.0155
	S2	0.13	0.0007	0.98	17.5	17.7	1.1E-03	5.4E-06	0.69	0.0829	0.0851	-3.6E-04	-1.8E-06	0.19	0.0135	0.0156
	S3	-0.01	-0.0001	0.22	19.8	19.9	4.4E-04	2.3E-06	0.77	0.0845	0.0853	-2.2E-05	-1.2E-07	0.00	0.0139	0.0153
	S4	0.08	0.0004	0.98	17.5	17.7	8.1E-05	3.8E-07	0.86	0.0826	0.0829	-1.6E-04	-7.2E-07	0.13	0.0137	0.0155
3/26/15	L1	2.78	0.0199	0.99	17.8	25.3	-4.5E-05	-3.2E-07	0.73	0.0826	0.0828	1.3E-04	9.2E-07	0.10	0.0139	0.0160
	L2	1.77	0.0127	1.00	17.5	22.0	3.7E-06	2.6E-08	0.02	0.0826	0.0827	2.6E-04	1.9E-06	0.27	0.0142	0.0160
	L3	2.00	0.0150	1.00	17.5	21.3	2.1E-05	1.6E-07	0.40	0.0826	0.0827	9.9E-05	7.4E-07	0.03	0.0141	0.0160
	L4	2.04	0.0160	1.00	18.2	23.0	-1.2E-05	-9.7E-08	0.10	0.0826	0.0828	7.7E-05	6.1E-07	0.03	0.0140	0.0157
	B1	0.83	0.0093	1.00	17.5	20.5	1.2E-03	1.3E-05	0.98	0.0823	0.0867	-6.8E-06	-7.7E-08	0.00	0.0138	0.0156
	B2	0.66	0.0075	0.99	17.6	20.0	5.0E-03	5.6E-05	0.90	0.0902	0.1100	1.5E-05	1.7E-07	0.00	0.0140	0.0157
	B3	1.22	0.0137	0.98	17.9	24.2	2.7E-02	3.1E-04	0.99	0.0840	0.2250	-1.6E-05	-1.8E-07	0.01	0.0140	0.0157
	B4	0.29	0.0032	0.99	17.8	18.6	1.7E-04	1.9E-06	0.95	0.0840	0.0845	5.2E-05	5.9E-07	0.02	0.0142	0.0159
	U1	4.84	0.0424	1.00	17.3	29.6	4.0E-05	3.5E-07	0.65	0.0790	0.0791	1.7E-04	1.5E-06	0.13	0.0139	0.0158
	U2	3.81	0.0273	1.00	18.4	25.6	3.4E-05	2.4E-07	0.28	0.0789	0.0791	-1.0E-04	-7.4E-07	0.04	0.0140	0.0157
	U3	4.15	0.0297	1.00	17.8	27.3	6.1E-06	4.4E-08	0.03	0.0789	0.0790	1.1E-04	8.1E-07	0.06	0.0140	0.0158
	U4	2.70	0.0236	0.99	18.3	25.3	1.2E-05	1.0E-07	0.09	0.0789	0.0790	-6.4E-05	-5.6E-07	0.03	0.0143	0.0161
	C1	0.69	0.0099	0.99	16.7	20.1	3.8E-02	5.5E-04	0.98	0.0837	0.2800	-7.2E-05	-1.0E-06	0.12	0.0139	0.0156
	C2	0.55	0.0086	1.00	16.8	19.5	3.4E-02	5.4E-04	0.99	0.0888	0.2750	-4.7E-06	-7.4E-08	0.00	0.0138	0.0155
	C3	1.11	0.0146	0.99	16.8	22.5	3.9E-02	5.1E-04	0.99	0.0813	0.2890	-7.5E-05	-9.9E-07	0.13	0.0136	0.0153
	C4	0.29	0.0039	0.99	16.7	17.9	2.7E-02	3.5E-04	0.98	0.0799	0.1840	6.9E-05	9.0E-07	0.06	0.0140	0.0157
4/9/15	T1	5.13	0.0367	1.00	16.8	29.0	3.2E-04	2.3E-06	0.90	0.0789	0.0797	-2.6E-05	-1.9E-07	0.00	0.0140	0.0156
	T2	4.18	0.0366	1.00	16.8	27.5	3.0E-04	2.6E-06	0.82	0.0789	0.0797	-1.6E-04	-1.4E-06	0.17	0.0139	0.0155
	T3	3.93	0.0309	0.99	16.9	28.1	2.3E-04	1.8E-06	0.97	0.0789	0.0796	-6.1E-05	-4.8E-07	0.02	0.0134	0.0152
	T4	3.42	0.0270	1.00	18.2	26.3	1.7E-04	1.3E-06	0.92	0.0790	0.0794	9.6E-05	7.5E-07	0.07	0.0138	0.0155
	S1	0.76	0.0033	1.00	18.2	19.3	1.4E-02	6.2E-05	0.99	0.1040	0.1250	9.4E-05	4.1E-07	0.02	0.0135	0.0152
	S2	0.95	0.0044	1.00	16.8	18.3	5.3E-02	2.4E-04	0.73	0.0800	0.1710	-2.0E-04	-9.3E-07	0.09	0.0134	0.0154
	S3	0.48	0.0022	1.00	16.9	17.6	1.3E-02	6.0E-05	0.84	0.0903	0.1090	-7.3E-05	-3.4E-07	0.01	0.0133	0.0150
	S4	0.67	0.0029	0.99	16.8	17.7	1.8E-02	7.7E-05	0.97	0.0793	0.1000	-2.3E-04	-9.9E-07	0.09	0.0132	0.0152
	L1	5.91	0.0388	1.00	17.5	30.5	-9.3E-05	-6.1E-07	0.87	0.0789	0.0791	8.3E-06	5.4E-08	0.00	0.0133	0.0153
	L2	4.01	0.0263	1.00	17.2	24.5	-9.9E-05	-6.5E-07	0.88	0.0790	0.0792	8.1E-05	5.3E-07	0.02	0.0138	0.0158
	L3	3.35	0.0240	1.00	17.2	23.6	-1.1E-04	-7.6E-07	0.90	0.0790	0.0792	1.4E-04	9.7E-07	0.06	0.0139	0.0155
	L4	2.25	0.0161	0.98	17.0	22.2	-6.0E-05	-4.3E-07	0.69	0.0790	0.0792	8.7E-06	6.3E-08	0.00	0.0134	0.0154
	B1	3.83	0.0335	0.99	17.1	26.5	1.2E-01	1.1E-03	0.32	0.0808	0.6680	6.4E-04	5.6E-06	0.77	0.0137	0.0162
	B2	1.23	0.0121	1.00	16.9	20.4	5.7E-03	5.7E-05	0.91	0.0818	0.1050	-3.2E-05	-3.1E-07	0.01	0.0134	0.0155
	B3	3.21	0.0253	1.00	17.9	26.6	1.8E-01	1.4E-03	0.82	0.0949	0.6680	6.9E-05	5.5E-07	0.03	0.0134	0.0152
	B4	1.09	0.0096	1.00	17.0	19.8	3.2E-03	2.8E-05	0.92	0.0798	0.0894	-1.6E-05	-1.4E-07	0.00	0.0139	0.0153

Cont.	CO ₂					CH ₄					N ₂ O					
	Flux μmol/m ² -s	Slope μmol/L-s	R ² -	Min μmol/L	Max μmol/L	Flux μmol/m ² -s	Slope μmol/L-s	R ² -	Min μmol/L	Max μmol/L	Flux μmol/m ² -s	Slope μmol/L-s	R ² -	Min μmol/L	Max μmol/L	
4/23/15	U1	2.58	0.0225	0.98	21.6	28.2	2.6E-04	2.3E-06	0.99	0.0835	0.0841	4.7E-05	4.1E-07	0.01	0.0143	0.0160
	U2	2.02	0.0159	0.99	18.3	23.0	2.0E-05	1.6E-07	0.32	0.0834	0.0835	-1.1E-04	-8.9E-07	0.06	0.0142	0.0160
	U3	3.66	0.0320	0.97	17.5	25.7	1.0E-05	8.8E-08	0.13	0.0835	0.0836	1.2E-05	1.1E-07	0.00	0.0145	0.0160
	U4	2.69	0.0235	1.00	17.3	24.0	2.9E-05	2.6E-07	0.62	0.0834	0.0836	-2.8E-05	-2.5E-07	0.00	0.0143	0.0160
	C1	1.72	0.0271	1.00	19.7	26.5	3.3E-02	5.2E-04	0.99	0.2220	0.3640	-1.9E-07	-3.1E-09	0.00	0.0142	0.0161
	C2	1.28	0.0201	0.98	19.9	24.8	2.0E-01	3.2E-03	0.55	2.0000	3.1100	1.4E-04	2.2E-06	0.25	0.0144	0.0158
	C3	1.44	0.0227	1.00	19.3	24.0	2.7E-02	4.2E-04	0.55	0.8900	1.0200	4.1E-05	6.4E-07	0.02	0.0141	0.0157
	C4	0.59	0.0093	0.97	19.8	21.6	1.7E-01	2.6E-03	0.78	5.8100	6.3600	-1.6E-04	-2.5E-06	0.20	0.0149	0.0161
	T1	4.52	0.0356	1.00	17.4	28.6	1.0E-03	8.0E-06	0.99	0.0838	0.0868	-2.0E-05	-1.6E-07	0.00	0.0146	0.0161
	T2	4.35	0.0428	0.99	17.5	30.6	7.6E-05	7.5E-07	0.85	0.0837	0.0840	-4.1E-05	-4.0E-07	0.02	0.0144	0.0161
	T3	3.57	0.0281	1.00	17.3	27.0	4.8E-05	3.8E-07	0.88	0.0836	0.0837	7.5E-05	5.9E-07	0.03	0.0144	0.0166
	T4	3.56	0.0280	1.00	17.3	26.1	1.0E-04	8.1E-07	0.94	0.0836	0.0838	-1.7E-05	-1.4E-07	0.00	0.0143	0.0165
	S1	0.90	0.0044	0.99	17.3	18.7	8.4E-03	4.1E-05	0.98	0.0835	0.0954	6.4E-05	3.2E-07	0.01	0.0140	0.0164
	S2	0.82	0.0038	0.29	17.4	22.8	1.2E-01	5.6E-04	0.90	0.0841	0.2230	2.0E-04	9.4E-07	0.03	0.0142	0.0166
	S3	0.87	0.0044	0.97	17.4	18.9	6.0E-03	3.1E-05	0.33	0.1340	0.1640	5.1E-05	2.6E-07	0.00	0.0144	0.0166
	S4	1.01	0.0047	0.98	17.4	18.9	7.0E-01	3.3E-03	0.67	0.0966	1.2800	-2.7E-04	-1.2E-06	0.13	0.0145	0.0163
	L1	6.20	0.0444	1.00	17.7	29.4	1.7E-05	1.2E-07	0.28	0.0834	0.0835	3.5E-05	2.5E-07	0.00	0.0143	0.0159
	L2	4.65	0.0333	1.00	17.6	28.5	-3.1E-05	-2.2E-07	0.64	0.0832	0.0833	9.8E-06	7.0E-08	0.00	0.0144	0.0159
	L3	4.51	0.0323	0.99	17.5	26.1	1.4E-04	1.0E-06	0.89	0.0834	0.0838	2.6E-05	1.8E-07	0.00	0.0141	0.0161
	L4	4.92	0.0352	0.99	17.3	28.2	-5.8E-05	-4.1E-07	0.85	0.0832	0.0834	-9.1E-05	-6.5E-07	0.05	0.0142	0.0157
	B1	1.58	0.0177	0.99	20.0	24.5	-1.2E-01	-1.3E-03	0.78	2.6600	3.0000	-1.2E-04	-1.3E-06	0.09	0.0147	0.0163
	B2	0.83	0.0093	1.00	17.7	21.4	5.8E-02	6.5E-04	0.94	0.0882	0.3280	9.2E-05	1.0E-06	0.14	0.0141	0.0164
	B3	1.05	0.0118	0.99	22.3	24.2	-1.2E-01	-1.4E-03	0.85	3.7400	3.9700	-4.5E-04	-5.0E-06	0.38	0.0146	0.0160
	B4	1.17	0.0142	1.00	17.4	21.7	1.8E-02	2.2E-04	0.98	0.0894	0.1600	-2.0E-05	-2.4E-07	0.00	0.0142	0.0162
5/7/15	U1	7.99	0.0899	1.00	17.7	35.8	3.2E-05	2.8E-07	0.32	0.0841	0.0843	-1.9E-05	-1.7E-07	0.00	0.0135	0.0153
	U2	5.95	0.0469	1.00	17.8	30.6	-2.4E-05	-1.9E-07	0.28	0.0838	0.0839	5.7E-05	4.5E-07	0.01	0.0135	0.0153
	U3	7.09	0.0621	1.00	21.1	37.0	-7.6E-05	-6.6E-07	0.80	0.0836	0.0838	3.2E-05	2.8E-07	0.00	0.0133	0.0153
	U4	6.93	0.0545	1.00	18.0	33.6	-1.4E-05	-1.1E-07	0.10	0.0832	0.0834	5.5E-05	4.4E-07	0.01	0.0134	0.0152
	C1	5.16	0.0369	1.00	17.3	28.6	3.4E-02	2.4E-04	0.99	0.0921	0.1660	-1.2E-04	-8.8E-07	0.06	0.0136	0.0154
	C2	4.31	0.0308	1.00	15.9	24.1	1.3E+00	9.5E-03	0.95	0.1230	2.2900	3.1E-05	2.2E-07	0.00	0.0138	0.0154
	C3	7.54	0.0539	1.00	17.1	32.5	3.9E-02	2.8E-04	0.94	0.5390	0.6490	-1.0E-04	-7.1E-07	0.05	0.0140	0.0154
	C4	2.00	0.0113	1.00	16.6	19.2	3.3E-01	1.8E-03	0.81	0.1120	0.5840	3.0E-06	1.7E-08	0.00	0.0142	0.0155
	T1	9.64	0.0890	0.99	17.5	37.4	5.0E-03	3.6E-05	0.99	0.0823	0.0925	-1.9E-04	-1.4E-06	0.15	0.0138	0.0156
	T2	8.23	0.0648	1.00	17.1	34.2	4.2E-05	3.3E-07	0.57	0.0821	0.0822	-3.8E-05	-3.0E-07	0.01	0.0137	0.0156
	T3	6.23	0.0491	1.00	17.1	31.3	5.0E-04	4.0E-06	0.95	0.0820	0.0832	5.0E-05	3.9E-07	0.01	0.0136	0.0156
	T4	7.57	0.0542	0.99	16.5	33.1	2.4E-04	1.7E-06	0.97	0.0821	0.0827	-1.7E-04	-1.2E-06	0.14	0.0140	0.0156
	S1	2.14	0.0129	0.99	21.7	25.4	3.5E-01	2.1E-03	0.80	0.6730	1.4900	-1.7E-04	-1.0E-06	0.06	0.0139	0.0156
	S2	1.00	0.0056	0.88	22.5	23.3	-2.4E+00	-1.4E-02	0.99	15.8000	18.2000	-9.3E-05	-5.2E-07	0.01	0.0145	0.0156
	S3	2.52	0.0132	0.98	20.5	24.0	-1.2E+00	-6.3E-03	0.99	6.2600	8.0900	-2.5E-04	-1.3E-06	0.14	0.0142	0.0155
	S4	0.86	0.0048	0.79	20.0	20.9	1.0E+00	5.8E-03	0.50	9.3900	11.4000	6.0E-04	3.4E-06	0.40	0.0139	0.0155
	L1	12.29	0.0880	1.00	18.9	43.1	1.7E-03	1.2E-05	1.00	0.0821	0.0853	2.8E-05	2.0E-07	0.00	0.0141	0.0154
	L2	9.78	0.0841	1.00	16.7	33.7	1.5E-03	1.0E-05	0.99	0.0822	0.0849	-1.2E-04	-8.0E-07	0.05	0.0142	0.0157
	L3	7.15	0.0512	1.00	17.1	31.5	1.5E-03	1.1E-05	1.00	0.0826	0.0858	-1.1E-04	-8.2E-07	0.05	0.0141	0.0159
	L4	9.52	0.0625	1.00	17.1	34.6	9.8E-04	6.4E-06	0.97	0.0820	0.0838	-7.6E-05	-5.0E-07	0.02	0.0137	0.0153
	B1	0.68	0.0077	0.94	16.3	18.3	3.7E-01	4.2E-03	0.90	0.0959	1.1600	6.5E-05	7.3E-07	0.04	0.0144	0.0159
	B2	2.91	0.0286	1.00	20.3	28.1	-2.8E-02	-2.8E-04	0.51	1.3800	1.5200	7.4E-05	7.3E-07	0.08	0.0143	0.0154
	B3	4.80	0.0630	0.96	20.0	35.8	-1.2E-05	-1.6E-07	0.08	0.1980	0.1980	-2.1E-03	-2.7E-05	0.75	0.0018	0.0102
	B4	2.46	0.0277	0.99	18.7	27.7	4.6E-02	5.2E-04	0.95	0.1170	0.3070	7.5E-05	8.4E-07	0.06	0.0135	0.0155
5/21/15	U1	4.36	0.0343	1.00	18.1	30.6	-4.1E-04	-3.3E-06	1.00	0.0844	0.0856	1.6E-03	1.2E-05	0.89	0.0101	0.0157
	U2	2.91	0.0229	1.00	23.5	28.1	-2.2E-04	-1.7E-06	0.95	0.0846	0.0850	5.4E-05	4.3E-07	0.01	0.0142	0.0160
	U3	3.79	0.0332	1.00	18.2	26.8	-2.6E-04	-2.3E-06	0.99	0.0845	0.0851	-2.6E-05	-2.3E-07	0.00	0.0141	0.0159
	U4	3.34	0.0263	0.99	18.2	24.9	-2.4E-04	-1.9E-06	0.97	0.0850	0.0855	-5.8E-05	-4.6E-07	0.02	0.0143	0.0158
	C1	6.04	0.0432	1.00	17.5	30.8	-8.5E-05	-6.1E-07	0.82	0.0851	0.0853	8.1E-05	5.8E-07	0.03	0.0141	0.0160
	C2	4.15	0.0297	1.00	22.9	32.9	-3.0E-05	-2.1E-07	0.53	0.0847	0.0849	1.3E-04	9.1E-07	0.07	0.0143	0.0162
	C3	4.30	0.0261	1.00	17.8	24.8	-9.7E-05	-5.9E-07	0.85	0.0841	0.0844	8.7E-05	5.3E-07	0.02	0.0143	0.0158
	C4	6.59	0.0519	0.99	17.4	31.5	-1.1E-04	-8.4E-07	0.92	0.0843	0.0846	1.6E-04	1.3E-06	0.09	0.0144	0.0162
	T1	6.39	0.0503	0.98	18.8	33.8	-7.3E-04	-5.7E-06	0.98	0.0830	0.0846	-1.0E-04	-8.1E-07	0.04	0.0141	0.0158
	T2	6.80	0.0595	1.00	17.4	32.0	-4.1E-04	-3.6E-06	0.99	0.0836	0.0845	6.5E-05	5.7E-07	0.02	0.0144	0.0159
	T3	5.10	0.0446	1.00	18.0	29.0	-4.8E-04	-4.2E-06	0.99	0.0834	0.0844	5.6E-05	4.9E-07	0.01	0.0142	0.0161
	T4	5.44	0.0389	1.00	19.5	29.2	-8.4E-04	-4.6E-06	0.98	0.0830	0.0841	-5.2E-06	-3.7E-08	0.00	0.0140	0.0155
	S1	2.28	0.0138	0.99	28.4	32.9	-1.9E-04	-1.1E-06	0.96	0.0838	0.0842	5.1E-04	3.1E-06	0.43	0.0139	0.0161
	S2	6.39	0.0315	0.99	20.3	29.6	-2.8E-04	-1.4E-06	0.97	0.0839	0.0844	9.5E-04	4.7E-06	0.67	0.0141	0.0167
	S3	2.71	0.0134	1.00	17.7	21.5	-5.0E-05	-2.5E-07	0.47	0.0844	0.0845	1.2E-03	5.9E-06	0.77	0.0142	0.0169
	S4	3.61	0.0211	0.98	18.8	23.2	-1.2E-04	-7.3E-07	0.83	0.0845	0.0847	1.3E-03	7.9E-06	0.74	0.0142	0.0168
	L1	8.91	0.0638	0.97	17.9	36.9	-5.0E-04	-3.6E-06	0.98	0.0833						

Cont.		CO ₂					CH ₄					N ₂ O				
		Flux μmol/m ² -s	Slope μmol/L-s	R ² -	Min μmol/L	Max μmol/L	Flux μmol/m ² -s	Slope μmol/L-s	R ² -	Min μmol/L	Max μmol/L	Flux μmol/m ² -s	Slope μmol/L-s	R ² -	Min μmol/L	Max μmol/L
7/15/15	U1	5.12	0.0403	1.00	17.9	30.3	-9.2E-05	-7.2E-07	0.91	0.0799	0.0802	8.7E-04	6.9E-06	0.24	0.0073	0.0123
	U2	4.28	0.0337	1.00	17.8	28.3	-4.7E-05	-3.7E-07	0.66	0.0799	0.0801	4.9E-04	3.9E-06	0.45	0.0118	0.0143
	U3	4.35	0.0342	1.00	16.9	27.4	-9.1E-05	-7.1E-07	0.85	0.0798	0.0801	3.2E-06	2.5E-08	0.00	0.0126	0.0144
	U4	3.56	0.0312	1.00	16.5	25.5	-4.5E-05	-4.0E-07	0.47	0.0798	0.0801	-9.2E-05	-8.1E-07	0.03	0.0113	0.0146
	C1	0.70	0.0055	1.00	19.0	20.6	1.0E-04	8.3E-07	0.80	0.0802	0.0805	8.6E-05	6.8E-07	0.06	0.0126	0.0142
	C2	0.87	0.0068	1.00	16.3	18.2	1.1E-03	9.0E-06	0.99	0.0804	0.0831	-1.5E-05	-1.2E-07	0.00	0.0124	0.0143
	C3	1.32	0.0094	1.00	16.4	19.2	1.2E-03	8.5E-06	0.99	0.0802	0.0830	2.7E-05	1.9E-07	0.00	0.0129	0.0145
	C4	0.72	0.0052	1.00	16.1	17.3	5.4E-04	3.8E-06	0.98	0.0802	0.0811	-1.7E-04	-1.2E-06	0.08	0.0127	0.0143
	T1	6.25	0.0410	0.99	20.2	33.4	-1.8E-04	-1.2E-06	0.96	0.0797	0.0801	1.9E-04	1.3E-06	0.13	0.0132	0.0150
	T2	5.70	0.0408	1.00	18.2	30.0	-9.5E-05	-6.8E-07	0.76	0.0797	0.0800	3.4E-04	2.5E-06	0.31	0.0120	0.0148
	T3	6.18	0.0443	1.00	16.6	29.8	-1.3E-04	-9.7E-07	0.87	0.0796	0.0800	4.7E-04	3.4E-06	0.56	0.0132	0.0153
	T4	4.33	0.0310	0.99	17.4	26.2	-8.5E-05	-6.1E-07	0.81	0.0798	0.0801	1.2E-04	8.7E-07	0.07	0.0129	0.0144
	S1	1.16	0.0182	0.95	19.1	24.5	1.1E-03	1.7E-05	0.93	0.0829	0.0881	3.3E-05	5.2E-07	0.02	0.0126	0.0142
	S2	1.08	0.0169	0.97	17.4	22.6	2.4E-03	3.8E-05	0.89	0.0824	0.0959	-4.6E-05	-7.2E-07	0.04	0.0129	0.0145
	S3	1.07	0.0168	0.98	17.8	23.1	1.4E-03	2.3E-05	0.96	0.0809	0.0884	2.6E-05	4.1E-07	0.02	0.0126	0.0144
	S4	0.59	0.0078	0.97	16.7	19.3	2.2E-03	3.0E-05	0.81	0.0810	0.0943	-4.5E-06	-8.0E-08	0.00	0.0127	0.0149
	L1	7.31	0.0480	1.00	21.4	36.2	-1.8E-04	-1.2E-06	0.92	0.0804	0.0809	-5.3E-05	-3.5E-07	0.01	0.0129	0.0146
	L2	4.22	0.0289	0.98	20.1	28.7	-2.4E-04	-1.6E-06	0.97	0.0821	0.0826	1.9E-06	1.3E-08	0.00	0.0116	0.0144
	L3	4.39	0.0288	1.00	17.6	27.1	-9.6E-05	-6.3E-07	0.83	0.0809	0.0812	3.1E-04	2.0E-06	0.29	0.0123	0.0151
	L4	6.55	0.0469	1.00	17.9	29.8	-1.3E-04	-9.5E-07	0.90	0.0805	0.0808	8.5E-05	6.1E-07	0.02	0.0130	0.0148
7/28/15	B1	4.05	0.0532	0.99	22.8	33.8	2.2E+00	2.9E-02	0.83	2.9500	9.8500	1.3E-04	1.7E-06	0.23	0.0136	0.0147
	B2	2.78	0.0385	0.99	17.4	32.4	4.2E-01	5.5E-03	0.99	0.1140	2.2000	9.7E-05	1.3E-06	0.27	0.0131	0.0149
	B3	2.25	0.0354	0.99	19.9	29.4	1.1E+00	1.8E-02	1.00	5.5100	10.2000	6.6E-05	1.0E-06	0.08	0.0135	0.0153
	B4	4.08	0.0535	1.00	16.9	31.1	7.8E-02	1.0E-03	0.97	0.1420	0.4100	1.0E-04	1.3E-06	0.10	0.0131	0.0150
	U1	3.70	0.0285	0.99	16.2	23.9	-2.8E-04	-2.0E-06	0.98	0.0818	0.0825	-8.5E-05	-6.1E-07	0.04	0.0133	0.0144
	U2	3.88	0.0278	0.99	16.9	25.0	-3.7E-04	-2.6E-06	0.97	0.0815	0.0825	1.7E-04	1.2E-06	0.12	0.0128	0.0146
	U3	3.25	0.0233	1.00	16.9	23.0	-2.6E-04	-1.8E-06	0.90	0.0817	0.0823	1.0E-04	7.5E-07	0.03	0.0131	0.0148
	U4	4.11	0.0294	1.00	18.3	25.0	-3.2E-04	-2.3E-06	0.89	0.0820	0.0826	2.2E-05	1.6E-07	0.00	0.0132	0.0146
	C1	4.37	0.0313	0.98	20.1	29.2	-2.5E-04	-1.8E-06	0.92	0.0831	0.0837	1.2E-05	8.8E-08	0.00	0.0131	0.0148
	C2	6.23	0.0378	0.98	17.7	29.0	-5.1E-04	-3.1E-06	0.96	0.0827	0.0836	-2.4E-05	-1.4E-07	0.00	0.0131	0.0147
	C3	4.48	0.0294	0.96	16.9	25.1	-2.0E-04	-1.3E-06	0.83	0.0829	0.0834	-8.9E-05	-4.6E-07	0.01	0.0132	0.0148
	C4	5.46	0.0287	0.97	16.3	25.4	-2.7E-04	-1.4E-06	0.86	0.0831	0.0836	-1.1E-04	-5.7E-07	0.02	0.0131	0.0148
	T1	5.60	0.0401	0.99	17.8	29.5	-1.1E-03	-7.7E-06	0.99	0.0810	0.0833	1.3E-05	9.5E-08	0.00	0.0129	0.0143
	T2	5.46	0.0391	0.97	17.2	29.7	-5.6E-04	-4.0E-06	0.96	0.0814	0.0828	1.5E-04	1.1E-06	0.11	0.0128	0.0146
	T3	5.91	0.0423	0.98	18.6	31.7	-1.0E-03	-7.5E-06	0.97	0.0799	0.0821	2.5E-05	1.8E-07	0.01	0.0129	0.0142
	T4	5.42	0.0356	0.99	18.4	28.3	-1.0E-03	-6.8E-06	0.98	0.0803	0.0822	-5.4E-05	-3.5E-07	0.01	0.0128	0.0143
	S1	2.51	0.0152	0.93	16.4	21.4	-1.3E-04	-8.0E-07	0.74	0.0821	0.0825	9.9E-05	6.0E-07	0.03	0.0132	0.0150
	S2	2.27	0.0112	0.87	20.2	23.8	-8.7E-05	-4.3E-07	0.26	0.0818	0.0821	2.1E-04	1.0E-06	0.09	0.0129	0.0145
	S3	2.51	0.0132	0.95	17.9	21.8	-1.8E-04	-9.5E-07	0.82	0.0820	0.0824	1.5E-04	7.6E-07	0.06	0.0127	0.0144
	S4	6.25	0.0352	1.00	18.2	29.5	-4.4E-04	-2.5E-06	0.97	0.0809	0.0818	1.5E-04	8.4E-07	0.08	0.0126	0.0149
8/10/15	L1	7.85	0.0475	0.95	18.1	36.6	-5.7E-04	-3.4E-06	0.98	0.0798	0.0811	5.8E-05	3.5E-07	0.02	0.0130	0.0146
	L2	5.96	0.0361	0.93	18.0	29.5	-6.7E-04	-4.1E-06	0.97	0.0801	0.0813	-8.3E-05	-5.0E-07	0.03	0.0131	0.0145
	L3	3.94	0.0258	0.96	17.9	27.3	-3.7E-04	-2.4E-06	0.95	0.0803	0.0812	-2.3E-05	-1.5E-07	0.00	0.0132	0.0145
	L4	4.59	0.0329	0.96	18.5	30.7	-4.0E-04	-2.9E-06	0.94	0.0809	0.0820	6.6E-05	4.7E-07	0.03	0.0128	0.0147
	B1	5.37	0.0704	0.98	17.6	36.3	7.5E-03	9.8E-05	0.95	0.0916	0.1210	4.6E-04	6.1E-06	0.80	0.0133	0.0160
	B2	4.94	0.0649	0.97	20.4	38.4	2.5E-02	3.3E-04	0.96	0.2170	0.2940	8.1E-04	1.1E-05	0.92	0.0133	0.0170
	B3	5.20	0.0683	1.00	23.3	39.6	5.0E-01	6.6E-03	0.99	0.1020	1.6200	3.3E-04	4.4E-06	0.80	0.0133	0.0154
	B4	3.87	0.0508	0.96	19.6	34.9	5.0E-03	6.5E-05	0.07	0.3960	0.4880	3.3E-04	4.4E-06	0.70	0.0135	0.0153
	U1	3.52	0.0252	0.99	20.4	27.9	-3.4E-04	-2.4E-06	0.96	0.0817	0.0825	6.6E-04	4.8E-06	0.52	0.0122	0.0148
	U2	2.88	0.0227	0.99	17.7	24.0	-3.1E-04	-2.4E-06	0.92	0.0820	0.0827	-1.4E-04	-1.1E-06	0.06	0.0122	0.0150
	U3	2.42	0.0190	0.99	18.4	23.3	-2.8E-04	-2.2E-06	0.98	0.0820	0.0826	-1.6E-05	-1.3E-07	0.00	0.0127	0.0149
	U4	2.64	0.0189	1.00	18.5	24.2	-3.6E-04	-2.6E-06	0.97	0.0819	0.0826	2.0E-03	1.4E-05	0.87	0.0092	0.0145
	C1	6.19	0.0375	0.97	17.6	28.9	-5.2E-04	-3.2E-06	0.94	0.0816	0.0827	1.1E-04	6.6E-07	0.05	0.0137	0.0154
	C2	5.71	0.0375	0.98	20.5	31.5	-5.3E-04	-3.5E-06	0.98	0.0817	0.0828	2.2E-05	1.4E-07	0.00	0.0134	0.0152
	C3	3.82	0.0251	0.94	17.5	25.7	-3.5E-04	-2.3E-06	0.96	0.0820	0.0828	6.2E-05	4.0E-07	0.02	0.0137	0.0153
	C4	3.44	0.0226	0.93	17.3	24.8	-2.8E-04	-1.9E-06	0.90	0.0819	0.0825	4.0E-05	2.6E-07	0.01	0.0136	0.0151
	T1	7.77	0.0382	0.97	18.1	30.2	-1.4E-03	-7.0E-06	0.96	0.0799	0.0823	-1.5E-04	-7.2E-07	0.08	0.0136	0.0151
	T2	5.49	0.0360	0.94	17.8	29.6	-6.8E-04	-4.5E-06	0.87	0.0808	0.0825	9.0E-05	5.9E-07	0.04	0.0137	0.0151
	T3	2.78	0.0219	0.92	17.6	23.8	-5.3E-04	-4.2E-06	0.93	0.0814	0.0827	-1.0E-04	-7.9E-07	0.05	0.0138	0.0153
	T4	4.81	0.0345	0.95	17.0	27.2	-1.1E-03	-7.8E-06	0.97	0.0810	0.0835	3.9E-05	2.8E-07	0.01	0.0137	0.0152
8/10/15	S1	1.54	0.0101	0.82	19.2	22.4	2.4E-05	1.6E-07	0.05	0.0822	0.0825	1.3E-04	8.5E-07	0.05	0.0136	0.0157
	S2	2.27	0.0137	0.96	17.8	21.9	-1.2E-04	-7.0E-07	0.30	0.0823	0.0828	-1.2E-05	-7.3E-08	0.00	0.0139	0.0152
	S3	1.71	0.0094	0.88	17.3	20.0	-4.2E-06	-2.1E-08	0.00	0.0826	0.0828	2.0E-04	9.7E-07	0.10	0.0137	0.0155
	S4	2.98	0.0157	0.97	17.5	22.3	-4.3E-04	-2.3E-06	0.97	0.0823	0.0831	5.8E-05	3.0E-07	0.01	0.0140	0.0154
	L1	8.33	0.0489	1.00	19.5	34.2	-7.2E									

Cont.	CO ₂					CH ₄					N ₂ O						
	Flux μmol/m ² -s	Slope μmol/L-s	R ² -	Min μmol/L	Max μmol/L	Flux μmol/m ² -s	Slope μmol/L-s	R ² -	Min μmol/L	Max μmol/L	Flux μmol/m ² -s	Slope μmol/L-s	R ² -	Min μmol/L	Max μmol/L		
6/4/15	U1	4.79	0.0377	1.00	19.4	29.5	-2.7E-04	-2.1E-06	0.98	0.0825	0.0831	3.0E-04	2.4E-06	0.22	0.0137	0.0156	
	U2	2.94	0.0232	0.99	18.8	25.9	-1.0E-04	-8.1E-07	0.91	0.0825	0.0828	-5.0E-05	-4.0E-07	0.01	0.0133	0.0158	
	U3	4.04	0.0353	1.00	17.6	28.0	-1.5E-04	-1.3E-06	0.96	0.0824	0.0828	-5.6E-05	-4.9E-07	0.01	0.0140	0.0165	
	U4	3.97	0.0312	1.00	17.7	27.7	-1.8E-04	-1.4E-06	0.97	0.0825	0.0829	-5.9E-05	-4.7E-07	0.02	0.0139	0.0154	
	C1	1.09	0.0108	1.00	17.7	20.9	3.5E-04	3.4E-06	0.99	0.0830	0.0841	2.7E-05	2.6E-07	0.01	0.0135	0.0153	
	C2	0.91	0.0102	0.99	17.9	20.4	7.4E-04	8.3E-06	0.99	0.0858	0.0877	6.2E-05	7.0E-07	0.03	0.0139	0.0153	
	C3	1.57	0.0155	1.00	17.5	22.5	1.3E-03	1.3E-05	1.00	0.0830	0.0872	3.3E-06	3.3E-08	0.00	0.0134	0.0155	
	C4	-0.08	-0.0007	0.97	29.2	29.4	5.9E-04	5.2E-06	1.00	0.0832	0.0845	1.0E-04	8.9E-07	0.05	0.0134	0.0151	
	T1	5.61	0.0401	1.00	17.3	29.0	-2.5E-04	-1.8E-06	0.97	0.0825	0.0831	2.6E-04	1.9E-06	0.23	0.0136	0.0157	
	T2	4.93	0.0432	1.00	17.0	28.7	-1.5E-04	-1.3E-06	0.96	0.0827	0.0831	3.5E-04	3.0E-06	0.39	0.0133	0.0154	
	T3	4.31	0.0340	1.00	17.5	27.0	-1.5E-04	-1.2E-06	0.95	0.0827	0.0831	4.0E-05	3.2E-07	0.01	0.0139	0.0153	
	T4	4.12	0.0295	1.00	18.3	26.1	-1.4E-04	-1.0E-06	0.93	0.0829	0.0831	2.7E-04	1.9E-06	0.17	0.0134	0.0156	
	S1	0.79	0.0034	0.98	17.2	18.2	3.8E-04	1.6E-06	0.95	0.0834	0.0839	-3.1E-05	-1.3E-07	0.00	0.0136	0.0153	
	S2	0.87	0.0036	1.00	17.0	18.0	4.6E-04	1.9E-06	0.96	0.0834	0.0841	4.0E-04	1.6E-06	0.19	0.0131	0.0156	
	S3	0.61	0.0026	1.00	19.3	19.9	4.3E-04	1.9E-06	0.97	0.0835	0.0840	-8.2E-05	-3.5E-07	0.01	0.0135	0.0148	
	S4	0.41	0.0016	0.98	18.8	19.2	2.4E-04	9.5E-07	0.81	0.0841	0.0844	4.7E-05	1.9E-07	0.00	0.0134	0.0150	
	L1	6.34	0.0454	0.98	18.7	30.6	-1.0E-04	-7.5E-07	0.79	0.0838	0.0841	-1.1E-04	-7.7E-07	0.03	0.0132	0.0152	
	L2	3.74	0.0245	1.00	18.0	25.9	-1.0E-04	-6.6E-07	0.84	0.0843	0.0846	2.3E-04	1.5E-06	0.16	0.0132	0.0152	
	L3	2.94	0.0211	0.98	18.1	23.8	-9.4E-06	-6.7E-08	0.05	0.0843	0.0844	4.3E-04	3.1E-06	0.40	0.0135	0.0156	
	L4	4.54	0.0325	1.00	18.8	27.1	-1.0E-04	-7.4E-07	0.86	0.0842	0.0844	8.7E-05	6.2E-07	0.04	0.0136	0.0150	
	6/16/15	B1	2.31	0.0260	1.00	17.4	24.9	2.5E-01	2.8E-03	0.89	0.1410	0.9270	1.1E-04	1.2E-06	0.17	0.0141	0.0154
		B2	1.09	0.0123	0.94	19.2	22.1	1.1E-01	1.2E-03	0.99	0.1100	0.3920	1.7E-04	1.9E-06	0.19	0.0137	0.0152
		B3	1.51	0.0170	0.99	17.3	22.2	7.4E-01	8.3E-03	0.97	0.1120	2.5400	1.3E-04	1.4E-06	0.21	0.0135	0.0152
		B4	1.68	0.0189	1.00	17.7	22.2	1.0E-02	1.1E-04	0.99	0.1050	0.1310	1.5E-05	1.7E-07	0.00	0.0137	0.0155
U1		6.74	0.0590	1.00	16.5	34.2	-3.7E-04	-3.2E-06	0.99	0.0767	0.0776	9.6E-04	8.4E-06	0.65	0.0102	0.0147	
U2		6.64	0.0522	1.00	17.5	29.0	-4.5E-04	-3.6E-06	0.97	0.0767	0.0775	-7.7E-05	-6.1E-07	0.01	0.0120	0.0148	
U3		5.08	0.0445	1.00	16.7	28.2	-2.4E-04	-2.1E-06	0.96	0.0767	0.0774	2.2E-04	2.0E-06	0.13	0.0120	0.0148	
U4		6.83	0.0538	0.98	17.1	29.7	-3.8E-04	-3.0E-06	0.96	0.0768	0.0775	-2.1E-04	-1.6E-06	0.10	0.0127	0.0152	
C1		7.89	0.0565	1.00	16.1	31.9	-1.2E-04	-8.3E-07	0.86	0.0772	0.0775	1.6E-03	1.1E-05	0.88	0.0139	0.0178	
C2		5.02	0.0359	0.99	20.7	30.9	-1.5E-04	-1.1E-06	0.85	0.0781	0.0786	1.0E-03	7.4E-06	0.80	0.0140	0.0169	
C3		7.50	0.0537	1.00	18.3	32.9	-1.1E-04	-7.9E-07	0.77	0.0771	0.0774	6.7E-04	4.8E-06	0.68	0.0138	0.0161	
C4		15.26	0.0858	0.99	17.6	41.6	-8.1E-04	-4.6E-06	0.99	0.0760	0.0772	1.5E-04	8.5E-07	0.04	0.0118	0.0149	
T1		8.98	0.0643	1.00	16.8	33.2	-3.0E-04	-5.8E-06	0.99	0.0760	0.0774	-9.8E-05	-7.0E-07	0.03	0.0121	0.0145	
T2		10.90	0.0858	0.99	17.6	41.6	-5.8E-04	-4.6E-06	0.99	0.0760	0.0772	1.1E-04	8.5E-07	0.04	0.0118	0.0149	
T3		9.12	0.0718	1.00	16.3	36.1	-6.5E-04	-5.1E-06	0.99	0.0759	0.0773	-1.6E-04	-1.3E-06	0.13	0.0132	0.0147	
T4		9.65	0.0690	1.00	17.0	38.2	-7.4E-04	-5.3E-06	0.99	0.0754	0.0770	1.2E-04	8.3E-07	0.05	0.0121	0.0146	
S1		6.28	0.0380	0.98	17.4	27.6	-6.0E-05	-3.7E-07	0.43	0.0770	0.0772	1.2E-03	7.3E-06	0.80	0.0131	0.0161	
S2		5.85	0.0329	1.00	16.8	25.2	-1.3E-04	-7.2E-07	0.87	0.0768	0.0771	4.7E-04	2.6E-06	0.36	0.0129	0.0149	
S3		10.04	0.0527	0.99	16.6	29.9	-7.5E-05	-4.0E-07	0.57	0.0769	0.0771	1.9E-03	9.9E-06	0.86	0.0133	0.0168	
S4		13.30	0.0748	1.00	17.2	38.1	-9.2E-05	-5.2E-07	0.69	0.0770	0.0772	1.4E-03	7.9E-06	0.89	0.0137	0.0168	
7/1/15		L1	10.44	0.0747	1.00	18.3	38.8	-3.9E-04	-2.8E-06	0.98	0.0761	0.0770	3.8E-05	2.8E-07	0.01	0.0125	0.0146
		L2	9.03	0.0593	1.00	16.7	33.9	-5.2E-04	-3.4E-06	0.99	0.0761	0.0770	1.6E-05	1.1E-07	0.00	0.0131	0.0148
		L3	10.47	0.0750	1.00	18.5	39.0	-4.7E-04	-3.4E-06	0.98	0.0757	0.0767	-8.9E-05	-6.4E-07	0.04	0.0134	0.0151
		L4	10.36	0.0680	0.98	17.3	35.7	-4.2E-04	-2.8E-06	0.98	0.0764	0.0771	-2.2E-05	-1.5E-07	0.00	0.0131	0.0146
	B1	7.22	0.0812	0.98	16.1	38.2	8.8E-01	9.9E-03	0.97	0.0797	2.7000	5.0E-03	5.6E-05	0.99	0.0141	0.0299	
	B2	6.06	0.0597	1.00	17.0	31.7	1.1E-01	1.1E-03	1.00	0.1410	0.4370	2.1E-03	2.1E-05	0.97	0.0140	0.0194	
	B3	5.16	0.0677	1.00	19.7	37.5	4.4E-01	5.8E-03	1.00	0.1560	1.7300	1.3E-03	1.8E-05	0.95	0.0138	0.0185	
	B4	5.98	0.0673	0.99	16.5	33.9	1.4E-01	1.6E-03	1.00	0.1030	0.5300	1.7E-03	1.9E-05	0.95	0.0138	0.0194	
	U1	5.75	0.0503	0.99	18.1	33.9	-4.0E-04	-3.5E-06	0.99	0.0824	0.0835	-5.2E-05	-4.5E-07	0.02	0.0130	0.0147	
	U2	4.91	0.0386	1.00	18.5	30.6	-4.5E-04	-3.6E-06	0.99	0.0821	0.0832	-2.6E-05	-2.1E-07	0.00	0.0133	0.0145	
	U3	3.91	0.0342	1.00	16.9	28.5	-2.9E-04	-2.5E-06	0.99	0.0815	0.0825	1.2E-04	1.1E-06	0.12	0.0133	0.0148	
	U4	5.44	0.0429	0.99	16.4	27.7	-4.4E-04	-3.4E-06	0.99	0.0816	0.0825	2.9E-05	2.3E-07	0.00	0.0132	0.0148	
	C1	7.85	0.0562	1.00	18.6	34.2	-3.7E-04	-2.7E-06	0.98	0.0810	0.0817	1.0E-05	7.3E-08	0.00	0.0136	0.0150	
	C2	5.73	0.0410	1.00	17.2	30.4	-2.0E-04	-1.4E-06	0.96	0.0812	0.0817	6.6E-05	4.7E-07	0.02	0.0136	0.0152	
	C3	8.19	0.0586	1.00	16.8	32.8	-3.1E-04	-2.2E-06	0.95	0.0810	0.0817	5.8E-05	4.1E-07	0.02	0.0133	0.0148	
	C4	12.32	0.0647	1.00	17.8	33.2	-5.8E-04	-3.0E-06	0.98	0.0806	0.0814	7.3E-06	3.9E-08	0.00	0.0134	0.0151	
	T1	6.85	0.0540	1.00	20.7	37.7	-9.8E-04	-7.7E-06	1.00	0.0785	0.0809	-3.2E-05	-2.5E-07	0.01	0.0134	0.0148	
	T2	5.18	0.0408	0.99	18.1	31.2	-4.2E-04	-3.3E-06	0.98	0.0799	0.0810	2.1E-04	1.7E-06	0.19	0.0133	0.0151	
	T3	7.24	0.0570	1.00	16.7	33.5	-8.3E-04	-6.6E-06	1.00	0.0790	0.0809	9.8E-05	7.7E-07	0.05	0.0130	0.0146	
	T4	7.46	0.0534	1.00	16.3	33.3	-8.5E-04	-6.1E-06	1.00	0.0789	0.0808	1.4E-04	1.0E-06	0.10	0.0130	0.0151	
	S1	7.88	0.0477	1.00	25.0	35.3	-3.6E-04	-2.2E-06	0.95	0.0802	0.0807	5.5E-04	3.3E-06	0.28	0.0134	0.0158	
	S2	8.37	0.0471	1.00	18.6	30.3	-4.3E-04	-2.4E-06	0.95	0.0800	0.0806	-1.5E-05	-8.5E-08	0.00	0.0134	0.0150	
	S3	5.55	0.0291	1.00	17.7	25.6	-1.8E-04	-9.6E-07	0.88	0.0802	0.0805	2.4E-04	1.3E-06	0.09	0.0134	0.0152	
	S4	8.65	0.0524	1.00	18.0	32.4	-4.0E-04	-2.4E-06	0.94	0.0798	0.0805	2.8E-04	1.7E-06	0.20	0.0135	0.0152	
L1	8.89	0.0636	0.99	17.9	37.9	-4.8E-											

Cont.		CO ₂					CH ₄					N ₂ O				
		Flux μmol/m ² -s	Slope μmol/L-s	R ² -	Min μmol/L	Max μmol/L	Flux μmol/m ² -s	Slope μmol/L-s	R ² -	Min μmol/L	Max μmol/L	Flux μmol/m ² -s	Slope μmol/L-s	R ² -	Min μmol/L	Max μmol/L
8/26/15	U1	2.10	0.0165	1.00	18.4	23.0	-2.2E-04	-1.8E-06	0.94	0.0823	0.0828	-5.0E-05	-3.9E-07	0.01	0.0131	0.0148
	U2	2.54	0.0182	0.99	16.6	22.4	-2.3E-04	-1.7E-06	0.96	0.0821	0.0827	7.5E-05	5.3E-07	0.03	0.0135	0.0150
	U3	2.19	0.0173	1.00	16.5	20.6	-2.2E-04	-1.7E-06	0.95	0.0821	0.0825	1.3E-04	9.9E-07	0.06	0.0131	0.0148
	U4	2.81	0.0221	1.00	16.6	22.7	-2.8E-04	-2.2E-06	0.99	0.0822	0.0828	-9.5E-05	-7.5E-07	0.04	0.0132	0.0148
	C1	3.72	0.0225	1.00	17.9	24.4	-2.5E-04	-1.5E-06	0.96	0.0821	0.0825	6.7E-05	4.1E-07	0.02	0.0134	0.0149
	C2	4.32	0.0284	1.00	16.2	25.0	-2.0E-04	-1.3E-06	0.97	0.0820	0.0824	-7.1E-05	-4.7E-07	0.02	0.0133	0.0149
	C3	3.95	0.0259	1.00	16.4	24.7	-2.3E-04	-1.5E-06	0.96	0.0820	0.0826	1.3E-04	8.3E-07	0.08	0.0132	0.0147
	C4	6.15	0.0303	0.98	17.5	26.3	-3.8E-04	-1.9E-06	0.92	0.0817	0.0824	1.4E-04	6.9E-07	0.05	0.0134	0.0148
	T1	4.61	0.0302	1.00	19.0	27.3	-8.0E-04	-5.2E-06	0.99	0.0801	0.0816	-1.3E-05	-8.7E-08	0.00	0.0133	0.0149
	T2	6.94	0.0496	0.99	18.0	34.0	-6.6E-04	-4.7E-06	0.99	0.0801	0.0817	3.4E-05	2.4E-07	0.01	0.0135	0.0149
	T3	6.47	0.0425	1.00	16.2	29.4	-1.0E-03	-6.8E-06	1.00	0.0795	0.0816	-4.3E-06	-2.9E-08	0.00	0.0131	0.0148
	T4	4.85	0.0318	0.97	16.7	27.4	-7.0E-04	-4.6E-06	0.96	0.0800	0.0814	5.7E-05	3.8E-07	0.01	0.0129	0.0150
	S1	2.05	0.0115	0.95	18.3	21.8	-1.7E-04	-9.5E-07	0.89	0.0816	0.0819	7.3E-04	4.1E-06	0.62	0.0132	0.0155
	S2	5.38	0.0303	1.00	16.9	25.8	-4.0E-04	-2.2E-06	0.98	0.0812	0.0819	6.4E-04	3.6E-06	0.55	0.0129	0.0154
	S3	1.61	0.0085	0.97	16.9	19.4	-1.0E-04	-5.3E-07	0.75	0.0816	0.0818	7.2E-04	3.8E-06	0.57	0.0135	0.0155
	S4	3.51	0.0197	0.99	16.7	21.5	-1.7E-04	-9.8E-07	0.82	0.0815	0.0818	4.8E-04	2.7E-06	0.36	0.0135	0.0153
	L1	3.99	0.0262	0.98	16.3	24.3	-2.7E-04	-1.8E-06	0.95	0.0813	0.0819	-1.9E-04	-1.3E-06	0.16	0.0130	0.0146
	L2	5.07	0.0285	1.00	16.9	26.8	-5.2E-04	-2.9E-06	0.99	0.0809	0.0819	8.7E-05	4.9E-07	0.03	0.0130	0.0146
	L3	2.38	0.0144	0.97	20.5	24.5	-2.2E-04	-1.3E-06	0.91	0.0816	0.0821	-2.2E-05	-1.3E-07	0.00	0.0132	0.0146
	L4	4.19	0.0254	0.98	17.3	23.3	-3.0E-04	-1.8E-06	0.91	0.0816	0.0820	-2.4E-04	-1.5E-06	0.10	0.0130	0.0146
	B1	3.75	0.0493	1.00	17.1	31.2	3.9E-03	5.1E-05	0.97	0.1310	0.1480	2.5E-04	3.3E-06	0.42	0.0118	0.0152
	B2	4.44	0.0499	1.00	19.6	33.8	-6.1E-03	-6.8E-05	0.47	0.2060	0.2400	5.9E-04	6.6E-06	0.78	0.0140	0.0169
	B3	3.90	0.0341	1.00	24.5	32.7	2.4E-01	2.1E-03	0.98	2.0200	2.5000	2.2E-04	1.9E-06	0.23	0.0136	0.0151
	B4	3.76	0.0329	0.99	29.0	35.2	-4.6E-02	-4.0E-04	0.80	1.1700	1.2500	3.1E-04	2.7E-06	0.31	0.0140	0.0155
9/9/15	U1	2.09	0.0165	0.99	21.7	24.8	-4.8E-04	-3.8E-06	0.95	0.0863	0.0871	6.7E-04	5.2E-06	0.49	0.0124	0.0143
	U2	1.12	0.0080	0.98	19.6	21.7	-4.0E-04	-2.8E-06	0.91	0.0855	0.0863	-8.7E-04	-6.2E-06	0.64	0.0116	0.0144
	U3	1.26	0.0090	0.99	18.3	21.3	-1.8E-04	-1.3E-06	0.90	0.0821	0.0825	-8.4E-04	-6.0E-06	0.41	0.0111	0.0144
	U4	1.23	0.0097	0.99	19.4	22.4	-3.7E-04	-2.9E-06	0.98	0.0831	0.0841	3.1E-04	2.4E-06	0.34	0.0125	0.0142
	C1	3.03	0.0199	0.98	17.6	23.7	-2.5E-04	-1.6E-06	0.85	0.0805	0.0813	3.5E-05	2.3E-07	0.01	0.0131	0.0147
	C2	3.84	0.0232	0.99	18.8	23.3	-6.1E-04	-3.7E-06	0.98	0.0802	0.0809	-3.7E-05	-2.2E-07	0.00	0.0134	0.0145
	C3	4.07	0.0267	0.95	17.5	26.0	-4.5E-04	-3.0E-06	0.94	0.0795	0.0805	2.3E-04	1.5E-06	0.24	0.0132	0.0146
	C4	5.61	0.0276	0.93	17.7	24.6	-5.4E-04	-2.7E-06	0.89	0.0796	0.0804	-2.0E-04	-1.0E-06	0.07	0.0128	0.0146
	T1	6.05	0.0397	1.00	20.4	32.1	-1.5E-03	-1.0E-05	0.99	0.0770	0.0798	-2.5E-05	-1.7E-07	0.00	0.0130	0.0146
	T2	2.68	0.0185	0.97	16.9	23.1	-4.9E-04	-3.5E-06	0.93	0.0790	0.0803	-5.9E-04	-4.2E-06	0.50	0.0129	0.0157
	T3	4.55	0.0299	1.00	17.0	25.9	-1.3E-03	-8.5E-06	0.99	0.0778	0.0804	3.0E-05	2.0E-07	0.00	0.0131	0.0147
	T4	4.10	0.0299	0.99	18.8	27.0	-1.0E-03	-6.6E-06	0.98	0.0778	0.0798	8.8E-05	5.8E-07	0.03	0.0125	0.0145
	S1	3.82	0.0215	0.94	24.4	31.0	-4.6E-04	-2.6E-06	0.94	0.0794	0.0803	9.6E-05	5.4E-07	0.03	0.0128	0.0145
	S2	5.13	0.0252	0.98	18.6	24.9	-6.2E-04	-3.0E-06	0.95	0.0794	0.0802	2.5E-04	1.2E-06	0.10	0.0132	0.0150
	S3	5.15	0.0253	1.00	18.1	25.9	-4.7E-04	-2.3E-06	0.96	0.0790	0.0797	2.5E-05	1.2E-07	0.00	0.0132	0.0148
	S4	5.65	0.0342	1.00	21.0	30.9	-6.8E-04	-4.1E-06	0.99	0.0787	0.0799	1.2E-04	7.4E-07	0.05	0.0133	0.0150
	L1	3.05	0.0185	0.95	22.7	27.7	-4.4E-04	-2.7E-06	0.93	0.0790	0.0799	2.1E-04	1.3E-06	0.15	0.0136	0.0152
	L2	5.29	0.0298	1.00	17.7	26.6	-5.4E-04	-3.0E-06	0.87	0.0788	0.0799	-9.0E-05	-5.1E-07	0.03	0.0133	0.0148
	L3	5.36	0.0325	0.97	17.0	26.8	-9.9E-04	-6.0E-06	0.87	0.0784	0.0808	-1.3E-04	-7.7E-07	0.05	0.0136	0.0153
	L4	3.51	0.0230	0.99	16.6	23.8	-3.8E-04	-2.5E-06	0.92	0.0783	0.0791	-2.4E-05	-1.6E-07	0.00	0.0137	0.0150
	B1	2.38	0.0313	0.99	17.7	26.3	7.8E-04	1.0E-05	0.98	0.0831	0.0864	1.7E-04	2.3E-06	0.34	0.0138	0.0155
	B2	2.70	0.0304	1.00	22.0	27.7	-6.9E-03	-7.8E-05	0.83	0.4800	0.4960	4.7E-04	5.3E-06	0.54	0.0141	0.0158
	B3	4.18	0.0470	0.99	18.4	30.0	1.6E-01	1.9E-03	0.98	0.0973	0.5420	9.5E-04	1.1E-05	0.92	0.0138	0.0173
	B4	2.69	0.0265	0.99	17.1	24.7	4.6E-03	4.5E-05	0.84	0.1060	0.1230	4.3E-04	4.2E-06	0.66	0.0137	0.0161
9/23/15	U1	1.96	0.0155	1.00	17.2	21.9	-2.0E-04	-1.5E-06	0.77	0.0822	0.0828	-1.5E-04	-1.1E-06	0.09	0.0147	0.0165
	U2	1.37	0.0108	1.00	17.2	20.1	-2.2E-04	-1.8E-06	0.94	0.0820	0.0826	-3.6E-04	-2.9E-06	0.39	0.0141	0.0161
	U3	1.39	0.0109	1.00	17.2	20.2	-2.6E-04	-2.1E-06	0.96	0.0818	0.0824	-9.0E-05	-7.1E-07	0.04	0.0135	0.0155
	U4	1.89	0.0149	0.92	16.9	22.4	-3.6E-04	-2.9E-06	0.97	0.0814	0.0823	-6.7E-05	-5.3E-07	0.03	0.0134	0.0151
	C1	3.77	0.0229	0.98	17.9	25.5	-6.7E-04	-4.0E-06	0.95	0.0809	0.0823	7.1E-05	4.3E-07	0.02	0.0136	0.0154
	C2	3.65	0.0221	0.98	16.8	23.3	-5.9E-04	-3.6E-06	0.95	0.0811	0.0822	-2.3E-04	-1.4E-06	0.14	0.0136	0.0153
	C3	2.82	0.0171	0.95	16.7	22.0	-3.6E-04	-2.2E-06	0.81	0.0814	0.0822	5.0E-05	3.0E-07	0.01	0.0130	0.0155
	C4	3.02	0.0159	0.98	16.8	21.5	-4.0E-04	-2.1E-06	0.98	0.0815	0.0822	-8.3E-05	-4.4E-07	0.02	0.0138	0.0158
	T1	4.73	0.0287	0.99	17.6	27.6	-1.2E-03	-7.2E-06	1.00	0.0795	0.0819	-9.4E-04	-5.7E-06	0.61	0.0136	0.0167
	T2	5.41	0.0355	0.99	16.5	27.1	-9.7E-04	-6.4E-06	0.98	0.0804	0.0823	1.0E-04	6.6E-07	0.04	0.0135	0.0152
	T3	4.34	0.0311	1.00	16.6	27.7	-1.2E-03	-8.4E-06	0.99	0.0794	0.0822	1.2E-03	8.6E-06	0.51	0.0137	0.0183
	T4	7.14	0.0432	0.98	16.3	30.4	-1.8E-03	-1.1E-05	0.98	0.0787	0.0821	-4.6E-04	-2.8E-06	0.38	0.0138	0.0160
	S1	5.29	0.0277	1.00	21.4	29.3	-5.7E-04	-3.0E-06	0.99	0.0810	0.0819	1.0E-03	5.3E-06	0.72	0.0140	0.0165
	S2	5.76	0.0267	0.98	17.3	24.6	-6.5E-04	-3.0E-06	0.96	0.0812	0.0821	-9.2E-05	-4.3E-07	0.02	0.0136	0.0152
	S3	4.26	0.0210	1.00	16.9	23.1	-4.1E-04	-2.0E-06	0.98	0.0815	0.0821	2.1E-04	1.0E-06	0.08	0.0137	0.0159
	S4	2.52	0.0142	1.00	18.9	22.5	-2.9E-04	-1.6E-06	0.95	0.0816	0.0820	-3.3E-05	-1.8E-07	0.00	0.0136	0.0152
	L1	1.83	0.0111	0.95	16.8	20.0	-1.9E									

Cont.		CO ₂					CH ₄					N ₂ O				
		Flux μmol/m ² -s	Slope μmol/L-s	R ² -	Min μmol/L	Max μmol/L	Flux μmol/m ² -s	Slope μmol/L-s	R ² -	Min μmol/L	Max μmol/L	Flux μmol/m ² -s	Slope μmol/L-s	R ² -	Min μmol/L	Max μmol/L
10/7/15	U1	1.97	0.0155	0.99	18.8	22.7	1.9E-05	1.5E-07	0.05	0.0868	0.0871	1.2E-04	9.8E-07	0.07	0.0135	0.0152
	U2	1.25	0.0098	0.98	18.4	21.1	7.7E-05	6.1E-07	0.38	0.0862	0.0866	1.7E-05	1.3E-07	0.00	0.0134	0.0149
	U3	1.59	0.0125	0.99	18.3	21.7	-1.0E-05	-8.1E-08	0.04	0.0874	0.0876	8.7E-05	6.8E-07	0.04	0.0135	0.0149
	U4	1.45	0.0114	0.99	18.1	21.9	-1.7E-04	-1.4E-06	0.82	0.0869	0.0874	3.4E-05	2.7E-07	0.01	0.0135	0.0151
	C1	0.38	0.0059	0.93	18.1	20.0	7.6E-05	1.2E-06	0.30	0.0858	0.0868	7.1E-05	1.1E-06	0.11	0.0137	0.0159
	C2	0.34	0.0053	0.98	19.2	21.0	1.9E-04	3.1E-06	0.69	0.0868	0.0882	-5.4E-05	-8.6E-07	0.10	0.0141	0.0156
	C3	0.25	0.0039	0.90	17.7	18.8	4.9E-05	7.8E-07	0.04	0.0859	0.0875	-8.9E-05	-1.4E-06	0.17	0.0141	0.0154
	C4	0.45	0.0059	0.95	17.9	19.9	3.1E-04	4.0E-06	0.69	0.0857	0.0879	2.6E-05	3.5E-07	0.01	0.0138	0.0155
	T1	1.64	0.0108	0.99	17.6	20.8	-1.2E-06	-8.1E-09	0.00	0.0849	0.0850	2.1E-04	1.4E-06	0.20	0.0141	0.0155
	T2	2.95	0.0211	1.00	18.1	24.2	6.7E-07	4.8E-09	0.00	0.0850	0.0851	-8.6E-05	-6.1E-07	0.03	0.0135	0.0151
	T3	2.60	0.0186	0.99	17.5	23.0	-5.4E-05	-3.8E-07	0.61	0.0852	0.0854	1.8E-04	1.3E-06	0.13	0.0132	0.0152
	T4	1.87	0.0134	0.97	17.9	21.7	-1.5E-05	-1.1E-07	0.06	0.0853	0.0856	5.0E-05	3.6E-07	0.02	0.0141	0.0155
	S1	1.01	0.0047	0.98	18.5	19.9	2.7E-03	1.3E-05	0.99	0.0864	0.0901	-1.8E-04	-8.4E-07	0.06	0.0137	0.0157
	S2	0.42	0.0019	0.82	17.4	18.1	9.1E-04	4.0E-06	0.98	0.0867	0.0879	-9.5E-05	-4.2E-07	0.02	0.0138	0.0152
	S3	0.67	0.0031	0.91	17.1	18.2	7.6E-04	3.5E-06	0.98	0.0871	0.0882	-3.1E-04	-1.5E-06	0.17	0.0137	0.0154
	S4	-0.13	-0.0006	0.08	18.3	19.1	5.3E-04	2.2E-06	0.95	0.0874	0.0881	-8.7E-05	-3.6E-07	0.01	0.0134	0.0150
	L1	2.14	0.0141	0.98	18.4	22.5	-4.9E-05	-3.2E-07	0.42	0.0875	0.0877	8.3E-05	5.4E-07	0.02	0.0136	0.0152
	L2	1.06	0.0065	0.95	17.5	19.7	-1.1E-04	-6.6E-07	0.54	0.0873	0.0876	8.8E-05	5.4E-07	0.03	0.0136	0.0155
	L3	1.15	0.0075	0.93	17.6	20.0	3.6E-05	2.4E-07	0.35	0.0872	0.0874	6.3E-05	4.2E-07	0.02	0.0139	0.0154
	L4	1.21	0.0079	0.94	17.6	20.0	-2.9E-05	-1.9E-07	0.26	0.0873	0.0875	9.0E-05	5.9E-07	0.03	0.0134	0.0153
	B1	1.77	0.0233	1.00	17.5	24.4	3.1E-01	4.0E-03	0.96	0.1050	1.2100	1.2E-05	1.5E-07	0.00	0.0140	0.0157
	B2	1.14	0.0149	1.00	17.8	21.2	-2.1E-02	-2.8E-04	0.45	1.2000	1.3100	-3.7E-05	-4.8E-07	0.02	0.0137	0.0149
	B3	1.83	0.0206	0.96	20.1	25.9	6.1E-01	6.9E-03	0.81	0.3350	2.1300	1.9E-05	2.1E-07	0.00	0.0137	0.0151
	B4	0.28	0.0031	0.88	21.7	22.7	-1.1E-02	-1.2E-04	0.98	0.5200	0.5500	-1.1E-04	-1.2E-06	0.12	0.0138	0.0151
10/21/15	U1	1.10	0.0086	1.00	20.1	22.6	-9.7E-05	-7.7E-07	0.80	0.0940	0.0942	-4.8E-05	-3.8E-07	0.01	0.0144	0.0160
	U2	0.75	0.0059	0.97	20.3	21.7	-1.3E-04	-1.0E-06	0.87	0.0936	0.0940	1.3E-04	9.9E-07	0.07	0.0144	0.0158
	U3	0.68	0.0053	0.99	19.7	21.0	-4.9E-04	-3.9E-06	0.97	0.0921	0.0933	2.4E-04	1.9E-06	0.25	0.0144	0.0160
	U4	1.01	0.0080	0.99	19.0	21.2	-1.6E-04	-1.2E-06	0.75	0.0898	0.0903	-9.0E-05	-7.1E-07	0.06	0.0148	0.0163
	C1	0.52	0.0037	0.88	18.7	20.0	3.0E-03	2.2E-05	0.48	0.0887	0.0984	1.8E-04	1.3E-06	0.09	0.0151	0.0171
	C2	0.70	0.0042	0.92	18.7	20.0	2.9E-04	1.7E-06	0.97	0.0890	0.0895	3.7E-05	2.3E-07	0.00	0.0146	0.0160
	C3	0.64	0.0039	0.90	18.5	19.8	2.5E-04	1.5E-06	0.82	0.0895	0.0901	-3.2E-05	-2.0E-07	0.00	0.0146	0.0162
	C4	0.38	0.0020	0.77	18.8	19.4	3.4E-04	1.8E-06	0.89	0.0902	0.0906	-1.5E-04	-7.7E-07	0.05	0.0147	0.0162
	T1	1.46	0.0086	0.99	18.7	21.5	-2.2E-04	-1.5E-06	0.95	0.0880	0.0884	1.9E-04	1.3E-06	0.14	0.0148	0.0163
	T2	2.19	0.0157	1.00	18.3	23.0	-1.5E-04	-1.1E-06	0.96	0.0879	0.0882	6.5E-05	4.6E-07	0.02	0.0145	0.0163
	T3	1.81	0.0130	1.00	18.1	22.2	-3.8E-05	-2.7E-07	0.32	0.0882	0.0884	1.9E-04	1.4E-06	0.16	0.0147	0.0162
	T4	2.05	0.0134	0.99	18.4	21.7	-1.4E-04	-9.0E-07	0.80	0.0893	0.0895	1.3E-03	8.2E-06	0.84	0.0148	0.0174
	S1	1.39	0.0073	0.96	18.9	21.1	3.9E-03	2.0E-05	0.90	0.0938	0.0999	-1.7E-05	-9.1E-08	0.00	0.0144	0.0161
	S2	1.13	0.0059	0.99	18.5	20.3	5.9E-03	3.1E-05	1.00	0.0972	0.1060	-3.4E-05	-1.8E-07	0.00	0.0143	0.0160
	S3	0.45	0.0024	0.88	18.4	19.1	1.9E-03	1.0E-05	0.93	0.0989	0.1020	-1.3E-04	-8.6E-07	0.04	0.0143	0.0157
	S4	0.84	0.0044	0.99	21.8	23.0	3.9E-03	2.1E-05	0.99	0.0930	0.0987	9.6E-04	5.0E-06	0.60	0.0149	0.0175
	L1	2.03	0.0133	0.93	19.2	23.6	-2.4E-04	-1.6E-06	0.87	0.0904	0.0910	1.3E-04	8.3E-07	0.06	0.0144	0.0163
	L2	1.86	0.0113	0.94	19.2	23.2	-1.9E-04	-1.1E-06	0.55	0.0903	0.0909	-1.7E-04	-1.0E-06	0.13	0.0145	0.0158
	L3	1.23	0.0081	0.91	19.1	22.0	2.7E-05	1.8E-07	0.04	0.0905	0.0908	-5.3E-05	-3.5E-07	0.01	0.0143	0.0163
	L4	1.54	0.0101	0.92	18.1	21.0	-6.8E-05	-4.5E-07	0.34	0.0913	0.0917	-3.0E-05	-2.0E-07	0.00	0.0145	0.0162
	B1	0.95	0.0136	0.93	19.0	24.4	2.3E-01	3.3E-03	0.96	0.0944	1.0400	2.3E-04	3.4E-06	0.49	0.0144	0.0165
	B2	1.17	0.0153	0.99	18.5	23.1	2.2E-02	2.9E-04	0.97	0.1040	0.1820	1.9E-04	2.5E-06	0.32	0.0147	0.0168
	B3	1.48	0.0194	0.98	18.9	24.6	5.9E-01	7.7E-03	0.85	0.9310	3.8000	3.7E-04	4.9E-06	0.81	0.0147	0.0169
	B4	0.85	0.0095	0.99	18.2	20.9	1.3E-02	1.5E-04	0.92	0.2440	0.2810	1.8E-04	2.0E-06	0.24	0.0148	0.0167
11/4/15	U1	2.60	0.0205	1.00	18.1	23.7	-1.4E-05	-1.1E-07	0.05	0.0853	0.0855	1.5E-03	1.2E-05	0.91	0.0104	0.0144
	U2	2.00	0.0157	0.99	18.7	23.0	-3.1E-05	-2.5E-07	0.47	0.0852	0.0854	4.6E-05	3.7E-07	0.01	0.0131	0.0148
	U3	2.30	0.0181	1.00	18.7	23.2	-7.3E-05	-5.7E-07	0.73	0.0852	0.0855	7.7E-05	6.1E-07	0.02	0.0135	0.0156
	U4	2.09	0.0150	0.98	18.2	21.9	-3.9E-05	-2.8E-07	0.57	0.0854	0.0855	-1.4E-04	-9.8E-07	0.07	0.0136	0.0152
	C1	0.17	0.0015	0.80	17.5	18.2	-1.1E-05	-9.4E-08	0.03	0.0851	0.0853	-1.8E-04	-1.6E-06	0.25	0.0134	0.0150
	C2	0.13	0.0011	0.67	17.5	18.0	4.0E-05	3.5E-07	0.68	0.0846	0.0848	1.4E-04	1.3E-06	0.13	0.0137	0.0152
	C3	0.11	0.0008	0.19	17.7	18.7	-3.8E-05	-3.0E-07	0.29	0.0844	0.0846	-6.6E-05	-5.2E-07	0.03	0.0137	0.0150
	C4	0.20	0.0016	0.46	17.0	18.2	1.0E-04	8.0E-07	0.88	0.0841	0.0844	4.8E-05	3.8E-07	0.01	0.0135	0.0156
	T1	1.69	0.0111	1.00	19.0	21.6	-2.3E-05	-1.5E-07	0.21	0.0846	0.0847	6.6E-05	4.3E-07	0.01	0.0139	0.0153
	T2	2.40	0.0172	1.00	17.8	23.3	-3.8E-05	-2.7E-07	0.59	0.0847	0.0848	4.2E-05	3.0E-07	0.01	0.0136	0.0152
	T3	3.55	0.0254	0.99	18.1	24.3	-4.6E-05	-3.3E-07	0.84	0.0847	0.0849	1.4E-04	9.8E-07	0.06	0.0133	0.0151
	T4	2.54	0.0182	0.99	17.6	21.7	-5.5E-06	-3.9E-08	0.02	0.0848	0.0849	1.1E-04	8.1E-07	0.04	0.0138	0.0153
	S1	0.76	0.0199	0.96	21.2	26.7	1.9E-03	4.9E-05	0.95	0.0958	0.1100	4.2E-06	1.1E-07	0.00	0.0134	0.0150
	S2	0.60	0.0118	0.97	18.6	22.0	1.3E-03	2.6E-05	0.97	0.0879	0.0956	-6.7E-06	-1.3E-07	0.00	0.0135	0.0152
	S3	0.39	0.0154	0.99	18.9	26.1	6.3E-04	3.3E-05	0.84	0.0851	0.0993	-1.2E-05	-4.9E-07	0.02	0.0133	0.0148
	S4	0.63	0.0124	0.93	18.6	22.7	4.8E-04	9.4E-06	0.97	0.0863	0.0892	1.0E-05	2.0E-07	0.00	0.0135	0.0152
	L1	0.79	0.0048	0.67	33.7	35.5	-1.									

Cont.		CO ₂					CH ₄					N ₂ O					
		Flux μmol/m ² -s	Slope μmol/L-s	R ² -	Min μmol/L	Max μmol/L	Flux μmol/m ² -s	Slope μmol/L-s	R ² -	Min μmol/L	Max μmol/L	Flux μmol/m ² -s	Slope μmol/L-s	R ² -	Min μmol/L	Max μmol/L	
11/18/15	U1	1.47	0.0116	0.98	19.3	22.1	-4.6E-05	-3.6E-07	0.71	0.0847	0.0849	1.6E-05	1.3E-07	0.00	0.0139	0.0152	
	U2	0.82	0.0064	0.98	17.8	19.7	-2.8E-05	-2.2E-07	0.58	0.0847	0.0848	-3.5E-05	-2.8E-07	0.01	0.0139	0.0154	
	U3	1.04	0.0082	1.00	17.8	19.9	-7.0E-05	-5.5E-07	0.88	0.0846	0.0848	5.8E-05	4.6E-07	0.01	0.0135	0.0154	
	U4	0.63	0.0049	0.94	17.8	19.4	-2.8E-05	-2.2E-07	0.61	0.0846	0.0848	2.5E-05	2.0E-07	0.01	0.0139	0.0154	
	C1	0.06	0.0004	0.73	18.2	18.4	3.3E-06	2.6E-08	0.01	0.0847	0.0849	-1.4E-04	-1.1E-06	0.09	0.0138	0.0156	
	C2	0.08	0.0006	0.44	17.9	18.2	2.6E-05	2.0E-07	0.34	0.0848	0.0850	2.4E-05	1.9E-07	0.00	0.0139	0.0154	
	C3	0.04	0.0003	0.45	17.9	18.1	5.0E-05	3.6E-07	0.25	0.0848	0.0852	-1.1E-04	-7.8E-07	0.05	0.0139	0.0156	
	C4	0.03	0.0002	0.39	17.8	18.0	-4.1E-05	-3.0E-07	0.16	0.0849	0.0852	-3.3E-05	-2.4E-07	0.01	0.0139	0.0157	
	T1	0.49	0.0032	0.96	18.3	19.5	-2.8E-05	-1.8E-07	0.58	0.0848	0.0849	5.5E-05	3.6E-07	0.02	0.0139	0.0153	
	T2	0.73	0.0048	0.87	18.1	19.4	-2.5E-05	-1.7E-07	0.29	0.0848	0.0849	-1.9E-04	-1.3E-06	0.11	0.0139	0.0157	
	T3	0.64	0.0046	0.92	17.9	19.2	-2.4E-05	-1.8E-07	0.45	0.0848	0.0849	6.1E-06	4.4E-08	0.00	0.0138	0.0154	
	T4	-0.45	-0.0029	0.75	21.8	22.6	-1.0E-05	-6.7E-08	0.02	0.0848	0.0849	2.5E-04	1.6E-06	0.11	0.0139	0.0157	
	S1	0.12	0.0024	0.96	18.3	19.0	3.1E-03	6.1E-05	0.96	0.0903	0.1060	-4.5E-05	-8.9E-07	0.07	0.0141	0.0153	
	S2	0.26	0.0040	0.92	18.1	19.3	2.5E-03	3.9E-05	0.84	0.0850	0.0962	-2.1E-05	-3.3E-07	0.01	0.0140	0.0155	
	S3	0.39	0.0077	0.97	17.9	20.2	1.8E-03	3.5E-05	0.89	0.0849	0.0955	-4.5E-05	-8.8E-07	0.07	0.0139	0.0154	
	S4	0.47	0.0061	0.97	18.0	19.9	2.7E-04	3.6E-06	0.96	0.0851	0.0863	2.9E-05	3.8E-07	0.01	0.0135	0.0154	
	L1	1.55	0.0094	0.99	17.7	20.7	-1.2E-04	-7.3E-07	0.89	0.0847	0.0849	-1.2E-04	-7.2E-07	0.06	0.0139	0.0155	
	L2	1.50	0.0084	0.99	17.7	20.1	-1.7E-04	-9.4E-07	0.93	0.0846	0.0849	-1.7E-04	-9.6E-07	0.06	0.0138	0.0155	
	L3	0.86	0.0056	0.98	17.6	19.7	-4.1E-05	-2.7E-07	0.54	0.0848	0.0849	4.5E-05	3.0E-07	0.01	0.0134	0.0158	
	L4	1.56	0.0102	0.99	17.8	20.9	-1.3E-04	-8.8E-07	0.95	0.0846	0.0849	-3.4E-06	-2.3E-08	0.00	0.0136	0.0152	
	12/6/15	B1	1.01	0.0133	0.99	17.9	21.5	3.1E-01	4.0E-03	0.95	0.0861	1.0700	1.0E-04	1.4E-06	0.12	0.0139	0.0154
		B2	0.72	0.0071	0.96	18.1	20.7	1.2E-02	1.2E-04	0.97	0.0966	0.1300	-4.4E-05	-4.3E-07	0.02	0.0139	0.0154
		B3	0.53	0.0080	0.97	20.0	21.1	-1.3E-01	-1.5E-03	0.59	2.6300	3.0200	2.7E-04	3.1E-06	0.34	0.0144	0.0159
		B4	0.91	0.0090	0.99	18.3	20.9	1.1E-03	1.1E-05	0.94	0.0896	0.0928	3.7E-05	3.7E-07	0.01	0.0142	0.0155
U1		0.33	0.0026	0.87	18.9	19.8	-9.2E-05	-7.2E-07	0.79	0.0927	0.0931	1.4E-05	1.1E-07	0.00	0.0139	0.0156	
U2		-0.01	-0.0001	0.01	19.2	19.6	4.6E-05	3.3E-07	0.58	0.0927	0.0929	5.1E-05	3.6E-07	0.01	0.0142	0.0159	
U3		0.41	0.0032	0.95	19.1	19.8	1.3E-04	1.0E-06	0.48	0.0930	0.0933	2.5E-05	2.0E-07	0.00	0.0141	0.0158	
U4		0.18	0.0013	0.84	18.7	19.3	-2.9E-05	-2.1E-07	0.44	0.0933	0.0935	-2.4E-04	-1.7E-06	0.15	0.0138	0.0156	
C1		0.24	0.0038	0.80	19.4	21.5	3.4E-05	5.4E-07	0.23	0.0948	0.0952	1.3E-04	2.0E-06	0.20	0.0145	0.0162	
C2		0.42	0.0066	0.86	20.2	22.4	1.1E-04	1.8E-06	0.65	0.0946	0.0952	3.0E-05	4.7E-07	0.02	0.0142	0.0159	
C3		-0.06	-0.0009	0.69	18.8	19.0	1.5E-04	2.4E-06	0.69	0.0948	0.0951	-1.7E-04	-2.7E-06	0.11	0.0142	0.0157	
C4		0.04	0.0006	0.29	19.5	19.8	3.6E-04	5.7E-06	0.98	0.0956	0.0967	1.2E-04	1.9E-06	0.14	0.0144	0.0161	
T1		0.21	0.0014	0.80	20.8	21.4	6.6E-05	4.3E-07	0.66	0.0946	0.0947	9.7E-05	6.4E-07	0.04	0.0143	0.0155	
T2		0.66	0.0047	0.97	18.8	20.2	-4.0E-04	-2.9E-06	0.93	0.0938	0.0948	-4.2E-05	-3.0E-07	0.02	0.0143	0.0155	
T3		0.50	0.0036	0.97	18.3	19.3	-3.4E-04	-2.4E-06	0.71	0.0918	0.0924	-1.8E-05	-1.3E-07	0.00	0.0140	0.0156	
T4		0.55	0.0036	0.98	18.6	19.6	-3.3E-04	-2.2E-06	0.70	0.0909	0.0915	3.8E-05	2.5E-07	0.01	0.0142	0.0155	
S1		0.32	0.0017	0.99	18.5	19.0	7.9E-04	4.1E-06	0.99	0.0907	0.0920	-9.2E-05	-4.8E-07	0.02	0.0138	0.0155	
S2		0.17	0.0009	0.91	18.6	18.8	4.1E-04	2.0E-06	0.98	0.0898	0.0903	1.3E-04	6.4E-07	0.04	0.0143	0.0155	
S3		0.39	0.0021	0.98	18.5	19.0	7.5E-04	3.9E-06	0.98	0.0900	0.0911	-2.5E-07	-1.3E-09	0.00	0.0140	0.0157	
S4		0.21	0.0010	0.84	19.1	19.4	1.0E-04	4.6E-07	0.77	0.0900	0.0901	1.1E-04	5.2E-07	0.02	0.0144	0.0156	
1/7/16		L1	0.05	0.0003	0.07	22.5	22.9	-3.8E-05	-2.3E-07	0.51	0.0898	0.0900	7.2E-06	4.3E-08	0.00	0.0143	0.0160
		L2	0.62	0.0037	0.94	18.1	19.2	3.8E-05	2.3E-07	0.17	0.0898	0.0899	2.5E-05	1.5E-07	0.00	0.0139	0.0156
		L3	0.34	0.0022	0.83	18.1	18.8	4.2E-05	2.8E-07	0.48	0.0900	0.0901	-9.5E-05	-6.2E-07	0.03	0.0141	0.0157
		L4	0.60	0.0040	0.96	18.2	19.2	-7.3E-05	-4.8E-07	0.67	0.0899	0.0901	2.7E-05	1.8E-07	0.00	0.0139	0.0162
	B1	0.89	0.0117	0.96	19.2	22.0	9.0E-01	1.2E-02	0.95	0.0908	2.8000	-2.4E-05	-3.1E-07	0.01	0.0143	0.0157	
	B2	0.33	0.0038	0.92	18.2	19.5	-1.1E-03	-1.2E-05	0.82	0.1510	0.1560	-2.2E-04	-2.5E-06	0.32	0.0142	0.0161	
	B3	0.42	0.0066	0.96	19.2	20.9	-2.6E-04	-4.2E-06	0.73	0.0931	0.0947	-2.8E-05	-4.4E-07	0.01	0.0139	0.0159	
	B4	0.05	0.0005	0.82	18.4	18.5	5.4E-05	6.1E-07	0.46	0.0920	0.0923	-8.7E-06	-9.8E-08	0.00	0.0141	0.0156	
	U1	0.32	0.0028	0.97	19.3	20.2	-1.1E-04	-1.0E-06	0.37	0.0970	0.0975	9.8E-05	8.8E-07	0.07	0.0143	0.0159	
	U2	0.46	0.0040	1.00	19.2	20.6	-1.0E-04	-8.8E-07	0.88	0.0964	0.0969	1.1E-04	9.9E-07	0.13	0.0146	0.0161	
	U3	0.48	0.0042	0.99	19.2	20.5	-7.4E-05	-6.5E-07	0.87	0.0951	0.0954	6.5E-05	5.7E-07	0.03	0.0143	0.0160	
	U4	0.32	0.0028	0.99	19.3	20.2	-1.8E-04	-1.6E-06	0.94	0.0945	0.0950	4.0E-05	3.5E-07	0.02	0.0144	0.0158	
	C1	0.34	0.0054	0.98	20.5	21.8	7.2E-05	1.1E-06	0.78	0.0934	0.0938	3.0E-06	4.7E-08	0.00	0.0147	0.0164	
	C2	0.87	0.0136	0.92	19.5	24.4	1.6E-04	2.5E-06	0.74	0.0925	0.0936	2.6E-05	4.0E-07	0.02	0.0145	0.0162	
	C3	0.39	0.0044	0.98	19.1	20.6	2.4E-04	2.7E-06	0.83	0.0921	0.0931	2.2E-05	2.5E-07	0.01	0.0145	0.0163	
	C4	0.23	0.0031	0.97	19.2	20.1	-2.7E-05	-3.5E-07	0.35	0.0919	0.0921	1.1E-04	1.5E-06	0.15	0.0144	0.0163	
	T1	0.13	0.0009	0.94	18.9	19.2	-3.7E-05	-2.7E-07	0.20	0.0912	0.0914	3.3E-04	2.4E-06	0.37	0.0146	0.0163	
	T2	0.26	0.0019	0.99	19.9	20.5	5.0E-05	3.6E-07	0.35	0.0908	0.0910	3.4E-05	2.4E-07	0.01	0.0145	0.0161	
	T3	0.33	0.0029	0.99	18.8	19.7	3.8E-05	3.3E-07	0.19	0.0912	0.0915	8.4E-05	7.3E-07	0.05	0.0147	0.0164	
	T4	0.20	0.0014	0.97	19.1	19.5	-9.0E-05	-6.5E-07	0.72	0.0911	0.0914	1.8E-04	1.3E-06	0.16	0.0143	0.0161	
	S1	0.39	0.0018	0.94	19.1	19.7	5.1E-03	2.3E-05	0.96	0.0911	0.0995	-7.0E-05	-3.3E-07	0.01	0.0144	0.0161	
	S2	0.55	0.0026	0.93	21.6	22.4	1.1E-02	5.2E-05	0.97	0.0949	0.1100	-1.7E-04	-7.9E-07	0.07	0.0146	0.0162	
	S3	0.50	0.0023	0.94	19.9	20.7	1.6E-03	7.6E-06	0.29	0.1450	0.1500	-3.2E-06	-1.5E-08	0.00	0.0143	0.0164	
	S4	0.65	0.0026	0.99	19.5	20.4	2.4E-04	9.5E-07	0.03	0.1150	0.1170	7.1E-05	2.8E-07	0.01	0.0147	0.0164	
L1	0.55	0.0039	1.00	18.8	20.0	-3.5											

Cont.		CO ₂					CH ₄					N ₂ O				
		Flux μmol/m ² -s	Slope μmol/L-s	R ² -	Min μmol/L	Max μmol/L	Flux μmol/m ² -s	Slope μmol/L-s	R ² -	Min μmol/L	Max μmol/L	Flux μmol/m ² -s	Slope μmol/L-s	R ² -	Min μmol/L	Max μmol/L
1/27/16	U1	0.01	0.0001	0.26	18.5	18.6	-3.4E-05	-5.4E-07	0.55	0.0898	0.0901	1.5E-04	2.3E-06	0.31	0.0143	0.0162
	U2	0.02	0.0003	0.63	18.4	18.6	1.0E-05	1.6E-07	0.14	0.0897	0.0900	4.3E-06	6.7E-08	0.00	0.0147	0.0162
	U3	0.03	0.0005	0.85	18.4	18.6	3.2E-05	5.0E-07	0.29	0.0898	0.0901	1.4E-06	2.2E-08	0.00	0.0146	0.0162
	U4	-0.01	-0.0001	0.12	18.4	18.5	1.1E-05	1.7E-07	0.39	0.0899	0.0900	-1.6E-05	-2.5E-07	0.01	0.0146	0.0162
	C1	0.56	0.0098	0.87	18.6	22.6	5.0E-05	8.7E-07	0.85	0.0899	0.0903	5.7E-05	9.9E-07	0.08	0.0148	0.0163
	C2	0.81	0.0142	0.96	18.8	23.2	2.3E-05	4.1E-07	0.89	0.0899	0.0900	3.3E-05	5.8E-07	0.02	0.0146	0.0166
	C3	0.40	0.0069	0.92	18.8	21.1	3.1E-05	5.4E-07	0.53	0.0899	0.0903	3.4E-06	6.0E-08	0.00	0.0148	0.0162
	C4	0.38	0.0060	0.94	18.5	20.2	9.1E-05	1.4E-06	0.95	0.0898	0.0903	4.4E-07	7.0E-09	0.00	0.0150	0.0162
	T1	-0.30	-0.0030	0.66	19.1	20.3	-2.9E-05	-2.8E-07	0.69	0.0896	0.0898	6.4E-05	6.3E-07	0.03	0.0148	0.0165
	T2	0.07	0.0007	0.94	18.5	18.7	-1.2E-06	-1.2E-08	0.01	0.0895	0.0896	-5.2E-05	-5.1E-07	0.02	0.0147	0.0165
	T3	-0.02	-0.0003	0.37	18.3	18.5	-4.5E-06	-7.1E-08	0.15	0.0895	0.0896	2.5E-05	4.0E-07	0.02	0.0146	0.0162
	T4	0.02	0.0002	0.83	18.4	18.5	-2.0E-05	-2.0E-07	0.53	0.0894	0.0896	-2.3E-05	-2.3E-07	0.01	0.0142	0.0161
	S1	0.77	0.0038	0.91	18.4	19.9	6.7E-03	3.3E-05	0.90	0.0892	0.1020	1.4E-04	7.1E-07	0.07	0.0145	0.0160
	S2	0.68	0.0034	0.99	18.8	19.8	1.7E-03	8.5E-06	0.97	0.0915	0.0942	-7.7E-05	-3.8E-07	0.01	0.0142	0.0159
	S3	0.89	0.0044	0.73	18.7	20.4	5.9E-03	2.9E-05	0.38	0.0903	0.1070	-9.0E-06	-4.4E-08	0.00	0.0143	0.0157
	S4	0.70	0.0033	0.97	19.5	20.5	3.2E-03	1.5E-05	0.83	0.0909	0.1050	-5.4E-05	-2.5E-07	0.00	0.0141	0.0162
2/20/16	L1	-0.03	-0.0005	0.81	21.4	21.6	-6.4E-05	-1.0E-06	0.97	0.0887	0.0890	7.0E-05	1.1E-06	0.10	0.0146	0.0165
	L2	-0.02	-0.0002	0.14	20.0	20.3	-3.9E-05	-6.2E-07	0.93	0.0888	0.0890	1.4E-04	2.2E-06	0.30	0.0144	0.0165
	L3	0.05	0.0008	0.96	18.6	18.9	-2.3E-05	-3.6E-07	0.83	0.0889	0.0890	1.5E-04	2.4E-06	0.29	0.0145	0.0164
	L4	0.09	0.0013	0.98	18.5	18.9	-2.8E-05	-4.5E-07	0.88	0.0888	0.0890	-2.8E-05	-4.4E-07	0.02	0.0142	0.0160
	B1	0.10	0.0011	0.98	18.5	18.8	9.4E-02	1.1E-03	0.45	0.0893	0.5220	1.1E-04	1.3E-06	0.13	0.0144	0.0162
	B2	0.04	0.0006	0.95	18.5	18.6	5.2E-04	8.2E-06	0.91	0.0898	0.0917	1.4E-05	2.2E-07	0.01	0.0146	0.0159
	B3	0.02	0.0003	0.88	18.6	18.7	5.2E-05	8.3E-07	0.85	0.0893	0.0896	7.7E-06	1.2E-07	0.00	0.0141	0.0160
	B4	-0.11	-0.0018	0.75	19.6	20.4	3.0E-05	4.7E-07	0.66	0.0891	0.0893	-9.5E-05	-1.5E-06	0.21	0.0142	0.0161
	U1	-0.28	-0.0022	0.73	19.6	20.1	-1.7E-04	-1.3E-06	0.82	0.0877	0.0879	-1.3E-04	-1.0E-06	0.06	0.0144	0.0158
	U2	0.01	0.0001	0.06	18.4	18.5	1.5E-05	1.2E-07	0.20	0.0875	0.0877	5.4E-05	4.2E-07	0.02	0.0145	0.0160
	U3	-0.03	-0.0002	0.22	18.1	18.4	-1.9E-04	-1.5E-06	0.72	0.0863	0.0869	3.6E-05	2.8E-07	0.01	0.0142	0.0160
	U4	-0.03	-0.0002	0.29	17.9	18.0	-5.4E-06	-3.9E-08	0.01	0.0857	0.0858	-2.0E-05	-1.5E-07	0.00	0.0144	0.0159
	C1	0.09	0.0003	0.90	18.2	18.3	8.7E-05	3.3E-07	0.63	0.0857	0.0859	7.1E-05	2.7E-07	0.01	0.0141	0.0157
	C2	0.14	0.0006	0.94	18.1	18.2	1.2E-04	4.6E-07	0.84	0.0857	0.0858	9.3E-05	3.7E-07	0.01	0.0142	0.0157
	C3	0.06	0.0002	0.55	18.1	18.2	-2.6E-05	-9.6E-08	0.14	0.0856	0.0857	3.8E-05	1.4E-07	0.00	0.0141	0.0158
	C4	0.19	0.0007	0.98	17.9	18.1	1.4E-05	5.3E-08	0.08	0.0856	0.0857	-1.7E-04	-6.4E-07	0.04	0.0142	0.0160
3/2/16	T1	0.23	0.0015	0.99	17.9	18.4	7.4E-06	4.8E-08	0.03	0.0856	0.0857	3.3E-05	2.2E-07	0.00	0.0143	0.0160
	T2	0.26	0.0019	0.98	17.9	18.4	2.8E-05	2.0E-07	0.29	0.0856	0.0857	-1.9E-04	-1.4E-06	0.14	0.0144	0.0161
	T3	0.20	0.0014	0.96	17.9	18.3	2.4E-05	1.7E-07	0.31	0.0856	0.0857	6.8E-05	4.9E-07	0.02	0.0142	0.0159
	T4	0.20	0.0015	0.96	17.9	18.3	-2.4E-05	-1.7E-07	0.36	0.0857	0.0858	-3.4E-04	-2.4E-06	0.26	0.0139	0.0158
	S1	0.12	0.0007	0.86	17.9	18.2	-6.0E-07	-3.6E-09	0.00	0.0856	0.0857	1.7E-04	1.0E-06	0.13	0.0142	0.0156
	S2	0.12	0.0007	0.95	17.9	18.1	1.7E-05	9.8E-08	0.12	0.0867	0.0868	4.7E-05	2.7E-07	0.01	0.0142	0.0156
	S3	0.09	0.0006	0.93	18.1	18.3	-2.7E-06	-1.8E-08	0.00	0.0856	0.0857	4.8E-05	3.1E-07	0.01	0.0142	0.0158
	S4	0.15	0.0008	0.89	18.0	18.2	-2.0E-05	-1.1E-07	0.14	0.0853	0.0855	2.4E-04	1.3E-06	0.10	0.0140	0.0157
	L1	0.10	0.0006	0.90	18.8	19.1	-1.8E-05	-1.2E-07	0.31	0.0852	0.0853	5.8E-05	3.8E-07	0.02	0.0143	0.0162
	L2	0.06	0.0004	0.85	17.9	18.0	-1.4E-06	-8.7E-09	0.00	0.0852	0.0853	2.1E-04	1.3E-06	0.12	0.0143	0.0161
	L3	0.05	0.0004	0.82	17.8	18.0	-1.3E-05	-8.4E-08	0.12	0.0851	0.0852	-1.3E-04	-8.7E-07	0.06	0.0137	0.0157
	L4	0.09	0.0006	0.94	17.9	18.1	2.9E-06	1.9E-08	0.01	0.0851	0.0852	3.8E-06	2.5E-08	0.00	0.0141	0.0157
	B1	0.11	0.0013	0.94	18.1	18.4	5.4E-02	6.1E-04	0.82	0.5522	0.7417	-1.1E-04	-1.2E-06	0.04	0.0135	0.0156
	B2	0.14	0.0011	0.92	17.9	18.3	-8.1E-05	-6.4E-07	0.45	0.0853	0.0859	3.6E-05	2.8E-07	0.01	0.0142	0.0161
	B3	0.19	0.0016	0.98	17.9	18.4	1.3E-04	1.2E-06	0.92	0.0852	0.0855	-2.6E-05	-2.3E-07	0.00	0.0140	0.0160
	B4	0.04	0.0003	0.71	18.9	19.0	2.0E-05	1.7E-07	0.19	0.0854	0.0855	4.9E-05	4.3E-07	0.01	0.0141	0.0156

Cont.	CO ₂					CH ₄					N ₂ O					
	Flux μmol/m ² -s	Slope μmol/L-s	R ²	Min μmol/L	Max μmol/L	Flux μmol/m ² -s	Slope μmol/L-s	R ²	Min μmol/L	Max μmol/L	Flux μmol/m ² -s	Slope μmol/L-s	R ²	Min μmol/L	Max μmol/L	
3/16/16	U1	0.23	0.0017	0.86	18.7	19.2	-1.9E-04	-1.4E-06	0.50	0.0892	0.0897	3.3E-04	2.4E-06	0.23	0.0135	0.0151
	U2	0.39	0.0028	0.90	18.6	19.6	8.6E-06	6.2E-08	0.01	0.0890	0.0892	-8.6E-06	-4.7E-08	0.00	0.0137	0.0162
	U3	0.43	0.0034	0.97	18.8	20.0	8.6E-05	6.8E-07	0.26	0.0886	0.0891	4.1E-05	3.2E-07	0.01	0.0132	0.0150
	U4	0.23	0.0015	0.79	18.8	19.3	-5.8E-04	-3.8E-06	0.89	0.0883	0.0892	-6.2E-05	-4.0E-07	0.01	0.0136	0.0157
	C1	0.07	0.0002	0.10	18.6	18.8	1.3E-03	4.6E-06	0.54	0.0874	0.0893	-1.2E-04	-4.2E-07	0.01	0.0136	0.0152
	C2	0.42	0.0015	0.92	18.6	19.1	1.0E-03	3.6E-06	0.76	0.0879	0.0894	1.2E-04	4.2E-07	0.02	0.0135	0.0151
	C3	-0.05	-0.0002	0.14	18.6	18.7	-6.4E-04	-2.3E-06	0.39	0.0878	0.0884	-2.2E-04	-8.0E-07	0.04	0.0137	0.0152
	C4	-0.13	-0.0005	0.35	18.1	18.3	1.1E-03	4.1E-06	0.84	0.0875	0.0887	-2.3E-04	-8.2E-07	0.05	0.0137	0.0151
	T1	0.44	0.0029	0.96	17.3	18.2	-2.4E-06	-1.6E-08	0.00	0.0815	0.0816	-9.7E-05	-6.3E-07	0.04	0.0133	0.0152
	T2	1.11	0.0073	0.99	17.2	19.4	1.5E-04	9.7E-07	0.90	0.0816	0.0820	-1.1E-04	-7.2E-07	0.04	0.0135	0.0153
	T3	1.13	0.0074	1.00	18.0	20.2	5.6E-05	3.7E-07	0.49	0.0823	0.0825	-9.9E-05	-6.5E-07	0.04	0.0135	0.0150
	T4	0.83	0.0054	0.99	17.7	18.7	-1.7E-06	-1.1E-08	0.00	0.0826	0.0828	-4.0E-05	-2.6E-07	0.00	0.0134	0.0151
	S1	-0.07	-0.0004	0.73	17.7	17.8	1.5E-03	8.6E-06	0.13	0.1496	0.1558	1.2E-04	6.6E-07	0.03	0.0133	0.0147
	S2	0.05	0.0003	0.79	17.2	17.3	8.5E-03	4.4E-05	0.98	0.0864	0.0982	2.5E-04	1.3E-06	0.18	0.0135	0.0151
	S3	0.20	0.0011	0.88	17.1	17.4	3.7E-02	2.1E-04	0.89	0.0844	0.1280	-2.2E-04	-1.2E-06	0.08	0.0136	0.0153
	S4	0.51	0.0025	0.96	17.2	17.9	1.4E-03	6.8E-06	0.96	0.0928	0.0946	-2.0E-04	-9.9E-07	0.05	0.0136	0.0158
	L1	1.30	0.0079	0.98	16.8	19.4	2.1E-06	1.3E-08	0.00	0.0808	0.0810	3.6E-05	2.2E-07	0.00	0.0132	0.0149
	L2	0.95	0.0057	0.98	16.9	18.6	9.7E-06	5.9E-08	0.03	0.0809	0.0810	-1.9E-04	-1.2E-06	0.13	0.0138	0.0152
	L3	0.78	0.0047	0.98	16.9	18.4	2.2E-05	1.3E-07	0.14	0.0809	0.0810	1.0E-04	6.2E-07	0.03	0.0134	0.0152
	L4	0.87	0.0062	0.95	16.9	18.4	1.8E-06	1.3E-08	0.00	0.0809	0.0810	-1.6E-04	-1.2E-06	0.07	0.0131	0.0150
	B1	0.14	0.0019	0.94	17.1	17.6	4.8E-02	6.2E-04	0.88	0.1647	0.3261	3.1E-05	4.1E-07	0.01	0.0135	0.0150
	B2	0.35	0.0031	0.99	17.1	18.0	-4.2E-03	-3.7E-05	0.73	0.1442	0.1543	7.2E-05	6.3E-07	0.02	0.0135	0.0152
	B3	0.30	0.0024	0.99	17.1	17.9	1.5E-03	1.1E-05	0.95	0.0812	0.0850	-4.7E-05	-3.7E-07	0.01	0.0135	0.0152
	B4	0.07	0.0005	0.82	17.1	17.2	3.4E-04	2.4E-06	0.94	0.0825	0.0833	-1.1E-05	-7.8E-08	0.00	0.0134	0.0150

C.2 Global Warming Potential and Total Flux Calculations

Seasonal and annual fluxes from each site in the floodplain were estimated from the bimonthly flux measurements (**Table C-2**). First, fluxes from the four collars at each site were averaged for every sampling day for each site. Annual flux values were calculated by averaging flux measurements from the first 24 sampling days and converting from μmol/m²-s to kg/ha-yr for each gas for a 365-day period. Seasonal flux values were also calculated by averaging flux measurements from the designated time period and converted to kg/ha-yr for each gas for a 91.25-day period. Spring fluxes were measured from 3/13/2015 to 5/21/2015, summer from 6/4/2015 to 8/10/2015, fall from 8/26/2015 to 11/4/2015, and winter from 11/18/2015 to 3/2/2016. GWP for CH₄ and N₂O were calculated by multiplying the summed fluxes in kg/ha-yr by 72 and 289 respectively. A sample calculation for the annual CO₂ flux at the levee is shown below.

$$Annual\ CO_2\ Flux_{Levee} = F_{avg} \frac{\mu mol}{m^2\ s} \times \frac{86400\ s}{day} \times \frac{365\ day}{yr} \times M \frac{\mu g}{\mu mol} \times \frac{kg}{10^9\ \mu g} \times \frac{10^4\ m^2}{ha}$$

where M is the molar mass of CO₂ and F_{avg} is the average of the 24 CO₂ flux measurements from 3/13/2015 to 3/2/2016 taken at the levee. To calculate the summer CO₂ flux at the levee, the average of the 6 flux measurements taken from 6/4/2015 to 8/10/2015 would be used and the time period would be 91.25 days instead of 365.

Table C-2. Seasonal and annual GWP (kg CO₂ equivalents/ha-yr) for each site.

		Upland	Convergence	Active Floodplain	Slough	Levee	Inset Floodplain
CO ₂	Spring	47,984	29,958	65,581	17,801	75,377	18,298
	Summer	60,619	67,447	86,826	54,708	90,066	67,461
	Fall	23,565	30,204	51,241	33,720	35,936	31,564
	Winter	3,751	3,507	3,533	4,864	5,979	4,729
	Annual	33,980	32,779	51,795	27,773	51,839	30,513
CH ₄	Spring	-12	39,416	101	-18,255	49	16,368
	Summer	-99	6	-220	85	-133	211,622
	Fall	-69	-5	-202	304	-93	64,836
	Winter	-15	29	-17	711	-22	13,091
	Annual	-49	9,862	-84	-4,289	-50	76,479
N ₂ O	Spring	164	98	-54	501	132	-198
	Summer	856	624	409	1,226	116	3,101
	Fall	108	8	315	709	-53	1,032
	Winter	30	131	91	44	219	652
	Annual	289	215	190	620	103	1,147

C.3 Delineating the Stroubles Creek Floodplain at the Reach Scale

The following explanation details the process used in ArcGIS to estimate the total area covered by each selected location using elevation normalized to valley slope and total wetness index (TWI) classifications. A digital elevation model (DEM) with a 1 meter resolution (**Figure C-2**) was created using Blacksburg (**Figure C-1a**), VA LiDAR point cloud data. The elevation was normalized to the valley slope by subtracting the valley elevation from the DEM as explained by Jones et al. (2008). The valley elevation was set by the elevation of the centerline of Stroubles Creek. The TWI was calculated using the equation:

$$TWI = \ln \left(\frac{\alpha}{\tan(\beta)} \right)$$

where α is the upslope contributing area and β is the slope (Beven and Kirkby 1979). The TWI raster was created using the Blacksburg, VA DEM (**Figure C-1b**). The normalized elevation and

TWI rasters were clipped to a 208m reach of Stroubles Creek that included the study area (Figure C-3).

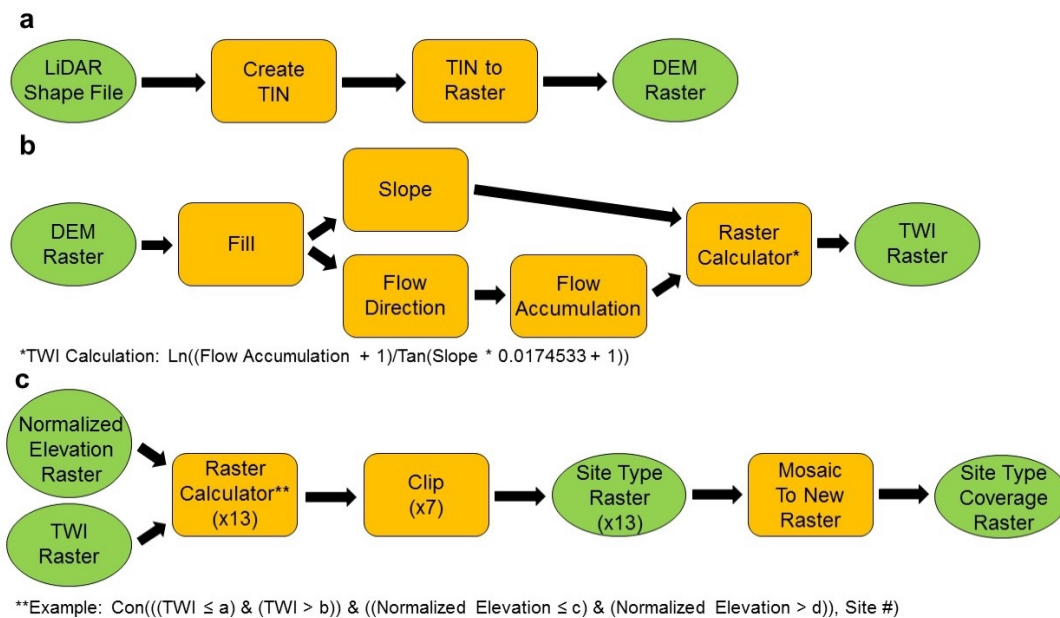


Figure C-1. Flow diagrams used to create (a) the DEM raster from the Blacksburg LiDAR data, (b) the TWI raster from the DEM raster, and (c) the total site type coverage raster from the normalized elevation and TWI rasters.

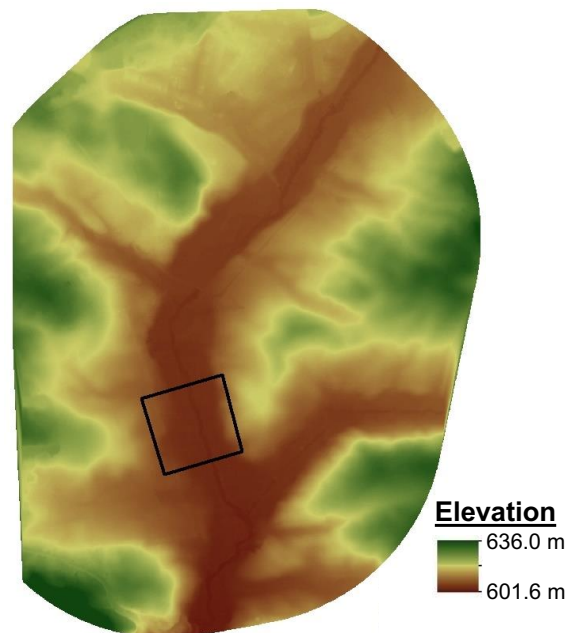


Figure C-2. Blacksburg DEM created from LiDAR data used to create TWI raster. Black box shows area used in analysis.

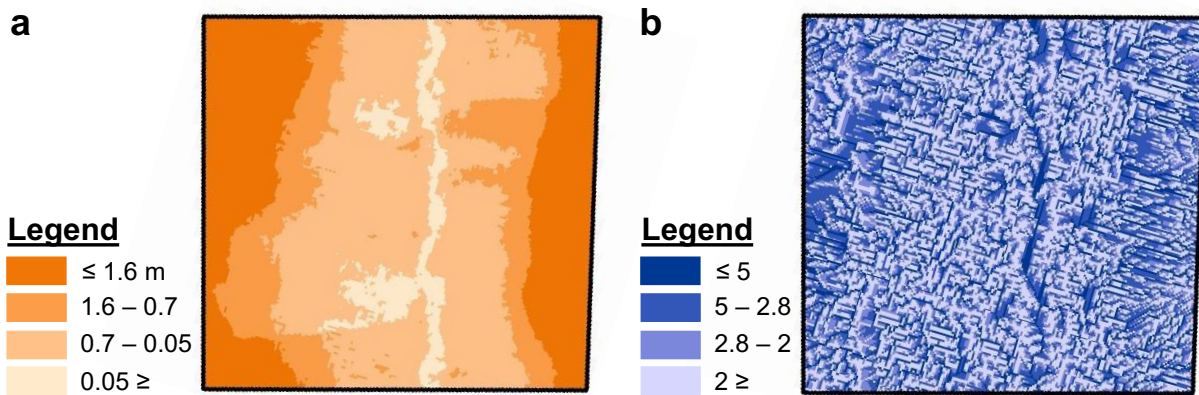


Figure C-3. The final (a) normalized elevation and (b) TWI rasters used in delineation estimate.

The ranges of normalized elevation and TWI for each site type were determined using the values of the original site locations (**Table C-3**). The levee area was restricted to an 8 meter and the inset floodplain and stream areas were restricted to a 3 meter distance from the centerline of the stream (**Figure C-4**). Total area coverage for the stream was estimated using an exclusion assumption. A raster was created for each range in normalized elevation and TWI and the rasters were mosaicked together to create one raster with cell classifications (**Figure C-1c**). Total area estimates were calculated using cell counts for each site type.

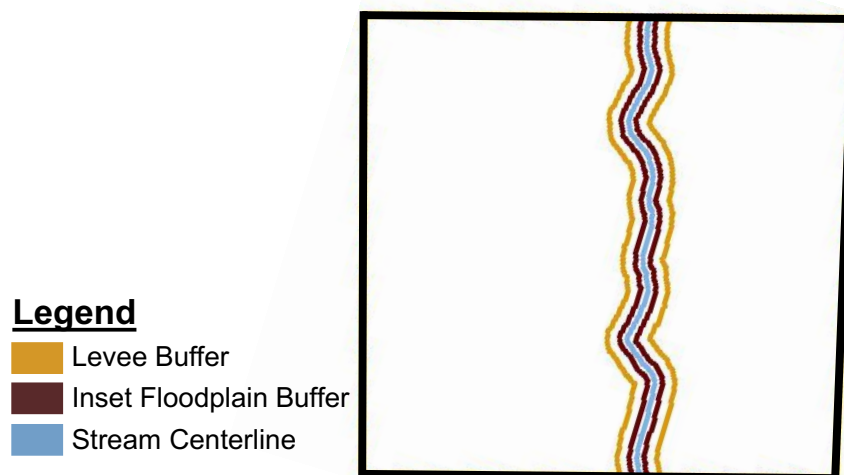


Figure C-4. The buffer outlines used to confine the inset floodplain, stream, and levee areas in the total site type coverage raster.

Table C-3. Normalized elevation and TWI values and ranges used for each site.

Cell Classification	Site Type	Normalized Elevation Value	TWI Value	Normalized Elevation Range	TWI Range
1	Upland	4.65	2.66	≥ 1.6	0.33 – 2.6
2	Convergence	0.49	8.87	0.05 – 0.7 0.7 – 1.6 $\leq 0.05^*$	≥ 7 ≥ 5 ≥ 7
3	Active Floodplain	1.05	2.84	0.05 – 0.7 0.05 – 0.7° 0.7 – 1.6 $\leq 0.05^*$	2 – 2.8 < 2 < 5 ≤ 2.8
4	Slough	0.41	2.94	0.05 – 1.1 $\leq 0.05^*$	2.8 – 7
5	Levee	0.56	1.04	0.05 – 1.6°°	< 2
6	Inset Floodplain	0.00	1.38	$\leq 0.05^{**}$	< 3
0	Stream	-	-	$\leq 0.05^{**}$	≥ 3

* At least 3 meters from stream centerline

** Within 3 meters from stream centerline

° At least 8 meters from stream centerline

°° Within 8 meters from stream centerline

References:

- Beven K. J., and M. J. Kirkby. 1979. A physically based, variable contributing area model of basin hydrology. *Hydrological Science Bulletin: des Sciences Hydrologiques* **24**:43-69.
- Jones, K. L., G. C. Poole, S. J. O'Daniel, L. A. K. Mertes, and J. A. Stanford. 2008. Surface hydrology of low-relief landscapes: Assessing surface water flow impedance using LIDAR-derived digital elevation models. *Applications of Remote Sensing to Monitoring Freshwater and Estuarine Systems* **112**:4148-4158.