ABSTRACT

Title of Document: PEDOGENESIS AND HYDROMORPHOLOGY OF SOILS IN MID-ATLANTIC BARRIER ISLAND LANDSCAPES

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Barrier islands are an important and dynamic component of coastal ecosystems. While a number of studies have focused on the geomorphology, landform dynamics, vegetation patterns, and ecology of barrier islands, there has been relatively little attention paid to the soils, which are an important ecosystem component. The goal of this study was to improve our understanding of the processes and factors influencing soil development on Mid-Atlantic barrier islands. The study was conducted at Assateague Island National Seashore, a barrier island located on the eastern coast of Maryland and Virginia. Study sites ranged in relative surface stability (soil age) and topography, allowing for comparison of the influence of time and soil moisture on pedogenic processes. Soil development was limited because of the young age of the soils and weathering resistant parent material. Evidence of pedogenesis was reflected primarily in accumulations of organic matter and formation of A and O horizons. Carbon accumulation was controlled by the magnitude of carbon inputs (plant

biomass), which increased with soil age and wetness, and by decomposition, which was regulated by soil saturation and anaerobiosis. On a global scale, average soil carbon stocks in these soils tend to be low, due to their young age and the environmental stresses faced by plants in these environments (which limits organic inputs). However, relatively high total carbon stocks were documented on the older, forested parts of the island. Soil wetness also affected the development of subsoil horizons. Weak Bw horizons, with brighter chromas and redder hues, were described in relatively well drained, oxidized soils due to slight accumulations of iron (hydro)oxides and organic matter. In poorly and very poorly drained soils iron was reduced, precluding the formation of Bw horizons. Reduced subsoil horizons had low chroma matrix colors. Despite meeting the requirements for hydric soils, many of the wet barrier island soils do not have morphologies typical of hydric soils. Nevertheless, the low chroma colors and organic accumulations at the surface (Oa horizon) proved to be a reliable indicator of soil wetness and became the basis for a proposed set of hydric soil field indicators for Mid-Atlantic barrier islands.

PEDOGENESIS AND HYDROMORPHOLOGY OF SOILS IN MID-ATLANTIC BARRIER ISLAND LANDSCAPES

By

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Dissertation submitted to the Faculty of the Graduate School of the
University of Maryland, College Park, in partial fulfillment
of the requirements for the degree of
Doctor of Philosophy
2014

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Acknowledgements

I am incredibly grateful to the many people who have helped me during my time as a graduate student at the University of Maryland and throughout my academic career. Thank you to Dr. Rabenhorst for serving as my advisor. I appreciate the knowledge, time, and experience that he devoted to my project and my development as a soil scientist. I am glad he was willing to take on a student with zero wetlands experience and provide so many great opportunities. Thank you to my committee members, Dr. Andrew Baldwin, Dr. Bruce James, Dr. Brian Needelman, and Dr. Karen Prestegaard for their contributions, suggestions, and help with various aspects of the project. I am appreciative of the continual encouragement and advice from Dr. Robert Graham, who has been a wonderful mentor even though I left the desert.

I am indebted to Mark Matovich for all of his help in the field and remaining motivated even on the particularly long, hot, mosquito-filled days. Thanks also to members of the pedology lab, Ashley Robey, Heather Hall, Ryan Adams, Elena Perry, Sara Elbeheiry, Nick Gilbert, Phil Clements, Dan Fenstermacher, Michelle Hetu, and Chris Palardy, for all of their help with field and laboratory work. I also appreciate the assistance of Gary Seibel and the UMD ENST Project Development Center with field instrumentation.

I appreciate the suggestions and field assistance from Rob Tunstead and Susan Demas, particularly in NRCS soil survey methods, soil classification, and obtaining NRCS characterization data. Susan was also a great hostess at the end of a number of long and dirty field days. This project grew out of hydric soil delineation questions raised by the Mid-Atlantic Hydric Soils Committee. The members of the committee

have provided suggestions and advice throughout the project and I have been very thankful for the many helpful discussions. I have appreciated (and greatly benefited from) their willingness to share their knowledge and wisdom regarding wetlands and soils. Thank you to the National Park Service Staff at Assateague Island National Seashore for their help and cooperation regarding field work, sampling, and instrumentation. Jonathan Chase was particularly helpful with plant identification and vegetation surveys, and I appreciate his willingness to share his time and expertise.

Thank you to the University of Maryland Department of Environmental Science and Technology for supporting me as a graduate student and providing an excellent academic experience. I am also thankful for the research funding received from the Maryland Agricultural Experiment Station and the USDA Natural Resources Conservation Service.

Finally, I cannot fully express how thankful I am for the family and friends who have provided support, encouragement, love, and laughs throughout my life and academic pursuits. They have always been there to cheer me on, provide an escape or distraction when it was needed, and were welcome recipients of my baking and cooking pursuits. My parents, Pete, Nick, Aunt Annie, Aunt Margaret, Rachel Allen, and Kate McNair have always been in my corner, and I am so grateful to have them in my life. Casie Smith, Clint Gill, Kimberly Monahan, Christie and Neal Miller, Karen Grubb, Michelle Hetu, and the ENST graduate student community have been my family at Maryland and I can’t thank them enough for their help, support, and friendship.

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CHAPTER 1: INTRODUCTION

Barrier islands are an important component of coastal environments. These narrow islands are separated from the mainland by a coastal bay or lagoon, and act as a physical barrier, protecting the mainland and the bay from storm surges and direct wave action of the ocean. The islands themselves can be relatively small in area; most are less than a few kilometers wide and up to several kilometers long. They are common along many of the world's coastlines, providing an important habitat and freshwater source for many marine and terrestrial animals. Barrier islands (and coastal environments in general) are shaped by the action of waves, tides, currents, and winds, and the landscapes can be in almost constant flux (Krantz et al., 2009). This dynamic nature also makes coastal ecosystems particularly susceptible to perturbations in geologic and environmental parameters, such as sea level rise, alterations in sediment movement processes, and changes in hydrologic patterns.

While proximity to the ocean makes barrier islands important as an ecosystem habitat, they have also become valuable to humans for residential, commercial, industrial, and recreational purposes. Human activity and development pressures are often in direct conflict with natural barrier island processes and morphodynamics (Riggs, 1976). Long-term barrier island migration (progradation or transgression) is necessary for the island to maintain its position relative to sea level and the mainland coast and is dependent upon rates of sea level rise, sand supply, and sea energy (Leatherman, 1979a). Human intervention and attempts to control these factors can greatly disrupt natural geomorphic processes of the islands, eventually leading to habitat destruction. These development pressures and their potential detrimental effects have led to the preservation and protection of some barrier islands by local, state, and federal government agencies and private organizations. However, a number of others are still subject to private development. Effective coastal management requires a comprehensive understanding of barrier islands systems and processes. Understanding of these processes will lead to greater insight as to how these systems could be affected by, or will respond to environmental pressures, including sea level rise, climate change, and development.

Soils are an important component of any ecosystem, and insight into the processes within the soil and across soil-water-air interfaces are critical to understanding of the ecosystem as a whole. To date, most studies of barrier island systems have been focused on plant community dynamics and the geologic and landform processes occurring on barrier islands (e.g., Davis, 1994; Doss, 1993; Jungerius, 2008; Oosting and Billings, 1942; Stallins, 2001; Stone and McBride, 1998; Tackett and Craft, 2010). Due to the perceived lack of soil development, pedogenesis (natural processes resulting in the development of soils) on barrier islands has received relatively little attention. Only in recent soil survey update efforts have official soil series been recognized and applied to soils on barrier islands in the Mid-Atlantic region of the Unites States (e.g., Barnhill, 1990; Barnhill, 1992; Demas and Burns, 2004; Gagnon, 2001; Hatch et al., 1985; Peacock and Edmonds, 1994; Soil Survey Staff, 2014b; Tant, 1992; Vasilas and Hole, 2002). While these updates are more detailed than previous mapping efforts and include taxonomic classifications of soils to the family and series level, understanding of the pedogenic processes and detailed characterizations of these soils are limited (National Cooperative Soil Survey, 2014). Soil map units, official soil series descriptions, and taxonomic classifications have been made from a limited number of pedons, and may not represent the full range of characteristics seen in these soils. Additionally, some of the toposequences or catenas (sequence of soils of similar age, parent material, and climatic conditions that vary in characteristics due to differences in topographic relief and drainage) contain “gaps”, and do not recognize the presence of very poorly or poorly drained non-tidal soils that have been observed. Questions also remain pertaining to the mineralogy and soil temperature classification of some of these soils.

Pedogenic processes, which are expressed by soil morphological properties and horizon differentiation, can be categorized as additions, removals, transfers, and transformations (Simonson, 1959). Materials affected by these processes can include organic matter, soluble salts, silicate clays, sesquioxides, and carbonates. Variations between soils at global, regional, and local scales, as well as horizon differentiation are attributed to differences in the magnitude and interaction of these processes. The role of each process in soil development is controlled by environmental factors affecting the soil. Jenny (1941) identified five “soil forming factors”: climate, topography, organisms (biota), parent material, and time. On a given barrier island, two of these factors, climate and parent material are relatively uniform, suggesting that differences in soils on the island are mainly a function of variation in time, topography, and biota. While climate and parent material (as soil forming factors) may be fairly uniform across the soils of a barrier island, they still influence soil development in how they interact with factors that show greater differentiation.

Climate variability on an island is minimal because of its relatively small spatial extent. Barrier islands are composed of unconsolidated sands, which can vary to some extent in particle size with depositional environment. Mineralogy on a given island tends to be fairly uniform because sediments (generally sands) are from the same source(s). The siliceous dominated sands tend to be weathering resistant, limiting clay formation and the availability of mineral cations, such as potassium, calcium, magnesium, and iron, necessary for plant growth.

Landforms on barrier islands can change frequently and sometimes dramatically due to storms, winds, and wave action. As such, landforms on an island can vary greatly in their relative surface stability, and therefore the time over which soil development has occurred. Since sands tend to have low water holding capacities and high hydraulic conductivity rates, perching of water in the subsoil is minimal and water tables are relatively level. Topographic relief can be used as an indicator of water table depth, with the deepest water tables occurring at the high points in the landscape. Vegetation influences soil development through contributions of organic matter which can accumulate in the soil, forming organic rich surface horizons or inducing mineral weathering. Plant species vary in the time it takes them to become established and mature (e.g., a forest community takes longer to develop than grasses). The species that colonize a soil and their level of biomass production is controlled by their access to water (among other factors). Plant communities that develop on barrier islands, and their levels of productivity vary along with landform stability (analog for time for the establishment of vegetation and soil development) and topography (analog for water table depth and plant water availability) (Ehrenfeld, 1990; USGS-NPS Vegetation Mapping Program, 1995).

At this point, soils on barrier islands have been mapped primarily based on differences in soil water drainage (as toposequences or catenas). Soils on barrier islands tend to be young (less than 1000 years) and few pedogenic processes occur in that short of a time frame. However, organic matter accumulation occurs rapidly in the first few hundred to thousand years of development (Birkeland, 1999), so organic matter accumulation may vary substantially in young soils that differ in age by only 100 years. Despite potentially similar hydrologic characteristics (depth to water table, frequency and duration of saturation), soils may differ among landforms reflecting the time over which soil development has occurred and the range of vegetation (species diversity and biomass production) observed among landforms.

Growing concern over rising atmospheric CO_2 levels has led to a greater interest in the potential for organic carbon sequestration in soils. On barrier islands, organic carbon sequestration could be particularly significant in soils associated with freshwater wetlands. Brevik and Homburg (2004) observed that coastal wetlands have the potential to sequester carbon at higher rates and for longer periods of time than other terrestrial soils because of landscape processes unique to these areas. Being relatively young soils, total carbon accumulations may be low compared to older soils; however the young age and geomorphic processes associated with these soils may allow for higher sequestration rates. Coastal wetlands in North America are estimated to sequester 10.9 Tg C annually, 21% of the net carbon sequestration in all North American wetlands (Bridgham et al., 2006). Biochemical effects of seawater intrusion through sea level rise and/or storm surges and extreme tidal events can significantly alter carbon cycles in coastal wetlands (Chambers et al., 2011). The lack of knowledge with regard to the magnitude of organic carbon storage, accumulation rates, and the influence of soil moisture, topography, water table depths, and marine inputs in barrier island soils limits our understanding of the role of these environments in the global carbon cycle.

Freshwater wetlands on barrier islands provide ecosystem services, however the recognition, delineation, and protection of these wetlands can be difficult because of the nature of the associated soils. Hydric soils are identified based on a set of nationally approved hydric soil field indicators (USDA-Natural Resources Conservation Service, 2010). However, young, sandy hydric soils often do not meet these indicators, making wetland delineation difficult (Kuehl et al., 1997; Lindbo, 1997). This could limit the ability of land use managers and regulators to protect these sensitive ecosystems. A better understanding of hydromorphology of barrier island soils is needed in order to improve methods for identifying hydric soils in these landscapes.

Objectives

The overarching goal of this project is to understand the processes and factors influencing the pedosphere and soil development on Mid-Atlantic barrier island landscapes. The pedosphere describes the soil, organisms, water, and air existing at the interface of the lithosphere, atmosphere, hydrosphere, and biosphere. The interactions of these zones drive soil formation processes.

The specific objectives of the project are to:

1) Identify the major landforms of Mid-Atlantic barrier islands and understand how the characteristics of, and geomorphic processes occurring on, these landforms influence soil development.

2) Understand how topographic factors (associated with water table depth and drainage) influence soil development on barrier island landscapes.

3) Document and understand the accumulation and dynamics of organic carbon in soils on barrier islands.

4) Explore whether soil morphological characteristics are diagnostic of hydric soils on barrier island landscapes.

Hypotheses

1) It is expected that soil development on barrier islands will be relatively weak compared to many soil systems because of the limited time for soil formation and the weathering resistant nature of the parent material.

2) Depth to water table and the frequency and duration of saturation will change along with topography. The availability of water for plants will influence soil morphology, particularly in the accumulation of organic matter (increased biomass production and decreased decomposition rates in wetter soils).

3) Recognizing that both landform and topography will influence soil morphology and rates of pedogenesis, it is expected that there will be landform-topography interactions, as the nature of topographic effects will differ among landforms. Soils with similar drainage characteristics will show more advanced

development (such as increased organic matter accumulation) on more stable (older) landforms, where there has been more time for pedogenesis to occur.

4) Vegetation characteristics, such as community composition and plant density, are expected to influence soil development, particularly in the accumulation of organic matter. Higher rates of biomass production are expected in wetter soils where plant available water is increased. Additionally, it is expected that plant community composition will reflect landform stability as shrubland and forest communities will require more time to become established than early colonizing herbaceous plants.

5) Hydric soils occurring in these landscapes will exhibit distinctive morphological features that can be used for identification and delineation.

CHAPTER 2: LITERATURE REVIEW

2.1 Barrier Islands and Coastal Environments

The coastal zone is a large physiographic region describing the area of interaction between the land, sea, and air. The coastal zone runs along the shore line and often extends several kilometers inland. These areas are dynamic, shaped by a number of processes including winds, waves, tides, and currents. Coastal zones can be highly sensitive; slight changes in geologic and environmental parameters can have drastic effects at local, regional, and global scales. Coastal zone ecosystems are made up of a number of geomorphic components, including barrier islands. Generally, barrier islands are elongate, ranging in size up to several kilometers long and less than a few kilometers wide, and are composed of unconsolidated marine sediments (Davis, 1994). They are aligned parallel to the mainland shore, and are completely separated from the mainland by bays, salt marshes, or a combination of wetland environments. Found on approximately 15% of the world’s coasts, barriers often form in areas where off-shore gradients and tidal ranges are low and wave energy is low to moderate (Glaeser, 1978; Ritter et al., 2002). In the United States alone, barrier island shorelines are just over 3000 miles (Pilkey and Fraser, 2003). Barrier islands are particularly extensive along the eastern United States, extending from New England, down the Atlantic Coast and Gulf of Mexico, to Texas, comprising approximately 27% of the eastern North American coastline (Glaeser, 1978).

Running parallel to the mainland coast, barrier islands protect the adjacent mainland and coastal bays and marshes from storm surges and direct wave action of the ocean (Stone and McBride, 1998). These unique, protected wetland environments are important habitats for a number of aquatic species. As the interface between terrestrial and marine ecosystems, the islands themselves provide a key habitat for marine and terrestrial species that are dependent upon both ecosystems for portions of their life cycle, nesting, reproduction, and/or food sources. Critical to the survival of many of these species is the existence of freshwater ponds and wetlands found throughout the islands (Hall, 2005). These freshwater environments support salt-intolerant plant species and provide habitats for a number of mammalian, amphibian, reptilian, and fish species.

2.2 Barrier Island Formation, Evolution, Stability, and Landforms

Barrier islands are young, dynamic environments, and their formation and morphological development has been greatly contested. There are three commonly cited theories explaining barrier island formation: 1) upbuilding of submarine bars, 2) longshore spit growth and segmentation by inlets, and 3) mainland beach ridge submergence. Schwartz (1971) suggested that under certain conditions any of these three processes could work independently or in combination to form barrier islands. Most current work in the area seems to support the idea of multiple causality of barrier islands, influenced by local geomorphic and environmental conditions (Bird, 2008; Davis, 1994). The relative roles of wave and tidal processes are influential on the size, shape, and formation of barrier islands (Davis, 1994).

The source and nature of the unconsolidated marine sands composing the island are influential on the development of landforms and soils. A constant sand supply is necessary for island formation and stability, counteracting the effects of erosion and sea level rise. Barrier islands are most abundant along coastal plains that contain an abundance of unconsolidated and semi-consolidated detrital sediments that can serve as an immediate sediment source (Glaeser, 1978). Other sources of sand can include shoreward drift of inner-shelf sediments and river discharge (Bird, 2008). From the source, sediment is transported and deposited on the barrier island by littoral drift occurring along the shoreline and overwash resulting from storm surges. Barrier islands vary in length and can occur in a variety of shapes. Over time they can remain stationary, widen through seaward progradation and beach and dune ridge formation, narrow due to erosion, or become transgressive, migrating landward across lagoons or swamps as a result of landward movement of sediments by overwash. Island migration is controlled by sediment supply, sea level rise, and sea energy, all of which can be directly or indirectly affected by human intervention.

Barrier islands along the Mid-Atlantic coastline are generally believed to have formed 5000 to 7000 years ago (Oertel and Kraft, 1994). Based on their morphologic characteristics, barrier islands in this region are divided into wave-dominated and tide-dominated barriers, differing in the dominant force driving erosion and deposition of sediments (Davis, 1994; Oertel and Kraft, 1994). Wave-dominated barriers tend to be relatively long and continuous as longshore currents redistribute sand along the beach. Generally inlets are opened by island breaching during large storms, and migrate or close rapidly as a result of these longshore currents (McBride, 1999). The interaction between waves and tides in tide-dominated barrier systems disrupts longshore sand movement. As a result, sand is not evenly distributed across the island resulting in islands with a drumstick shape, where one end of the island is trapping sand while the other erodes as little new sediment is received (Davis, 1994). Inlets on tide-dominated barriers are more common, but tend not to move and remain open for longer periods of time relative to those of wave-dominated barriers (McBride, 1999).

Assateague Island, located on the eastern coast of Maryland and Virginia, is an example of a wave-dominated barrier (Oertel and Kraft, 1994). Like many wave-dominated barriers, overwash processes during storm events results in a landward migration of the island (Leatherman, 1979a). This movement is called retreat, because sediment is moved landward, burying older parts of the system (such as the salt marshes) and extending into the bay or lagoon on the mainland side of the island (Fig. 2-1). As a result, portions of the landscape may vary in age, as older landforms are exposed on the seaward side or new deposits are made on the landward side of the island. Washover fans, created as sediment is deposited over and behind the beach and foredunes, tend to be much younger surfaces than the protected areas of the barrier core that are shielded from overwash. When sediment supply from longshore currents is abundant, buildup of the beach can result in seaward progradation of the island, and in some cases, multiple lines of shore-parallel dune ridges varying in relative age and surface stability (Davis, 1994).

Barrier island systems can be divided into a number of different geomorphic elements, unique in morphology as well as formation, development, and relative

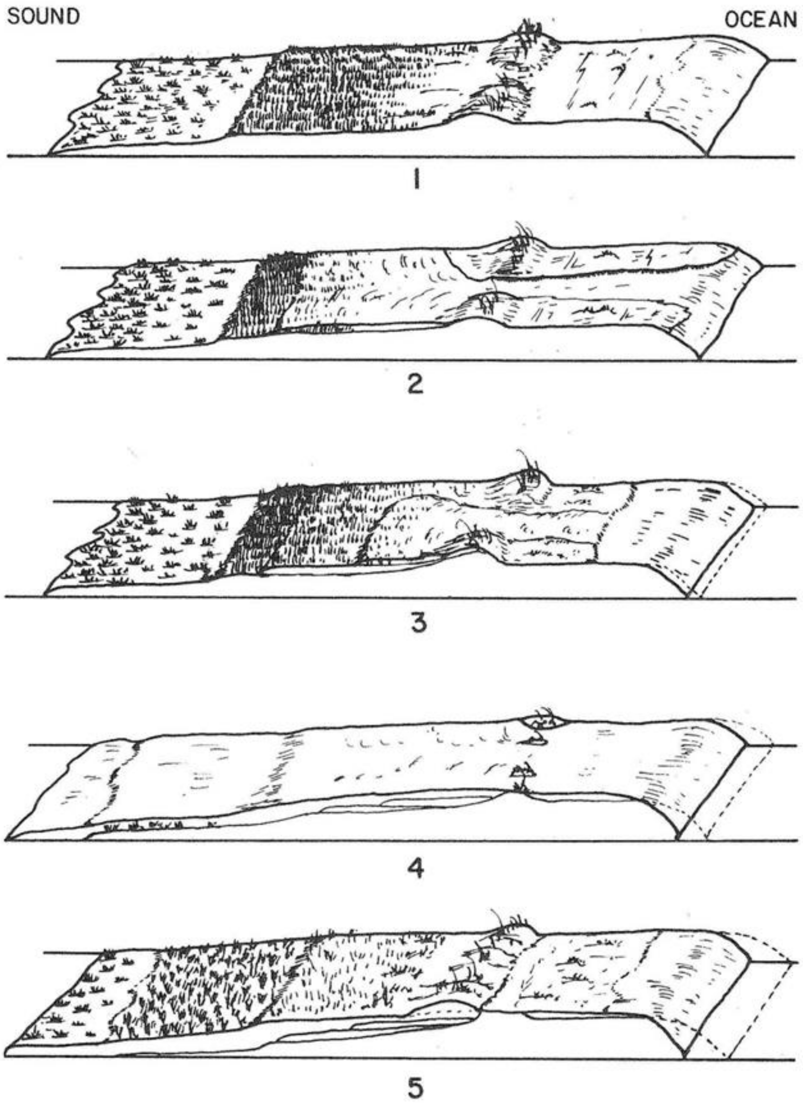

Fig. 2-1. Schematic diagram of barrier island retreat. Overwash events move sediment from the ocean side of the island, burying portions of the barrier core, marsh, and bay. Over time the entire island migrates towards the mainland. From Leatherman (1979a).

stability. While landforms vary across barrier islands of different regions, major landform components on Mid-Atlantic barrier islands include the beach, foredunes, barrier core, washover fans, tidal marsh, and the coastal lagoon or bay (Fig. 2-2). These regions are subjected to differing wind and water deposition and erosion processes, affecting relative surface stability, and therefore also affecting the duration of soil development and the establishment of vegetation.

The beach is defined as the accumulation of wave-washed, loose sediment extending from the outermost breakers to the landward limit of wave and swash action (Leatherman, 1979a; Oertel, 1985). Along the Mid-Atlantic coastline, prevailing southerly breezes and northerly flow of water in the summer months tends to be conducive towards a slow buildup of the beach and upper shoreface (Oertel and Kraft, 1994). Coastal storms, most frequent in fall and winter months, are the dominant cause of erosion on Mid-Atlantic beaches by producing longshore currents which move sand southward, as well as large overwash events (Dolan et al., 1988; Oertel and Kraft, 1994). Daily wave and tidal action along the beach causes constant reworking and movement of sediments and inundation by water, preventing the establishment of vegetation and soil development.

The foredunes are located behind the beach, above the extent of regular tidal influence. They are also very active from a geomorphic perspective, however their formation and development is driven primarily by aeolian processes. Dune topography is highly irregular as dune ridges grow and migrate in response to sand size and wind direction and velocity. Winds can be deflected or concentrated by variations in vegetation and topography. Dunes form as dry backbeach sand is

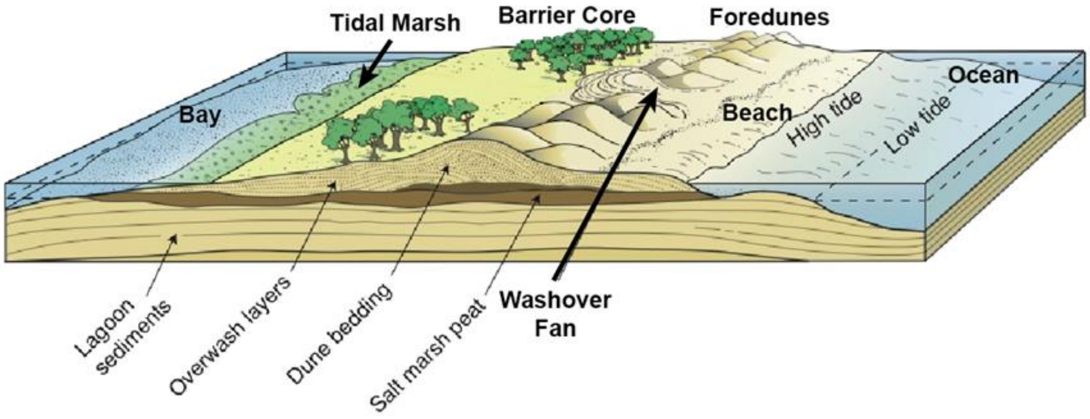

Fig. 2-2. Major landforms of Mid-Atlantic barrier islands. Landforms differ in formation, evolution, and relative stability due to depositional and erosional processes. Adapted from Neal et al. (2007).

transported by onshore winds and trapped in parallel lines of drift or vegetation. Vegetation is limited to species tolerant of frequent burial and sand movement, salt spray, and low nutrient and water holding capacity soils (Ehrenfeld, 1990). The dunal classification system described by Jungerius (2008), refers to the foredunes as white or yellow dunes, due to the limited soil development observed in these areas. Increased sand availability, often due to beach progradation or buildup can allow for the formation of multiple sets of dunes or shore-parallel dune lines as the shoreline extends seaward (Davis, 1994).

As new dunes form, those located further inland are protected from aeolian or water driven erosion and deposition. These relatively stable dunes and flats make up the barrier core, which extends to the marshes on the landward side of the island. The protection provided by the foredunes allows for the establishment of less stress-tolerant plants, allowing grassland, shrub thickets, and eventually woodland and maritime forest vegetation communities to develop (Ehrenfeld, 1990; Jungerius, 2008; Leatherman, 1979a; Morton et al., 2007). Greater stability on landforms in the barrier core also allows for the formation and development of soils, typically characterized by the accumulation of organic matter in surface horizons and weak subsoil development (Demas and Burns, 2004). Dunes in the barrier core have also been referred to as grey dunes or brown or black dunes, describing the color of the developing soils (Jungerius, 2008).

Washover fans are created during large storm events when storm surges or elevated waves flow through the foredunes, transporting and depositing sediment and seawater onto the foredunes, barrier core, marsh, and/or barrier lagoon. The frequency and magnitude of overwash events is controlled by a number of factors related to the geomorphology of the island and the fans themselves (Matias et al., 2010). In the Mid-Atlantic region, long term rates of deposition and erosion on washover fans closely corresponds to the frequency and magnitude of precipitation and overwash events relative to aeolian processes. During times of infrequent precipitation, aeolian processes can dominate sand movement reworking sediments and landforms (Kochel and Dolan, 1986; Kochel and Wampfler, 1989). On barrier islands of the Mid-Atlantic region, most sedimentation occurs as the result of overwash during large magnitude storm events (Kochel and Wampfler, 1989). Barrier islands along the Mid-Atlantic coast are subject to two different types of large storm events. Tropical storms, or hurricanes, occur from June through November. These storms are large in intensity, but often affect a smaller land area in a given storm. They occur with greater frequency further south along the Atlantic coastline. Extratropical storms, or nor'easters, typically occur from October through April. These storms are generally smaller in strength, but can affect a larger land area and occur more frequently, particularly further to the north. On Assateague Island, Kochel and Dolan (1986) estimated that in a normal year, three to four storms cause overwash deposition, but the majority of deposition occurs during large but less frequent storm events.

The landward side of the barrier island typically includes extensive intertidal flats, marshes, and/or mangrove swamps. Intertidal flats are vegetated areas of low relief. They are most common along microtidal coasts (Davis, 1994). Vegetated intertidal flats are dominantly marshes; however mangrove swamps are common in low latitudes (generally between 25^{o}N and S latitude, where hard freezes do not occur). Plant communities in salt marshes (and mangrove swamps) vary along with the tide and salinity gradient. Sediment deposition can occur as overwash across the barrier island, or through the movement of sediment along intertidal and subtidal channels within the bay and marsh. Particle size distribution of sediment in marshes and tidal flats can vary widely, reflecting different sedimentary processes and environments. Additionally, abundant vegetation and organic matter accumulation in salt marshes (and/or mangrove swamps) can lead to the development of thick peat layers.

The barrier island is separated from the mainland by an open water environment, generally termed a coastal bay. Coastal bays can be further categorized as estuaries or lagoons, based on differences in salinity and sedimentary environments. Estuaries are the most common type of coastal bay, and have inlets connecting them to the open water of the ocean. Estuaries accumulate sediment from the ocean through tidal currents, biogenic material produced in the estuary, and freshwater and terrigenous sediment from stream flow. Barrier islands along the Mid-Atlantic are separated from the mainland by estuarine environments, receiving freshwater inputs from mainland rivers and streams, as well as marine inputs through ocean inlets. Less common are backbarrier lagoons, which are entirely separated from the ocean. The lack of a connection to the ocean limits mineral deposition. Therefore, sediment derived from organic matter accumulation makes up a much larger component of accretion in lagoons. Any mineral sediment accumulation in lagoons is the result of overwash from the barrier island or mainland river discharge.

Inlets provide a connection between the coastal bays and marshes and the ocean. They form during large storm events when waves cut through the barrier island creating a channel from the ocean to the bay. Inlets vary in their size, length of time they remain open, and frequency with which they are opened or closed. The spatial distribution, frequency, and stability of inlets is regulated by the relative roles of waves and tides in the movement of sediment (McBride, 1999). Inlet breaching, sedimentation, and migration can also play a role in landward or seaward transgression of the barrier island by regulating the availability and movement of sand (Leatherman, 1979b). Wave-dominated barriers of the Mid-Atlantic, such as Assateague Island, have been cut extensively by inlets opened by island breaching during storms (Krantz, 2010; McBride, 1999). Due to longshore drift and sedimentation, these inlets tend to rapidly migrate southward and close, while inlets on tide-dominated barriers tend to be non-migratory and persist for longer periods of time (McBride, 1999). Former (or closed) inlets appear as relatively flat, low-elevation sections of the island, and can be identified through stratigraphic interpretations (Krantz, 2010; Leatherman, 1985). Common on relict inlets are washarounds, higher elevation aeolian sand accumulations shaped by frequent flooding of the surrounding low lying relict inlet or washover fan surface (Hayden et al., 1995; Krantz, 2010).

2.3 Soils of Barrier Islands and Coastal Regions

Prior to the 1980s, soils mapped on barrier islands were not correlated to specific soil series, but were lumped into miscellaneous land types such as Coastal

Beaches, Dune Sands, or Coastal Beach and Dune Land (Hall, 1973; Ireland and Matthews, 1974; Markley, 1977; Stevens, 1920). In more recent updates to soil surveys along the Mid-Atlantic coast, soil series have been developed and applied to soils found on barrier islands (Barnhill, 1990; Barnhill, 1992; Demas and Burns, 2004; Gagnon, 2001; Hatch et al., 1985; Peacock and Edmonds, 1994; Soil Survey Staff, 2014b; Tant, 1992; Vasilas and Hole, 2002) (Table 2-1). Soil map units in survey updates are more detailed and include taxonomic classifications of soils to the family and series level, but detailed characterizations of the soil series are still limited (National Cooperative Soil Survey, 2014).

Along the Atlantic coast, soil series mapped on barrier islands are split into two groups based on temperature regime. Soils mapped in Maryland and areas north are in a mesic temperature regime, having mean annual soil temperatures (at the 50 cm depth) of 8^{o}C or higher and less than 15^{o}C (Soil Survey Staff, 2010). Virginia and states further south are classified as thermic, with mean annual soil temperatures (at the 50 cm depth) of 15^{o}C or greater and less than 22^{o}C (Soil Survey Staff, 2010).

Within each of the regions of the Atlantic coast (Northeast, Mid-Atlantic, and Southeast and Gulf) the suite of soils mapped represent a catena, ranging from excessively drained to poorly or very poorly drained (Table 2-1). Each of these suites also includes very poorly drained, tidally influenced soils, generally mapped on the marshes adjacent to the barrier island. Of the non-tidal soils, most of the series are in sandy particle size classes, with the exception of some of the soil series in the Northeast, which are coarse-loamy or sandy. The non-tidal soils in the Northeast also tend to show more advanced pedogenesis (natural process resulting in soil

Table 2-1. Soil series mapped on barrier islands of the Mid-Atlantic coastline. Data compiled from the NRCS Web Soil Survey (Soil Survey Staff, 2014b).

Drainage Class	Series Name	Taxonomic Class	States Where Series is Mapped
Excessively	Hooksan	Mesic, uncoated Typic Quartzipsamments	MA NJ
Moderately Well	Hammonton	Coarse-loamy, siliceous, semiactive, mesic Aquic Hapludults	NJ DE MD
Poorly	Atsion	Sandy, siliceous, mesic Aeric Alaquods	NY NJ
Very Poorly	Mullica	Coarse-loamy, siliceous, semiactive, acid, mesic Typic Humaquepts	NJ DE MD
Very Poorly, tidal flooding	Appoquinimink	Fine-silty, mixed, active, nonacid, mesic Thapto-Histic Sulfaquents	NJ DE
Very Poorly, tidal flooding	Transquaking	Euic, mesic Typic Sulfihemists	NJ DE MD
Very Poorly, tidal flooding	Mispillion	Loamy, mixed, euic, mesic Terric Sulfihemists	NJ DE MD
Very Poorly, tidal flooding	Pawcatuck	Sandy or sandy-skeletal, mixed, euic, mesic Terric Sulfihemists	NH MA CT NY NJ DE
Excessively	Acquango	Mixed, mesic Typic Udipsamments	DE MD
Moderately Well	Brockatonorton	Mixed, mesic Aquic Udipsamments	DE MD
Poorly	Askecksy	Siliceous, mesic Typic Psammaquents	NJ DE MD
Poorly, tidal flooding	Saltpond	Sandy, mixed, mesic Haplic Sulfaquents	DE MD[†]
Very Poorly, tidal flooding	Purnell	Sandy, mixed, mesic Histic Sulfaquents	DE MD
Excessively	Assateague	Mixed, thermic Typic Udipsamments	VA
Moderately Well	Fisherman	Mixed, thermic Aquic Udipsamments	VA
Poorly	Camocca	Mixed, thermic Typic Psammaquents	VA
Very Poorly	Backbay	Fine-loamy, mixed, active, nonacid, thermic Histic Humaquepts	VA NC
Very Poorly, tidal flooding	Chincoteague	Fine-silty, mixed, active, nonacid, thermic Typic Sulfaquents	VA
Excessively	Newhan	Thermic, uncoated Typic Quartzipsamments (affected by salt spray)	VA NC SC FL AL MS
Excessively	Fripp	Thermic, uncoated Typic Quartzipsamments (support tree growth)	VA NC SC GA FL AL
Mod. Well to SW Poorly	Corolla	Thermic, uncoated Aquic Quartzipsamments (affected by salt spray)	VA NC GA FL AL MS
Somewhat Poorly	Ousley	Thermic, uncoated Aquic Quartzipsamments (support tree growth)	NC GA FL
Poorly	Duckston	Siliceous, thermic Typic Psammaquents (affected by storm tides)	VA NC GA FL AL MS
Poorly	Osier	Siliceous, thermic Typic Psammaquents (>5% silt + clay in control section)	MD VA NC SC GA FL AL MS LA TX
Very Poorly, tidal flooding	Carteret	Mixed, thermic Typic Psammaquents	NC
Very Poorly, tidal flooding	Bohicket	Fine, mixed, superactive, nonacid, thermic Typic Sulfaquents	VA NC SC GA FL MS

[†] OSD of the Saltpond series recognizes that the series may be present in MD, although it is not currently mapped in MD.

development) than soils mapped in the Mid-Atlantic and Southeast regions (Table 2-1). Outside of the Northeast, non-tidal soils are all Entisols, lacking the formation or development of subsurface diagnostic horizons. Soil series in the Northeast include Ultisols (subsoil clay accumulation), Spodosols (subsoil accumulation of organo-metallic complexes), and Inceptisols (weak subsoil development evidenced by changes in color), with Entisols only occurring in the excessively drained positions. Among the tidally influenced soils (across all regions), there is a range of particle size classes, likely owing to greater variability depositional environments on marshes relative to barrier islands. A number of these soils are Histosols (having greater than 40 to 60 cm of organic soil materials, depending on the degree of decomposition) or have a Histic epipedon (surface horizons of organic soil material, generally 20 to 40 cm thick). Organic horizons can form when organic carbon inputs are high and decomposition rates are low, such as on a highly productive, frequently saturated marsh. Many of the tidally influenced soils contain sulfidic materials within the upper 50 cm due to the influence of marine water (source of sulfur as sulfate) (Rabenhorst, 2001b).

In the Northeast and Southeast, soil series have been classified in siliceous families (or Quartzi- great groups) (Table 2-1). Soils in siliceous mineralogy classes have greater than 90% silica minerals (such as quartz, chalcedony, or opal) and other resistant minerals in the sand and coarse silt fractions (grain size diameters 0.02 to 2.0 mm) (Soil Survey Staff, 2010). In the Mid-Atlantic region, most of the series mapped on barrier islands have mixed mineralogy. However, there is very little mineralogy data available on soils in these landscapes, so generalizations regarding mineralogy must (at this point) be made with caution.

Characterization data (including mineralogy) is available for two soil pedons from Assateague Island National Seashore, MD (Acquango and Brockatonorton series). Of the fine sand fraction, mineral composition was 79-83% quartz, 5-9% feldspars, and 5-12% micas, opaque iron minerals (including ilmenite, magnetite, and hematite) and heavy minerals (including zircon, tourmaline, rutile, epidote, pyroxene, and hornblende) (National Cooperative Soil Survey, 2014). Similarly, mineral composition of the very fine, fine, and medium sand fraction (0-05-0.5 mm) of nine profiles on Virginia barrier islands (Assateague, Camocca, and Fisherman series) was 80-95% quartz, 3-15% feldspar, and 1-9% micas, opaque iron minerals, and heavy minerals (Hatch and Edmonds, 1992). Interestingly, despite being classified as siliceous (rather than mixed mineralogy), mineral composition of the soil series mapped in the Northeast is similar to soils in the Mid-Atlantic; average mineral composition of the fine sand fractions of 11 pedons is 78-86% quartz, 10-15% feldspars, and 4-12% micas, opaque minerals, and heavy minerals (National Cooperative Soil Survey, 2014). Average siliceous mineral contents of the fine sand fraction for the three soil series with available data, Hooksan, Hammonton, and Mullica, were 78%, 86%, and 84%, respectively, suggesting they may not actually classify as siliceous. The soil series mapped along the southeast Atlantic and Gulf Coasts tended to have slightly lower proportions of weatherable and mafic minerals, averaging 83-95% quartz, 2-10% feldspars, and 0-6% micas, opaque minerals, and heavy minerals (grain counts made on sand or fine sand fractions of 11 pedons)

(Hatch and Edmonds, 1992; National Cooperative Soil Survey, 2014). Optical grain counts performed at the Kellogg Soil Survey Laboratory are generally limited to the fine sand fraction, or the most abundant of the fine sand (0.1 to 0.25 mm diameter), very fine sand (0.05 to 0.1 mm diameter), or coarse silt fractions (0.02 to 0.05 mm diameter) (Burt and Soil Survey Staff, 2014). However, mineralogy classification (for siliceous families and Quartzi- great groups) is based on mineral content of the coarse silt and sand fractions (0.02 to 2.0 mm diameter) (Soil Survey Staff, 2010). In these sandy soils it is uncertain if the fine sand fraction (or any one sand fraction) is representative of the coarse silt and total sand mineralogy.

Trends in particle size and mineralogy are likely a reflection of the changing source of sediments along the coastline. Glacial sediments deposited on barrier islands in New England can have a range of particle sizes, from fine sands to cobbles, and there are many mixed-sediment barriers (FitzGerald et al., 1994). Glacial till and overwash sediments of the Northeast are relatively young (retreat of the Laurentide ice sheet in New England occurred 12,000 to 17,000 years ago) and derived from igneous and metamorphic rock. These sediments tend to be higher in mafic minerals (dominated by iron and magnesium), which are easily weathered. When these sediments are deposited on barrier islands of the Northeast and northern parts of the Mid-Atlantic region they are relatively unweathered.

Sediment deposited on islands and coastlines further south is transported by drift from further up the coast or by river discharge from the Piedmont region to the west (Oertel and Kraft, 1994). The Piedmont is a much older region geologically, and unlike the glacial deposits of the Northeast, has been extensively weathered. In addition to weathering prior to transport, the sediments (both from the Piedmont and more northern shorelines) are further weathered as they are moved along shore lines or rives and subjected to wave action. As a result, sediment deposited on barrier islands further south along the Atlantic coast may contain fewer weatherable and/or mafic minerals. The sediment deposited tends to be primarily quartz sand and other silica-based minerals, with trace amounts of heavy minerals that are resistant to weathering (Hall, 2005; Schneider and Kruse, 2003). Based on the mineralogy data available, there does seem to be a trend towards fewer mafic minerals and more resistant siliceous minerals to the south. This trend is not entirely reflected in the classification of the soils, but there is some question if the current mineralogy designations are reflective of the actual mineral compositions of these soils.

The mix of particle size classes and more advanced development in soils of barrier islands in the Northeast and Upper Mid-Atlantic may be the result of greater weathering of less resistant minerals and the range of particle sizes observed in the deposited sediment. More weatherable minerals allow for increased rates of pedogenesis and more developed soils (e.g., Ultisols, Spodosols, and Inceptisols). Further south, where sediments have been subjected to greater weathering before deposition, pedogenesis maybe more limited because the easily weathered minerals have already been broken down. The remaining sediment is resistant to weathering, limiting the formation of secondary clay minerals and the development of diagnostic subsurface horizons (i.e., Entisols). Soils are commonly sandy, with siliceous or quartz-rich mineralogy.

2.4 Soil Development in Young, Sandy Deposits

In a fresh sedimentary deposit, organic matter accumulation is often the earliest evidence of pedogenesis (Birkeland, 1999). Soil organic matter accumulation and its expression within the soil is the balance of additions (plant and animal biomass), removals (decomposition by microbial respiration), transfers (downward movement by water or animals), and transformations (decay from biomass materials to humic substances) (Simonson, 1959). Organic matter accumulation rates are initially slow as time is needed for the establishment of vegetation and the incorporation of organic matter into the soil (Jones et al., 2008; VandenBygaart and Protz, 1995). Once vegetation is established, soil organic matter can accumulate quite rapidly. Eventually, organic matter accumulation rates slow as decomposition rates increase with the establishment of microbial and fungal communities and biomass production reaches a maximum level (Jones et al., 2008; Lichter, 1998). Soil organic matter stocks reach a steady state condition as inputs are balanced by decomposition. The duration of the rapid organic carbon accumulation phase varies among soils, but most are thought to reach the steady state condition in less than 5000 to 20,000 years, and on average, in approximately 3000 years (Birkeland, 1999; Schlesinger, 1990). Chronosequence studies of sandy soils on coastal dunes and beach ridges have suggested this steady state condition may be reached even earlier, ranging from 60 to 3000 years (Barrett, 2001; Jones et al., 2008; Lichter, 1998; Nielsen et al., 2010; Protz et al., 1984; VandenBygaart and Protz, 1995). Syers et al. (1970) documented continued rapid organic carbon accumulation rates on sand dunes up to 10,000 years old in New Zealand. Ongoing, albeit minor, aeolian reworking of these soils may have allowed for this sustained period of rapid carbon accumulation. Disturbances to the system can lead to a shift in input and/or decomposition rates, changing the accumulation rates of organic matter in the system. The diversity and density of vegetation and biomass production is related to soil drainage, fertility, and age, influencing both rates and magnitude of total organic matter accumulation (Alvarez-Rogel et al., 2007; Jones et al., 2008; Lichter, 1998).

Lichter (1998) showed a close linkage between plant community succession and pedogenesis on a dune chronosequence along Lake Michigan. Primary succession grass and shrub communities were followed by a mixed coniferous forest. Increases in soil organic matter and organic acids (particularly with the establishment of conifers) can increase nutrient availability and mineral weathering rates (Jones et al., 2008; Lichter, 1998). Smits et al. (2005) described a similar rapid plant community transition in a Lake Michigan dune chronosequence, with shrubs replacing beach grasses after approximately 100 years. Trees began to colonize the dunes after 150 years, and the dunes were fully forested by coniferous species after 300 years. Barrier island soils tend to be nutrient limited because of the nature of the parent materials. The establishment of nitrogen fixing plants and shrubs (particularly *Morella cerifera*, wax myrtle, and *M. pensylvanica*, northern bayberry, on Mid-Atlantic barriers) have been shown to substantially increase nutrient availability in barrier island soils, allowing for less stress tolerant species to become established and dramatically changing the plant community composition (Brantley and Young, 2008; Day et al., 2004). Brantley and Young (2008) measured annual inputs of fixed nitrogen from leaf litter in *M. cerifera* thickets on Hog Island, VA ranging from 37 to 118 kg N $ha^{-1}yr^{-1}$.

In the absence of nitrogen fixing plants and microbes, atmospheric deposition is the main source of nitrogen inputs (Ehrenfeld, 1990); however, on Assateague Island, average (2000 through 2012) atmospheric deposition of nitrogen is only 14.5 kg N $ha^{-1}yr^{-1}$ (National Atmospheric Deposition Program, 2014). With increased nitrogen availability, species with higher requirements, such as trees (e.g., *Pinus taeda*, loblolly pine, on Mid-Atlantic barrier islands), can become established, and increased canopy cover can exclude herbaceous species (Brantley and Young, 2007; Ehrenfeld, 1990; Olff et al., 1993).

Initial soil development is mostly limited to the formation of O and A horizons as organic matter accumulates at the surface. In weathering resistant parent materials, chemical and physical weathering processes are slow limiting other pedogenic processes, such as the formation and translocation of clay minerals. Protz et al. (1984) observed well developed Ah horizons (mineral horizon with enrichment of organic matter, 5-6 cm thick, moist color 10YR 3/1, organic carbon contents of 0.3-1.2%), after 750 years on sandy, coastal soils in Ontario, Canada. Similarly, VandenBygaart and Protz (1995) described Ahe (mineral horizons with organic accumulation and evidence of eluviation) and LFH horizons (horizon characterized by the accumulation of slightly, moderately, and highly decomposed organic materials, equivalent to an O horizon in U.S. Soil Taxonomy) on 1000 and 1750 year old dune soils. Ahe horizons were 5 cm thick with moist colors of 10YR 3/1 and organic matter contents of 1.6%. LFH horizons were 1-2 cm thick and were a mixture of highly, moderately, and slightly decomposed leaves, twigs and woody material. The ability of the authors to estimate the time necessary for the formation of these features was restricted by the limited number of sites less than 1000 years old. In both studies, soil organic matter accumulation rates slowed after 1000 years suggesting that A and O horizons formed much earlier in the soil's history and had begun to approach steady state conditions within the span of the chronosequence (Protz et al., 1984; VandenBygaart and Protz, 1995). Studies of beach sand chronosequences on Vancouver Island, British Columbia have documented more rapid A horizon development, within 265 years, and Oe horizon formation in 127 years (Singleton and Lavkulich, 1987). Similarly, Barrett (2001) described 2 cm thick Oi horizons on 230 year old beach ridges of Lake Michigan. While Mid-Atlantic barrier islands are estimated to be between 5000 and 7000 years in age, many of the surfaces and landforms on the islands are far younger, on the order of tens to hundreds of years (Kraft, 1971; Oertel and Kraft, 1994).

While soil chronosequence studies conducted on dune and beach ridge deposits adjacent to the Great Lakes in the North Central United States and Canada (e.g., Barrett, 2001; Lichter, 1998; Protz et al., 1984; Singleton and Lavkulich, 1987; Smits et al., 2005; VandenBygaart and Protz, 1995) may give some insight into pedogenic processes in other sandy deposits, such as Mid-Atlantic barrier islands, there are important differences in the soil forming factors at these sites. Soils in the Great Lakes region are formed in deposits of glacio-fluvial origin containing somewhat higher weatherable mineral contents than estimated for barrier island deposits along the Mid-Atlantic coast and further south. In a Lake Michigan dune chronosequence studied by Smits et al. (2005), the parent material was approximately 80% quartz, 20% potassium and plagioclase feldspars, and less than 0.5% biotite, calcite, and hornblende. These less resistant minerals weather faster, potentially increasing rates of pedogenesis. On the other hand, colder temperatures (relative to the Mid-Atlantic region) may limit mineral weathering and biological activity. In these regions, development in sandy soils is characterized by the accumulation of organic matter and the formation of spodic horizons (characterized by the accumulation of amorphous A and/or Fe organic complexes) (Barrett, 2001; Lichter, 1998; Protz et al., 1984; Singleton and Lavkulich, 1987; VandenBygaart and Protz, 1995). Under favorable conditions, formation of spodic horizons can take place within in 400-750 years (Barrett, 2001; Lichter, 1998; Singleton and Lavkulich, 1987). Barrett (2001) observed weak cementation of spodic materials (ortstein) in soils on old beach ridges of Lake Michigan after 1050 years, with consistent cementation on ridges older than 3300 years. Spodic horizons have not been described in soils currently mapped on barrier islands of the Mid-Atlantic or Southeast U.S. coast. They have, however, been described in Pleistocene age dune deposits in this region, particularly in poorly to poorly drained landscape positions (Condron, 1990; Tan et al., 1999).

Formation of clay lamellae and continuous argillic horizons have been observed in older sand dune deposits (12,000 to 14,000 years and older) in western Indiana (Miles and Franzmeier, 1981). Sediments in these dunes were also of glacial origin, containing more fine materials (silt plus clay of 2-8% in C horizons) and have mixed mineralogy (>10% weatherable minerals). Clay accumulation and argillic horizon development has also been observed in a Lake Huron dune chronosequence in Ontario, Canada in soils ranging from 100 to 4700 years (VandenBygaart and

Protz, 1995). More weatherable parent materials, including sediment derived from 25% limestone, 11% dolostone, and 20% Precambrian mafic and metamorphic rocks, may partially explain the higher weathering rates, and increased formation of secondary clay minerals and finer particle size distribution.

Given the relatively few barrier island soil profiles with complete mineralogy data, it is difficult to draw firm conclusions on the differences between soils described in coastal dunes studies in other regions of the world. Differences in climate can play a large role in determining rates of mineral weathering and biological activity. Relative stability of the surface, or soil age, is also an important factor. Soils forming on Holocene-age Mid-Atlantic barrier islands are likely much younger than soils included in chronosequence literature. The time needed for soils on Mid-Atlantic barrier islands to develop the diagnostic horizons observed in other studies is uncertain. Also uncertain is the likelihood that soil surfaces on barrier islands will remain stable for sufficient periods of time for the development of subsoil diagnostic horizons. However, the suspected differences in mineralogy and soil age may, in part, explain the lack of significant soil development on Mid-Atlantic barrier island soils relative to sandy soils in other region.

The topographic relief of barrier islands is slight, generally less than 40 m, however it has a significant effect on the depth to water table (and plant available water), and therefore, the vegetation. High infiltration rates and hydraulic conductivity of sands limits runoff and ensures rapid downward movement of water in the soil. The high hydraulic conductivity, low water holding capacity, and uniformity of water movement through the profile prevents perching of water. As a result, the water table is fairly level despite greater variation in topography. Topographic position becomes an analog to the depth to the water table (Fig. 2-3). Excessively and well drained soils occur on higher points of the landscape, such as dune summits, where the water table is deeper. At low points of the landscape, such as interdunal swales and depressions, the water table is closer to the surface resulting in poorly and very poorly drained soils. Depth to water table and duration of saturation controls plant growth, development of anaerobic or reducing conditions in the soil, and decomposition and accumulation of organic matter. These factors are reflected in the soil in the formation of O or A horizons and redoximorphic features.

2.5 Vegetation and Organic Carbon Stocks on Barrier Islands

Plant communities on the barrier islands are closely tied to the general vegetation types of the mainland, however, they are also influenced by climatic variables and a number of geomorphic and topographic factors on the island itself (Ehrenfeld, 1990; Godfrey, 1976b). Barrier island plant communities can be broken into six major physiognomic types: forest, woodland, shrubland, dwarf-shrubland, herbaceous (includes grasses and forbs in uplands, freshwater wetlands and marshes, and intertidal marshes), and sparse vegetation (where total vegetation cover is usually less than 25%) (USGS-NPS Vegetation Mapping Program, 1995). Plant community characteristics (species composition, density, and production) on barrier islands are influenced by a number of factors, including water availability, soil nutrient availability, and the frequency and magnitude of wind and storms, sand movement, overwash events, and sea spray or salt water intrusion (Ehrenfeld, 1990). Studies of

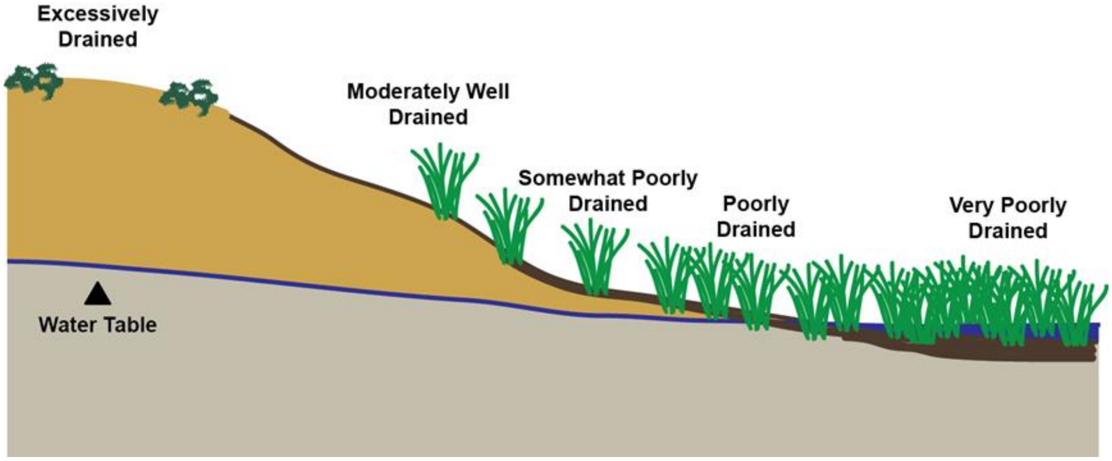

Fig. 2-3. Schematic diagram displaying relationships between topography, water table depths, and soil drainage classes on dune landscapes of Mid-Atlantic barrier islands.

dune chronosequences have documented a characteristic pattern of succession starting with sparse to no vegetation, initial colonization by herbaceous vegetation, followed by the establishment of shrub and forest species (Berendse et al., 1998; Ehrenfeld, 1990; Hayden et al., 1995; Lichter, 1998; Smits et al., 2005; Tackett and Craft, 2010). Ecological change is, at least in part, controlled by landform stability. Gradual island migration and formation of new dunes can result in relatively stable, protected barrier core areas. These areas are sheltered from wind, overwash, and sea spray, and less stress tolerant (but more productive) plant species become more competitive and can dominate plant communities (Ehrenfeld, 1990; Jungerius, 2008; Leatherman, 1979a; Morton et al., 2007). In contrast, frequent deposition on washover fans limits the establishment of vegetation to a few early colonizing species tolerant of frequent burial. Vegetation tends to be sparse and plant productivity is minimal. In addition to increasing stability (and soil age), a number of abiotic factors, such as salinity, vary along a gradient moving landward across a barrier island. Changes in these stress factors, in addition to surface stability, can have a considerable impact on successional pathways (Ehrenfeld, 1990; Olff et al., 1993).

Total ecosystem carbon (contained in vegetation and soil pools) increases with dune or soil surface age (Berendse et al., 1998; Conn and Day, 1993; Tackett and Craft, 2010). The accumulation of soil organic carbon is determined by the relative rates of organic matter inputs to the soil (net primary productivity) and decomposition (microbial respiration). When inputs of organic carbon in the soil are greater than decomposition rates, organic carbon accumulates in the soil, resulting in the formation of O and A horizons.

On barrier islands increased soil organic carbon has been associated with greater biomass production on older soils with more mature plant communities (Conn and Day, 1993; Tackett and Craft, 2010). Shifts in vegetation (herbaceous to woody plants), as well as increases in nutrient availability as organic matter accumulates in older soils, leads to greater biomass production (Conn and Day, 1993; Olff et al., 1993; Tackett and Craft, 2010). On the other hand, work by Dilustro and Day (1997) documented decreased biomass production in older barrier island dune soils due to nutrient limitations that develop over time (as soil nutrients become depleted), suggesting that plant productivity and carbon and nutrient dynamics are controlled by environmental factors in addition to soil age. The establishment of nitrogen fixing plant species, in particular, have been shown to substantially increase nitrogen availability in these nutrient poor soils, allowing for a transition to maritime forest species with higher nutrient requirements and increased productivity (Brantley and Young, 2008; Brantley and Young, 2010). In the absence of nitrogen fixing plants and microbes, atmospheric deposition is the main source of nitrogen inputs on barrier islands (Ehrenfeld, 1990).

Depth to water table and duration of saturation influences the availability of water to plants, and therefore plant growth and organic carbon inputs to the soil. Water table dynamics in dune systems can be especially variable, having a large impact on plant species diversity and density even within a small area (Dilustro and Day, 1997; Grootjans et al., 1998). Topographic position and drainage class have been closely linked to plant community type and primary productivity (Dilustro and Day, 1997; Rheinhardt and Faser, 2001; USGS-NPS Vegetation Mapping Program, 1995). Influence of marine water inputs through groundwater upwelling, storm surges, or sea spray can also play a role in plant community development and primary productivity (Greaver and Sternberg, 2007; Sykora et al., 2004).

Decomposition is the oxidation of organic carbon by microbial respiration. Microbial species composition and activity is influenced by many of the same environmental factors controlling plant growth (e.g., nutrient availability, soil moisture, temperature, salinity, and organic matter availability and quality) (Rajaniemi and Allison, 2009). Under saturated and reducing conditions, microbial activity (and decomposition) is decreased as microbial anaerobic respiration is slow relative to aerobic respiration. In wetlands, for example, net retention of carbon occurs because plant biomass production is high, but decomposition rates are low (carbon inputs surpass carbon lost through decomposition) (Mitsch and Gosselink, 2007).

2.6 Barrier Island Wetlands and Problematic Hydric Soils

Within a barrier island, a freshwater lens exists above the denser saline groundwater, and serves as a freshwater source for plants and animals on the barrier island (Hall, 2005). In low lying areas, the water table approaches or intersects the soil surface forming a wetland or pond (Fig. 2-3). These freshwater wetlands occur in open or closed interdunal depressions. Diurnal groundwater fluctuations due to tides are minimized with increased distance from the ocean (Nielsen, 1990). Therefore, water levels in most freshwater ponds on barrier islands do not fluctuate with the tide. Instead, water table dynamics are controlled predominantly by precipitation and evapotranspiration (Doss, 1993; Hall, 2005; Shedlock et al., 1993). Evapotranspiration rates vary over the course of the year and can result in potential shifts in groundwater gradients (Doss, 1993). This could have greater significance in barrier island systems, resulting in shifts in groundwater chemistry due to the proximity of the saline groundwater. While interdunal swales and ponds are dominantly freshwater systems fed by precipitation, saline water inputs can result from sea spray, overwash and surface flow, inflow of saline groundwater, and flooding from the coastal bay depending on geomorphology, hydrology, and location on the island (Hall, 2005). Influxes of saline water can impact vegetation (species composition and productivity) and microbial activity (decomposition rates).

Wetlands are defined as “areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions” (U.S. Army Corps of Engineers Environmental Laboratory, 1987). This definition explicitly mentions three environmental parameters necessary for wetland delineation: hydrophytic vegetation, hydrology, and hydric soils. A hydric soil, as defined by the National Technical Committee for Hydric Soils (NTCHS), is a “soil that formed under conditions of saturation, flooding, or ponding long enough during the growing season to develop anaerobic conditions in the upper part” (Federal Register, 1994). Hydric soils are identified or delineated in the field using a set of field indicators approved by the Natural Resource Conservation Service (NRCS) and the NTCHS (USDA-Natural Resources Conservation Service, 2010).

The indicators are regionally specific, and based on characteristic morphologies that develop in soils subjected to repeated periods of saturation and reduction.

Soils that are anaerobic and contain one (or more) of the chemically reduced forms of N, Mn, Fe, or S are considered reduced. For a soil to become reduced it must be saturated, O_2 gas must be depleted, and biological activity must occur to reduce NO_3^-, Fe (III) and Mn(IV) (hydro)oxides, SO_4^{2-}, and/or CO_2. Organic matter decomposition is carried out by soil microbes, which oxidize organic carbon for growth of cellular biomass. Under aerobic conditions, electrons released through organic matter oxidation are used to reduce O_2. However, during prolonged periods of saturation, O_2 is depleted by microbial activity. Low diffusivity of O_2 under saturated conditions limits O_2 replenishment in the soil promoting anaerobic respiration. Electrons produced by oxidation of organic carbon compounds are instead transferred to alternative electron acceptors, NO_3^-, Mn(IV) oxides, Fe(III) (hydro)oxides, SO_4^{2-}, or CO_2, which are transformed to their reduced form. Anaerobic respiration is less thermodynamically favorable than aerobic respiration, so decomposition is slowed, allowing organic matter to accumulate in the soil. Prolonged reducing conditions or alternating periods of reduction and oxidation of Fe and Mn compounds in the soil lead to the formation of soil redoximorphic features (Soil Survey Staff, 2010). These features, along with the accumulation of organic carbon or production of H_2S gas, can be useful for identifying hydric soils in the field, and are the basis for the Hydric Soil Field Indicators (USDA-Natural Resources Conservation Service, 2010).

Redoximorphic features are formed by the reduction, translocation, and accumulation of Fe and Mn compounds, and include redox concentrations, redox depletions, and reduced matrices (USDA-Natural Resources Conservation Service, 2010; Vepraskas, 2001). Redox concentrations are zones of Fe(III) and/or Mn(IV) (hydro)oxide accumulation. They are formed when reduced and soluble forms of Fe and Mn are translocated, become oxidized, and precipitate. Fe(III) (hydro)oxide are red, yellow, or brown (Bigham et al., 2002), while Mn(IV) oxides are generally black in color (Dixon and White, 2002). Redox concentrations made up of Fe and/or Mn minerals can occur as masses, pore linings, nodules, or concretions. Masses are soft accumulations occurring in the matrix, whereas pore linings are accumulations along ped (naturally formed soil aggregate) surfaces or root channels. Nodules and concretions are hard, spherical bodies cemented by Fe and/or Mn (hydro)oxides. When broken in half, concretions are distinguished from nodules by the presence of concentric layers (Vepraskas, 2001).

Redox depletions are zones of low chroma (≤ 2) soil formed as Fe(III) and Mn(IV) (hydro)oxides are lost through reduction. Depletions can form most easily along ped faces and root channels. Under anaerobic, reducing conditions, Fe(III) and Mn(IV) are reduced to Fe^{2+} and Mn^{2+}, which are highly soluble and colorless in soil solution. Instead of the red, yellow, brown, and black coatings of Fe(III) and Mn(IV) (hydro)oxides, the unmasked mineral grains are visible, and these light colored areas are the depletions (Vepraskas, 2001). Clay depletions differ in that they form from a loss of clay in addition to the loss of Fe(III) and Mn(IV) (hydro)oxides (Vepraskas, 2001).

Under reduced conditions Fe^{2+} remains in solution, however if the soil is exposed to O_2, the Fe can be oxidized and precipitated as Fe(III) (hydro)oxides. The soil color will change to a redder hue or higher chroma as a result. Soils that have a low chroma (≤ 2) color, but change color upon exposure to O_2 are described as having a reduced matrix (Vepraskas, 2001). Depleted matrixes occur when Fe has been reduced and leached from the soil. The soil has a low chroma matrix (≤ 2), but does not change color when exposed to O_2 because there is no available Fe^{2+} to be oxidized and precipitated.

Anaerobic respiration utilizing an alternative electron acceptor (NO_3^{2-}, Fe (III), Mn(IV), SO_4^{2-}, or CO_2) is less thermodynamically favorable than aerobic respiration, so under reducing conditions, decomposition (carbon oxidation) rates are slower. As a result, partially decomposed organic matter accumulates in the soil. This can result in thick organic surface horizons (O horizons) and/or dark, organic-rich mineral surface horizons (A horizons) (Collins and Kuehl, 2001; USDA-Natural Resources Conservation Service, 2010). Organic horizons are divided into three groups, which differ in their degree of decomposition. Oi (fibric) horizons are slightly decomposed plant materials or peat, and plant remains are recognizable. Oa (sapric) horizons are muck or highly decomposed plant material, where plant remains are no longer recognizable. Oe (hemic) horizons are moderately decomposed or mucky peat. A horizons are mineral horizons, but can have sufficiently highly proportions of organic material to be referred to as having mucky mineral textures (e.g., mucky sand).

In soils that have been saturated and reduced for long periods of time, SO_4^{2-} can be reduced to H_2S gas (Vepraskas and Faulkner, 2001). This reaction produces a distinct “rotten egg” odor in the soil. Since SO_4^{2-} reduction occurs at a lower redox potential than Fe and Mn oxides, this reaction will only occur in wetter, more reducing sites (USDA-Natural Resources Conservation Service, 2010). This reaction is also limited by the availability of SO_4^{2-}. While it occurs in higher concentrations in marine waters, SO_4^{2-} concentrations are generally low in freshwater systems (Fanning et al., 2002; Rabenhorst, 2001a).

The Hydric Soil Field Indicators were developed using these morphological features (e.g., redox features, accumulations of organic matter, and sulfide odors) in order to quickly identify hydric soils in the field eliminating the need to monitor the frequency and duration of saturated and reducing soil conditions (USDA-Natural Resources Conservation Service, 2010). In the absence of, or in addition to, morphological indicators, an α,α'-dipyridyl indicator solution can be used to qualitatively test for the presence of reduced Fe^{2+} in soil solution (Childs, 1981). When soluble Fe^{2+} is present, as under reduced conditions, a pink to red color will develop through the formation of a ferrous α,α'-dipyridyl complex. The lack of a color change could indicate Fe^{2+} is not present, either because the soil is oxidized (all Fe exists as Fe(III)), the soil is reduced, but Fe has not been reduced to Fe^{2+}, or the soil is reduced but there is no Fe^{2+} present.

Identification of hydric soils on barrier islands, and in other young, sandy deposits, presents particular difficulties because these soils often do not express hydromorphic indicators as observed in other soil environments. The relatively young age of the barrier islands, the dynamic nature of the landforms on the island, and the weathering resistant mineralogy (quartz-rich sands) combine to limit soil development in these systems, and thus also limit the use of currently recognized

Hydric Soil Field Indicators (Kuehl et al., 1997; Lindbo, 1997). Low amounts of Fe in the parent material results in soils with a low chroma even under non-hydric conditions. Non-hydric soils could be erroneously recognized as hydric because of the low chroma. These non-hydric soils have sometimes been referred to as having “dry hydric morphologies” (Robinette et al., 2004). Alternatively, due to low Fe concentrations, hydric soils may not develop redoximorphic features, such as Fe concentrations and depletions, or show positive reactions with α,α’-dipyridyl dye.

In sandy soils, Kuehl et al. (1997) found field indicators reflecting organic carbon accumulation to be the most useful in hydric soil recognition, particularly the presence of muck or mucky mineral surface layers. A new sedimentary deposit will contain very little, if any, organic matter, but once vegetation is established organic matter accumulates and A and O horizon formation can begin. However, it is uncertain how quickly organic matter accumulates in barrier island soils. Given the suspected low concentrations of iron and young age of Mid-Atlantic barrier island soils, characteristics of organic matter accumulation may show the most usefulness as indicators of soil wetness.

CHAPTER 3: PEDOGENESIS AND LANDSCAPE RELATIONSHIPS OF SOILS ON MID-ATLANTIC BARRIER ISLANDS

3.1 ABSTRACT

Soil characteristics and pedogenic processes are relatively unstudied on Mid-Atlantic barrier islands, despite their value for recreational, residential, commercial, and industrial development. In this study we looked at soil development across various landforms and drainage conditions to assess how soil surface stability and water availability influenced soil development. Ten topographic transects were established on different landforms of the island, ranging in duration of soil surface stability and mode of deposition and formation. Soils were compared between transects to evaluate soil formation over time (ranging from less than 1 to 228 years), and within transects to assess the influence of drainage (ranging from very poorly to excessively drained). Soil development was fairly limited due to the young age and weathering resistant nature of the parent material. Major evidence of pedogenesis across the chronosequence was in the accumulation of organic matter and the formation of A and O horizons. Organic carbon accumulation was influenced by proximity of the water table to the soil surface, with greater organic carbon accumulation occurring in wetter topographic positions. Frequency and duration of saturation also impacted subsoil development, producing subtle, but noticeable color differences between oxidized and reduced horizons. Based on our observations of the soils at Assateague Island National Seashore, we identified a number of limitations in the current soil series and taxonomic classifications used in mapping Mid-Atlantic

barrier islands. This study also documents the presence of sulfidic materials in these non-tidal systems, raising additional questions regarding taxonomic classification.

3.2 INTRODUCTION

Barrier islands are an important geomorphic component of coastal zone ecosystems. They make up about 15% of the world's coastlines and are particularly extensive along the east coast of North America (Glaeser, 1978; Ritter et al., 2002). Barrier islands are generally elongate, up to several kilometers long and less than 1-2 kilometers wide and composed of unconsolidated marine sediments (Davis, 1994). They are aligned roughly parallel to the mainland shore and are separated from the mainland by bays, lagoons, and/or marshes. The islands provide physical protection for the mainland and adjacent bays and marshes by absorbing the impact of storm surges and the direct wave action of the ocean (Stone and McBride, 1998). Existing at the interface between marine and terrestrial ecosystems, barrier islands provide a unique habitat essential to aquatic and terrestrial species that rely on both ecosystems for portions of their life cycle, nesting, reproduction, and/or food sources. In addition to providing an important ecological role, barrier islands are also valuable to humans for recreational, residential, commercial, and industrial purposes, and thus can face serious developmental pressures.

Barrier islands are young, dynamic environments and the relative roles of wave, tidal, and storm processes are influential on their size, shape, formation, and development (Davis, 1994). The source and nature of the unconsolidated marine sediments comprising the island are influential on the landforms and the development of soils. Barrier island systems can be divided into a number of different geomorphic elements, including the beach, foredunes, barrier core, overwashes, tidal marshes, and coastal lagoon. Differences in the marine and sub-aerial deposition and erosional processes across these landforms affect their relative stability, and therefore, the duration of soil development and the establishment of vegetation. More extensive reviews of the landforms and geomorphology of barrier islands are provided by Davis (1994), Leatherman (1979a), and Oertel (1985).

Pedogenesis in sandy coastal soils is highly dependent upon parent material mineralogy and the duration of soil development. Initial soil development and pedogenesis in soils formed in weathering resistant parent materials is mostly limited to the development of O and A horizons as organic matter accumulates at the surface. While Mid-Atlantic barrier islands are estimated to be between 5000 and 7000 years in age, many of the surfaces and landforms on the islands are far younger, on the order of tens to hundreds of years (Havholm et al., 2004; Kraft, 1971; Oertel and Kraft, 1994). Accumulation of organic matter is often closely linked to water table depth and vegetation, as they control primary production and organic carbon inputs, as well as organic carbon decomposition rates.

Prior to the 1980s, soil mapping efforts on barrier islands were limited, and soils were typically lumped into miscellaneous land types, such as Coastal Beaches, Dune Sands, or Coastal Beach and Dune Land (Hall, 1973; Ireland and Matthews, 1974; Markley, 1977; Stevens, 1920). In more recent soil survey updates along the Mid-Atlantic coast, soil series have been developed and applied to barrier island landscapes (Barnhill, 1990; Barnhill, 1992; Demas and Burns, 2004; Gagnon, 2001; Hatch et al., 1985; Peacock and Edmonds, 1994; Soil Survey Staff, 2014b; Tant, 1992; Vasilas and Hole, 2002). However, understanding of the pedogenic processes and detailed characterizations of these soils are limited (National Cooperative Soil

Survey, 2014). While there has been extensive research on plant communities (e.g., Hill, 1986; Shao et al., 1996), ecological succession (e.g., Ehrenfeld, 1990; Tackett and Craft, 2010), and geomorphology and landform dynamics (Havholm et al., 2004; Kochel and Wampfler, 1989; Morton and Sallenger, 2003; Morton et al., 2007) on barrier islands, knowledge and understanding of the pedogenic processes of these systems is limited. In an ecosystem, soils link the biologic, lithologic, and hydrologic factors, and play an influential role in each of these systems. Greater understanding of the soils improves our understanding of the system as a whole and our ability to protect and manage these valuable ecosystems.

The objective of this study was to better understand the processes and factors influencing the pedosphere and soil development on Mid-Atlantic barrier island landscapes. We focused on two factors, time (related to landform stability) and soil moisture (reflected in topography). Since barrier islands are relatively small in area, the soil forming factors of climate and parent material are relatively constant across the island. The biotic factor influences soil development, but is itself influenced by the other soil forming factors. We hypothesized that age and landform stability will have a significant influence on observable soil properties. Additionally, within a given landform soil characteristics will vary as a function of topography.

3.3 MATERIALS AND METHODS

3.3.1 Study Site

Assateague Island National Seashore is a barrier island located along the eastern coast of Maryland and Virginia (Fig. 3-1a). The island is approximately 60

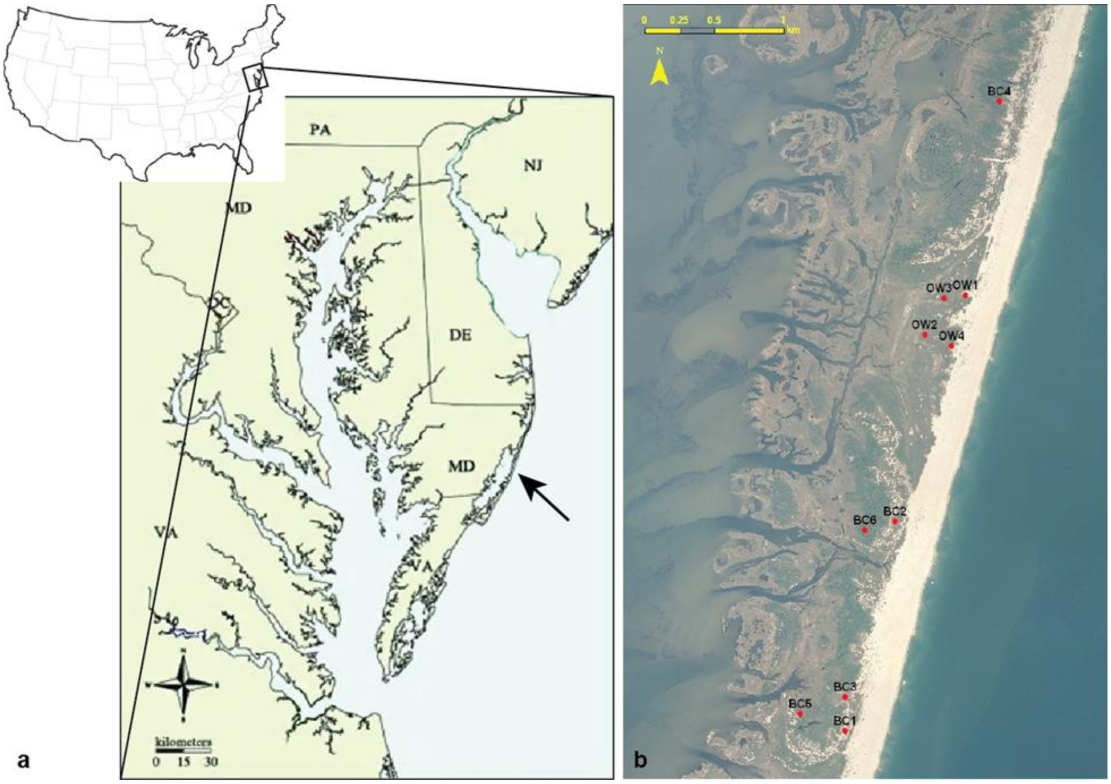

Fig. 3-1. Location of study sites at Assateague Island National Seashore, MD, USA. (a) Regional map of Maryland and surrounding states showing location of Assateague Island (indicated by arrow), (b) aerial photograph of a portion of the island with ten transects included in the study. Six sites are located in the barrier core (BC) and four sites are in an overwash zone (OW).

km long, ranges from 0.5 to 4.5 km wide, and typical of barrier islands of the Mid-Atlantic region. The island is jointly managed by the National Park Service, U.S. Fish and Wildlife Service, and the State of Maryland. As protected federal and state owned land, human manipulation of the island is somewhat limited, allowing for the study of processes that are more reflective of the natural conditions and factors influencing soil development in these landscapes.

The major landforms on the island were identified using aerial photography, USGS geomorphology maps (Morton et al., 2007), Worcester County soil survey maps (Demas and Burns, 2004), and digital elevation models. Delineated landforms included beaches, foredunes, barrier core, overwashes, and tidal flats and marshes. Ten study sites were established in the barrier core and overwash zones (Fig. 3-1b). The barrier core is the central part of the island, lying between the foredunes (on the ocean side of the island) and marshes (on the landward side) (Morton et al., 2007). Overwash zones can be, or previously have been, flooded by high water and waves during storms. They can be divided into inactive zones that were historically overwashed by storm surges, but are now protected from surges and overwash during most storm events, or active zones that are still regularly flooded and receive depositions (Morton et al., 2007).

Sites were selected to encompass the range of landforms and vegetation communities across the barrier island landscape. Vegetation ranged from relatively sparse herbaceous and dwarf-shrub species on washover fans and moderately well drained dunes, to shrub or tree dominated communities on relatively stable dune fields and barrier flats. At each site, a topographic transect was established, ranging from the most excessively or best drained soils at dune crests and summits to poorly or very poorly drained areas in swales and depressions (Table 3-1). Along each transect a high (moderately well drained or drier soils), mid (somewhat poorly, poorly, or very poorly drained soils), and low (poorly or very poorly drained soils) positions were established for soil sampling and monitoring. In order to avoid the interference of water table depth, only soils from similar topographic positions were used to compare pedogenesis over time (as a soil chronosequence). Within a transect, comparisons of the high, mid, and low positions were used to evaluate the influence of soil moisture on soil development.

Constant wave and wind action on the beach and foredune areas of the island prohibit or greatly restrict soil formation and development; therefore these areas were excluded from the study. Also omitted from the study were soils in the marshes, since marsh soils have been studied more extensively and are better understood (e.g., Darmody and Foss, 1979; Fernandez et al., 2010; Gammill and Hosier, 1992; Hussein et al., 2004; Redfield, 1972).

3.3.2 Field Methods

Site Descriptions, Instrumentation, and Monitoring

Topographic relief along each of the transects was measured using a level and rod. Relative elevation was measured at 1.0 m intervals along the transect and at each of the topographic positions (high, mid, and low). Topographic profiles were joined to available LIDAR data to determine actual elevations for each of the transect points. Vegetation surveys were conducted at each of the sites. In August 2012, plant species

Table 3-1. Characteristics of study sites at Assateague Island National Seashore, MD, USA.

Transect[†]	Landform[‡]	Topographic Position[§]	Surface Age[¶]	Elevation	Median Water Table[#]	Drainage Class[††]	Average Electrical Conductivity[‡‡]
			years	m	m		dS m^{-1}
OW4	Washover Fan	High	<1	1.02	-0.44	MW	4.9 (±5.3)
		Mid	13	0.84	-0.35	SP	3.1 (±2.3)
		Low	13	0.72	-0.23	PD	7.0 (±8.0)
OW1	Washover Fan	High	13	1.08	-0.55	MW	1.0 (±1.7)
		Mid	13	0.93	-0.37	SP	0.9 (±1.5)
		Low	13	0.73	-0.16	PD	0.9 (±2.2)
OW2	Back-barrier Flat	High (Dune)	43	0.97	-0.53	MW	1.4 (±1.5)
		Mid	167	0.58	-0.13	PD	4.2 (±1.3)
		Low	167	0.39	0.00	VP	6.3 (±1.7)
OW3	Back-barrier Flat	High (Dune)	52	0.90	-0.65	MW	2.0 (±2.4)
		Mid	148	0.33	-0.15	VP	5.0 (±0.5)
		Low	148	0.29	0.01	VP	6.4 (±0.7)
BC1	Dune Field	High (Dune)	101	1.42	-0.64	MW	1.7 (±2.1)
		Mid (Dune slack)	101	0.93	-0.14	VP	4.7 (±1.7)
		Low (Dune slack)	101	0.80	-0.02	VP	3.2 (±2.1)
BC3	Barrier Flat	High	120	1.23	-0.66	MW	3.7 (±2.3)
		Mid	120	0.99	-0.33	SP	3.6 (±2.9)
		Low (Swale)	120	0.63	-0.05	VP	5.1 (±3.6)
BC4	Barrier Flat	High	144	1.41	-0.69	MW	1.1 (±1.6)
		Mid	144	1.02	-0.37	SP	1.6 (±1.2)
		Low	144	0.75	-0.16	VP	1.9 (±2.4)
BC2	Dune Field	High (Dune)	148	1.37	-0.46	MW	4.7 (±2.1)
		Mid (Dune slack)	148	1.00	-0.09	VP	6.2 (±2.8)
		Low (Dune slack)	148	0.90	0.03	VP	5.5 (±4.1)

Transect[†]	Landform[‡]	Topographic Position[§]	Surface Age[¶]	Elevation	Median Water Table[#]	Drainage Class[††]	Average Electrical Conductivity[‡‡]
BC5	Dune Field	High (Dune)	190	1.20	-1.20	ED	0.2[§§]
		Mid	190	0.46	-0.40	SP	5.9 (±3.4)
		Low (Dune slack)	190	0.21	-0.07	VP	5.6 (±2.5)
BC6	Dune Field	High (Dune)	228	0.40	-0.37	SP	6.4 (±3.1)
		Mid (Dune slack)	228	0.15	-0.07	VP	8.9 (±5.1)
		Low (Dune slack)	228	-0.02	0.07	VP	5.7 (±2.6)

[†] Transects beginning with "OW" are located in overwash areas of the island. Transects in the barrier core begin with "BC".

[‡] Landforms were defined using terminology of Schoeneberger and Wysocki (2012).

[§] Topographic positions assigned with the transect. Micro-landforms (where applicable) are given in parenthesis. Micro-landforms were defined using terminology of Schoeneberger and Wysocki (2012).

[¶] Ages of soil surface determined by comparisons of historical aerial photos of Assateague Island (sites younger than 60 years) or by Optically Stimulated Luminescence (OSL) dating techniques.

[#] Median water tables measured from February 2011 through January 2013.

[††] Drainage Classes: ED = Excessively drained, MW = Moderately well drained, SP = somewhat poorly drained, PD = poorly drained, VP = Very poorly drained. Given the young age of theses soils, there was not always development of the redoximorphic features (e.g., organic accumulation, redox concentrations) typically used in assigning drainage classes. Therefore, we used the frequency and duration of saturation at given depths in addition to morphological features in order to determine the drainage class. General criteria for each of the drainage classes has been provided by the Natural Resource Conservation Service (Soil Survey Division Staff, 1993).

[‡‡] Electrical conductivity (reported as temperature adjusted specific conductance) of soil pore water was measured monthly from February 2012 through January 2013. Pore water was collected from 100 cm deep piezometers at high and mid positions. At low positions, samples were collected from surface water (when present), 25 cm, 50 cm, and 100 cm. Value presented is the average of all measurements at the low position. Standard deviations are given in parentheses.

[§§] Water table at BC5H was almost always deeper than 100 cm, so value given is not an average, but a single measurement.

were identified and percent cover was estimated at each of the topographic positions of the transects.

Two meter deep wells were installed at high, mid, and low positions along each transect. Automatic recording data loggers were programmed to measure water table daily (6 am and 6 pm). Hourly measurements were made in fall 2011 and summer 2012 to ensure that water tables were not influenced by tides or show greater daily fluctuations than could be captured by twice daily measurements. Average diurnal variation was generally less than 10 cm, but did not follow a tidal cycle and appeared to be driven by evapotranspiration. Water level in a well is a measure of the total hydraulic head over the entire depth of the well. However, the soils on Assateague Island (and most Mid-Atlantic barrier islands) are sandy and have relatively constant hydraulic conductivities with depth. Comparisons of well readings and free standing water depths showed that conditions were generally hydrostatic, and total hydraulic head was roughly equal to the water table depth. Therefore, well readings were used as a measure of water table depth.

Soil pore water was sampled from piezometers located at the high, mid, and low positions. Piezometers were 100 cm deep at the high and mid locations. At the low positions piezometers were 25, 50, and 100 cm deep. When there was ponding at the surface (generally in late winter, spring, and following large storm events), surface water was collected at the low positions. Electrical conductivity (reported as temperature adjusted specific conductance) was measured on water samples monthly from February 2012 through January 2013 using a portable electrical conductivity meter (YSI Model 85, YSI, Incorporated, Yellow Springs, OH).

Soil temperature classes used in taxonomic classification are determined based on the mean annual soil temperature 50 cm below the surface (Soil Survey Staff, 2010). Soil temperatures in these landscapes, as well as the magnitude of variability of soil temperature between landforms and landform positions, are uncertain. Temperature loggers were buried at 10, 30, and 50 cm depths at high, mid, and low topographic positions along three of the transects (BC2, BC6, OW3) and at 50 cm at the mid positions of three additional transects (BC1, BC5, OW2). Loggers were programmed to record temperature every 3 hours. Since weather conditions can be highly variable along the coastline, precipitation and air temperature was measured on the island. Four tipping-bucket rain gauges with data loggers were installed at a central location among (within 3 km of) the study sites. Gauges were installed in the overwash zone where vegetation coverage is low and would not interfere with precipitation collection. Precipitation was recorded in 0.254 mm (0.01 inch) increments. To document air temperature, three recording temperature loggers were installed near study sites approximately 1.8 m above the ground surface and shielded from direct sunlight. Temperature was recorded every 90 minutes. Additional precipitation and temperature data were obtained from a National Weather Service Remote Automatic Weather Station (RAWS) located on Assateague Island, approximately 9.5 km south-southeast from our rain gauges (8.0 km south-southeast from our air temperature loggers) (Western Regional Climate Center, 2013). Comparison of the air temperature and precipitation data collected at our sites and the RAWS site over the course of the study (2011-2013) showed that conditions were similar enough between the two locations that the long-term data set provided by the

National Weather Service would accurately represent long-term conditions at our sites.

Soil Descriptions and Sampling

Soil morphology was described at high, mid, and low positions along each of the transects according to the procedures of Schoeneberger et al. (2012). Soils were described in small hand-dug pits to the depth of the water table. An auger was used to describe the soil below the water table to at least 2 m. A section of Al pipe (10 cm inside diameter, 2.0 m length) was used as an adjustable casing to facilitate collection of saturated sandy soils while using a bucket auger. Pedons in very poorly and poorly drained positions were described in the summer of 2011 when water tables were lowest and a greater portion of the soil profile could be exposed and described in a small pit. Soils in better drained positions were described in the fall of 2011 and winter of 2011–2012 when moister conditions made excavation of a small pit more feasible.

Soil reaction to H_2O_2 (color change) and observations of H_2S gas odors were used to identify the presence of sulfides in saturated soil horizons (Fanning et al., 2002). The presence of Fe^{2+} was determined using α,α’-dipyridyl in saturated soils (Childs, 1981). Soil reaction with α,α’-dipyridyl was evaluated visually and classified as very weak, weak, moderate, or strong based on a set of standards created in the laboratory. Since soil color variation between horizons in sandy, quartz-rich soils is often subtle, measurements of soil value and chroma were made to the half unit, by interpolating between chips using the X-Rite Munsell Soil Color Book (X-Rite Incorporated, Grand Rapids, MI) as a guide (Rabenhorst et al., 2014).

Within each pedon, soils were sampled by horizon for further laboratory analyses and characterization. Sampled soils were stored in sealed plastic sampling bags to ensure they remained at field moisture conditions prior to analyses. In order to assess soil carbon stocks, three replicate 7.5 cm diameter soil cores were collected at each transect position to a depth of 50 cm using 60 cm aluminum tubes. Cores were frozen to limit biological activity and to ease the extraction of a continuous, intact core.

3.3.3 Laboratory Methods

Soil pH was measured using a combination glass electrode on field moist samples using approximately a 1:1 soil: water paste. Measurements were made within 1-2 days of collection to limit any effects of oxidation. Soil horizons that were saturated for the majority of the year (based on water table measurements) were incubated at room temperature under moist aerobic conditions to determine if sulfidic materials were present (Soil Survey Staff, 2010). Soil pH was monitored weekly on incubated samples for a period of approximately 4 months. If sulfidic materials are present in a soil, the pH will drop dramatically as sulfides (S^{2-}) are oxidized and sulfuric acid (H_2SO_4) is formed.

Sampled mineral horizons were air dried, crushed, and sieved to pass through a 2 mm sieve. Coarse fragments (>2 mm) were divided into gravels and shell fragments (where applicable), and coarse fragments and fines were weighed to determine percent gravel (and shell fragment) content for all horizons. Particle size analysis was performed on all soil horizons. Samples with sand textures were sieved using a set of nested sieves (opening sizes 1 mm, 0.5 mm, 0.25 mm, 0.1 mm, 0.05 mm, and pan) to determine sand size fractions (vcos, cos, ms, fs, and vfs) and fines (silt and clay combined). Particle size of finer textured samples was determined by the pipette method (Gee and Or, 2002). Organic horizons were air dried and crushed to homogenize the sample.

In addition to color measurements made in the field, color measurements were also made using a digital colorimeter (Konica-Minolta Chroma Meter CR300, Minolta Corporation, Ramsey, NJ). Dry and moist color measurements were made after samples had been sieved and homogenized.

For organic carbon determination, approximately 2 g of the fine earth fraction was ground with a mortar and pestle to pass through a #60 mesh (0.25 mm) sieve and dried at 105^{o}C. Organic samples were initially ground with a coffee grinder, and then ground with a mortar and pestle to pass through a #60 mesh sieve and dried at 105^{o}C. Total carbon was measured by dry combustion at 950^{o}C using a LECO CHN-2000 analyzer (LECO Corporation, St. Joseph, MI) (Nelson and Sommers, 1996). Potentially calcareous soils were identified by the presence of shells, reaction (effervescence) following treatment with 10% HCl, or a soil pH > 7. All calcareous soil horizons were pre-treated with 5% sulfurous acid to remove calcium carbonate prior to organic carbon determinations (Balduff, 2007; Nelson and Sommers, 1996).

To assess soil carbon stocks, sampled cores were extracted, horizons were delineated and horizon thickness was measured. The entire sample from each horizon was dried and sieved to remove gravels and shell fragments (> 2 mm). Samples were weighed to determine bulk density (volume was determined by the cross-sectional area of the aluminum tube times horizon thickness). Organic carbon was determined using the same method as described for bulk soil samples.

Iron (hydro)oxides were extracted with dithionite-citrate-bicarbonate using a modification of methods by Fanning et al. (1970). Extractions were made on duplicate 5.00 g samples of soil using 25 mL of citrate bicarbonate and 0.4 g of sodium dithionite in a hot water bath (80°C). Following centrifugation (15 minutes at 1500 rpm) supernatant was decanted in to 100 mL volumetric flasks. Samples were washed with 25 mL distilled water, centrifuged again, and supernatant decanted into flasks. Flasks were brought to volume with distilled water, and iron in solution (DCB Fe) was measured on diluted samples using an atomic absorption spectrometer (PerkinElmer AAnalyst 400, PerkinElmer, Inc., Shelton, CT) (Loeppert and Inskeep, 1996).

3.3.4 Determination of Soil Age

In order to assess relative landform stability and develop soil chronofunctions, soil surface age was estimated using a variety of methods (Table 3-2). On the particularly young landforms (e.g., overwash zones, less than 60 years old), aerial photographs dating back to 1952 were compared to assess surface stability and estimate the age of soil surfaces. The date of the overwash event is a “time zero” for the soil developing in the uppermost portion of the profile. The photographs were used to constrain the time of the disturbance. The age assigned to the young (less than

Table 3-2. Summary of estimations of soil age for the ten study sites at Assateague Island National Seashore, MD, USA. Age estimations were made using comparisons of historical aerial photography, Optically Stimulated Luminescence (OSL) dating, and Accelerator Mass Spectrometry (AMS) radiocarbon dating.

Transect	Position	Dating Method[†]	Horizon[‡]	Depth[§]	Age[¶]	Remarks
				cm	years	
OW4	High	Aerial photographs, Personal observations	na	na	<1	Washover fan formed between October 1991 and May 1997 photographs, and expanded further by March 1999 photograph Deposition following Hurricane Irene, August 2011 Deposition following Hurricane Sandy, October 2012 Soil description made in March 2012
	Mid	Aerial photographs, Personal observations	na	na	13±1	Washover fan formed between October 1991 and May 1997 photographs, and expanded further by March 1999 photograph Deposition following Hurricane Irene, August 2011 Deposition following Hurricane Sandy, October 2012 Soil description made in August 2011
	Low	Aerial photographs, Personal observations	na	na	13±1	Washover fan formed between October 1991 and May 1997 photographs, and expanded further by March 1999 photograph Deposition following Hurricane Sandy, October 2012 Soil description made in June 2011
OW1	All	Aerial photographs, Personal observations	na	na	13±1	Washover fan formed between October 1991 and May 1997 photographs, and expanded further by March 1999 photograph Deposition following Hurricane Sandy, October 2012 Soil description made in June 2011 (Mid and Low) and February 2012 (High)

Transect	Position	Dating Method[†]	Horizon[‡]	Depth[§]	Age[¶]	Remarks
				cm	years	
OW2	High	Aerial photographs	na	na	43±3	Appears to be a broad, relatively level, unvegetated barrier flat in aerial photograph from 1952, dunes are visible in 1966 photograph, but the OW2 dune is not visible until 1972 photograph
	High	OSL	2C3	53	167±33	
OW3	High	Aerial photographs	na	na	52±7	Appears to be a broad, relatively level, unvegetated barrier flat in aerial photograph from 1952, OW3 dune is present in 1966 photograph
	High	OSL	Bw3	53	148±23	
BC1	All	Aerial photographs	na	na	nd	Unvegetated in 1952, 1966, 1982, and 1983 photographs Wet depressional area not apparent in 1983, but visible in 1991
	High	OSL	C2	53	101±23	
BC2	All	Aerial photographs	na	na	nd	Unvegetated in 1952 and 1966 photographs Wet depressional area not apparent in 1966, but visible in 1972
	High	OSL	Bw2	48	148±27	
	High	Radiocarbon	2Cg/Ab	77-123	760±30	organic sediment
	High	Radiocarbon	3Aseb	198-214	880±30	organic sediment
	Mid	Radiocarbon	3Aseb2	174-186	200±30	peat

Transect	Position	Dating Method[†]	Horizon[‡]	Depth[§]	Age[¶]	Remarks
				cm	years	
BC3	All	Aerial photographs, Personal observations	na	na	nd	Distinct washover fan in 1952 and 1966 photographs. In later photographs it appears to periodically flood, but less evidence of overwash deposition Flooding and ponding following Hurricanes Irene (August 2011) and Sandy (October 2012), but no evidence of sedimentary deposition
	High	OSL	Cg	53	120±20	
	Mid	Radiocarbon	Ab/Cg	76-87	1260±30	organic sediment
	Mid	Radiocarbon	2Aseb	235-240	1830±30	organic sediment
BC4	All	Aerial photographs	na	na	nd	Small inlet is located along the transect in the 1952 photograph, but not visible in later photographs Mixed vegetation in all photographs, but extent and proportion of shrub and tree coverage fluctuates between pictures
	Mid	OSL	C	37	144±20	
	Mid	Radiocarbon	ACb	45-71	510±30	organic sediment
BC5	All	Aerial photographs	na	na	nd	Trees visible in 1952 photograph, cover becomes denser in later photographs
	High	OSL	Bw1	53	190±37	
	High	Radiocarbon	2Ab1	198-216	590±30	organic sediment
	Mid	Radiocarbon	2Ab2	131-136	140±30	peat

Transect	Position	Dating Method[†]	Horizon[‡]	Depth[§]	Age[¶]	Remarks
				cm	years	
BC6	All	Aerial photographs	na	na	nd	forested in 1952 photograph and succeeding photographs
	High	OSL	Cse1	50	228±37	
	High	Radiocarbon	2Aseb	138-157	650±30	organic sediment
	High	Radiocarbon	2Oase	157-174	240±30	peat

[†] Aerial photographs of Assateague Island National Seashore were taken in June 1952, September 1966, April 1972, 1982, January 1983, October 1991, May 1997, March 1999, October 2003, March-April 2004, June-July 2005, August 2007, February-April 2008, July 2009, November 2009, June 2011, August 2011 (post-Hurricane Irene), and October 2012 (post-Hurricane Sandy). Optically Stimulated Luminescence (OSL) dating was performed by the University of Georgia Luminescence Laboratory, Athens, GA. Radiocarbon determinations were made by Beta Analytic Inc., Miami, FL using Accelerator Mass Spectrometry (AMS) methods. Radiocarbon determinations were either made on organic material in the bulk sample (organic sediment) or on distinct organic fragments (peat) as indicated under Remarks.

[‡] na = not applicable

[§] na = not applicable

[¶] nd = not determined

60 years) overwash deposits was the midpoint between the most recent photograph showing deposition and the photograph prior to the disturbance. Error assigned to each of these age estimates is the difference between the midpoint and the date of the photographs (greater error is occurs when there is a greater interval of time between photographs). The aerial photographs at the older sites also gave suggestions of changes in landform and vegetation over the past 60 years.

Distinct depositional events can be identified by the presence of buried surface horizons with darker colors and increases in organic matter. Additionally, changes in texture (which ranged from coarse to fine sands throughout most soil profiles) and/or the presence or absence of gravels and shells can be used to identify distinct depositional events and mode of deposition (Davis Jr. et al., 2003; Leatherman, 1985).

In many of the soil profiles, buried surfaces rich in organic matter (Oa and Ab horizons) were described. It appears that at one time these horizons were at the surface for a significant period of time, accumulated organic matter, and then were rapidly buried. Where possible, buried surfaces were sampled and dated using radiocarbon techniques. Radiocarbon determinations were made by Beta Analytic Inc., Miami, FL using Accelerator Mass Spectrometry (AMS) methods. The radiocarbon determinations were either made on organic matter in the bulk soil sediment or on distinct plant fragments. The age of the buried organic materials can give an estimate of the time of burial and suggest a maximum age of the soil forming in the overlying deposit. However, incorporation of younger organic material, through translocation, bioturbation, or disturbance, can complicate age estimates.

Additionally, the age of the organic matter prior to burial is not accounted for in the determination. Error assigned to each age estimate represents potential errors introduced by the analytical methods, and do not account for errors introduced by sample heterogeneity or how accurately the age of the sample represents the actual time of sample burial.

In some cases, sufficient time has not elapsed between depositional events to allow for the development of organic-rich horizons and distinct buried surfaces cannot be identified. This makes it difficult to determine if the age estimated for the buried organic-rich horizon is reflective of the age of the soil forming at the surface. Multiple depositional events could have occurred between the burial of the surface and the deposit of the current surface, making the soil forming at the current surface much younger than the age indicated by the buried organic rich surface. Where organic-rich buried surfaces are not present, insufficient, or would not be representative of the age of the overlying soil, Optically Stimulated Luminescence (OSL) dating has been used to estimate the age of relatively young, coastal deposits (Ballarini et al., 2003; Madsen and Murray, 2009). OSL dating estimates the time since a quartz or feldspar grain has been exposed to sunlight or heat. Therefore it can be used to determine the time since a mineral grain was buried by the formation or alteration of a sedimentary environment. Detailed reviews of luminescence dating principles and OSL dating methods are provided by Lian and Roberts (2006) and Madsen and Murray (2009). Samples were collected from a depth of approximately 50 cm from the high or mid position at relatively stable transects (older than 60 years, based on geomorphology and aerial photography). In order to collect the sample, a hole was dug to approximately 60 cm and a PVC tube (diameter 7.5 cm, length 10 cm) was hammered into the internal profile face (50-55 cm depth), capped, and sealed. Tubes were sent to the University of Georgia Luminescence Laboratory, Athens, GA for preparation and analysis. By collecting samples at 50 cm we assumed that minor surface disturbances or bioturbation would not have caused exposure of the sample since the most recent deposition. We are also assuming that samples collected at 50 cm were deposited at the same time as the current soil surface, and that the surface has remained sufficiently stable for soil development in the time since deposition. Error assigned to OSL dates is reflective of error introduced by analytical methods and do not reflect the suitability of the sample to provide and accurate estimate of the current soil surface age.

3.3.5 Soil Development Index

In an attempt to quantify changes in soil morphology and pedogenesis, simplified versions of the Soil Development Index (SDI) (Harden, 1982) were calculated, focusing on melanization and rubification. Calculations were made using field measurements of soil color (determined using a Munsell Soil Color Book) and digital measurements (made with a colorimeter). Field measurements were made on moist soil samples and value and chroma were estimated to half units. Digital measurements were made on remoistened sieved and homogenized soil samples. Hue, value, and chroma were measured a tenth of a unit.

Melanization is the darkening of the soil matrix (decrease in value) relative to the parent material. Melanization is usually the result of an increase in organic matter content. For each horizon, melanization was quantified using the equation:

$$\text{Melanization} = \left[\frac{(V_{pm} - V_h)}{(V_{pm} - V_h)_{max}}\right] \qquad [1]$$

where V_{pm} is color value of the parent material, V_h is the color value of the horizon, and $(V_{pm} - V_h)_{max}$ is the maximum change in value observed across all horizons and profiles within the overall study area. The change in value was divided by the maximum observed change in order to normalize the values so that the two properties (melanization and rubification) could be evaluated on similar scales (Harden, 1982). An increase in the melanization value indicates a decrease in value or darkening relative to the parent material (field measured value = 5, digitally measured value = 5.1).

Rubification is the reddening of hue and brightening (increase) in chroma associated with the accumulation of iron (hydro)oxides and organic matter. This typically occurs in the subsoil with the formation and development of a B horizon. In order to compare hues, the reported hues were converted to a numerical format. For example, 7.5YR = 7.5, 10YR = 10.0, 2.5Y = 12.5, etc. Rubification was calculated for each horizon using the equation:

$$\text{Rubification} = \left(\frac{\left(\frac{H_{pm} - H_h}{2.5}\right)}{\left(\frac{H_{pm} - H_h}{2.5}\right)_{max}}\right) + \left(\frac{(C_h - C_{pm})}{(C_h - C_{pm})_{max}}\right) \qquad [2]$$

where H_{pm} is the hue of the parent material, H_h is the hue of the horizon, $\left(\frac{H_{pm} - H_h}{2.5}\right)_{max}$ is the maximum change in hue observed across all horizons and profiles within the overall study area, C_h is the chroma of the horizon, C_{pm} is the chroma of the parent material, and $(C_h - C_{pm})_{max}$ is the maximum change in chroma observed across all horizons and pedons within the overall study area. Again, the change in hue and chroma for the horizon was divided by the maximum observed change in order to normalize the values, ensuring that rubification and melanization values were on similar scales (Harden, 1982). The change in hue was divided by 2.5 so that one unit of change in hue would be equivalent to one page in the Munsell Color Book. A larger rubification value indicates a redder hue and brighter chroma relative to the parent material (field measured hue = 2.5Y, chroma = 2; digitally measured hue = 0.5Y, chroma = 1.8) in the soil matrix.

The properties (melanization and rubification) can be analyzed independently or together as a SDI. For each of the properties, the value calculated for each horizon (Eq. 1 and 2) was multiplied by horizon thickness to give the horizon index. Horizon indices were summed for the profile and divided by the total profile thickness to give the profile index, which is essentially a weighted average of the property change over the depth of the profile. To calculate the SDI, horizon melanization and rubification indices (Eq. 1 and 2) are added together and then multiplied by horizon thickness to give a horizon index. The horizon indices are summed for each profile and divided by the total profile thickness to give the SDI.

Organic horizons were not included in calculations of the SDI or individual properties since they are not formed from the same parent material as the mineral soil. The change in color of an organic horizon relative to the mineral parent material would not have significance in quantifying melanization or rubification processes.

In this study, the soil profile was considered to be the soil surface to a recognizable buried surface (Ab). The SDI was used to quantify rates of soil change, so buried soils were excluded from the calculations, since they represent previous periods of pedogenesis. Greater index values represent more advanced soil development. Harden (1982) included a number of other morphological properties in the Soil Development Index, including texture, percent clay, structure, and consistence. These properties were not included in our index since they did not change over the course of this chronosequence.

3.4 RESULTS AND DISCUSSION

3.4.1 Landform Characteristic and Ages

The ten transects, located in the barrier core and overwash areas, were grouped by landform, using the terminology of the Natural Resource Conservation Service (NRCS) Geomorphic Description System (Schoeneberger and Wysocki, 2012). Landforms included washover fan, back-barrier flat, barrier flat, and dune field (Fig. 3-1b and Table 3-1). The mode of deposition and formation of the landforms was reflected in the nature of the sediments in the soil profile (Table 3-3). Changes in the sand size fractionation, presence/absence of shell fragments and gravels, and the nature of the buried surfaces provide evidence of lithologic discontinuities and landform development over time.

Transects OW4 and OW1 were both located on active washover fans. During large storm events, storm surges can breach the primary dune line transporting and depositing sediment over the island. The size and extent of the fan as well as the

Table 3-3. General characteristics and distinguishing features of landforms and soils at Assateague Island National Seashore, MD, USA.

Landform	Age of Surface[†]	Mode of Deposition and Characteristics of Sediments	Characteristics of Buried Surfaces
	years		
Overwash Fan	0-20	Overwash: Textures range from coarse to fine sands; 0-12% gravels and/or shells	Mineral horizons with sand textures (Ab horizons) Organic C: 5-10 g kg^{-1} Often several buried surfaces within a profile Evidence of distinct depositional events based on changes in sand fractionation and presence or absence of gravels and shells
Back-Barrier Flat	40-150	Upper Unit, Aeolian: Textures are sands; 0% gravels and/or shells Lower Unit, Overwash: Textures range from coarse to fine sands; 0-8% gravels and/or shells	No distinct buried surface horizons Evidence of lithologic discontinuities and distinct depositional events based on changes in sand fractionation and presence/absence of gravels and shells
Barrier Flat	100-150	Overwash / possible Aeolian reworking: Textures range from coarse to fine sands; 0-2% gravels and/or shells	Some evidence of buried surface horizons based on slight increases in organic carbon and darker colors
Dune Field	100-230	Upper Unit(s), Aeolian: Textures range from sand to fine sand; 0% gravels and/or shells Lower Unit, Overwash / Sedimentation: Textures range from sand to clay loam and silty clay loam	Mineral (Ab) and/or organic horizons (Oa) Coarse-loamy to fine-loamy textures containing 30-50% plant fragments Organic Carbon: 30-190 g kg^{-1} Generally occurring 1-2 m below soil surface

[†] Ages of soil surface determined by comparisons of historical aerial photos of Assateague Island (sites younger than 60 years) or by Optically Stimulated Luminescence (OSL) dating techniques.

frequency of depositional events are controlled by climatic conditions and island geomorphology and topography (Kochel and Wampfler, 1989; Morton and Sallenger, 2003). Kochel and Wampfler (1989) estimated a long term average accretion rate of 10-15 cm per year on Assateague Island washover fans, resulting from an average of four overwash producing storms per year. Based on our comparison of historical aerial photography of the washover fans included in this study, large, disruptive depositional events occurred on the order of every 10-15 years at these two sites (Table 3-2). Smaller events likely occur more frequently, but may not greatly impact these sites, or the magnitude of the deposition was not large enough to greatly disturb the vegetation detectable in the aerial photographs. However, during the course of this study, two large depositions of new sediment (5-30 cm each) occurred on OW4 as a result of Hurricane Irene (August 28, 2011) and Hurricane Sandy (October 29, 2012) (Fig. 3-2). The OW1 transect was not disturbed during Hurricane Irene, but received 5-10 cm of sediment during Hurricane Sandy. Vegetation patterns in the aerial photographs suggest that prior to Hurricane Irene, sediment was deposited on both fans between 1997 and 1999. Since the topographic high point in the OW4 transect was described after Hurricane Irene, but before Hurricane Sandy, the age of this site was assumed to be less than 1 year. The mid and low points of OW4 and all of the points in the OW1 transect were described prior to Hurricanes Irene and Sandy, so these surfaces were estimated to have a maximum age of 13±1 years.

Distinct depositional events could be identified in the soil profile by changes in the proportion of sand fractions, and in some cases, by thin buried A horizons.

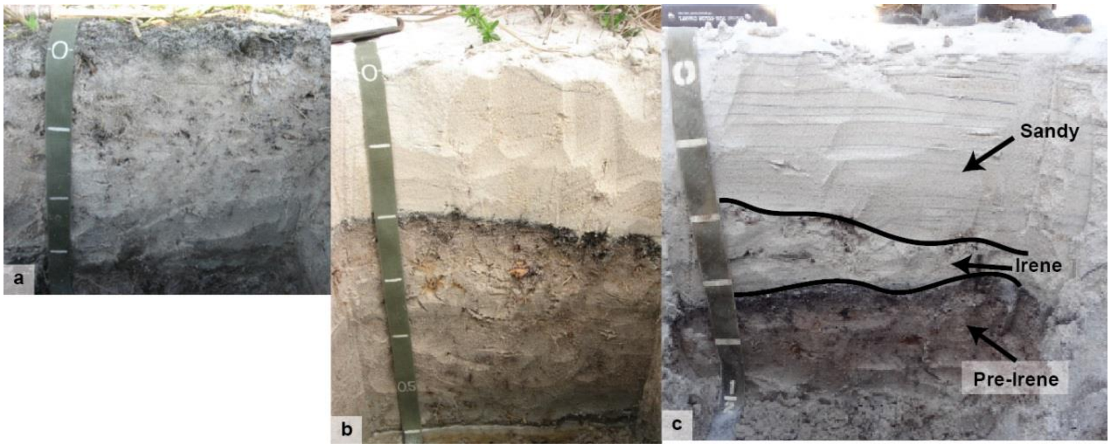

Fig. 3-2. Soil profile of site OW4H at Assateague Island National Seashore, MD, USA. (a) August 2011, prior to Hurricane Irene, (b) September 2011, after Hurricane Irene, (c) November 2012, after Hurricane Sandy. Deposits from each event are labeled accordingly, note that some of the Hurricane Irene deposits appear to have been eroded prior to, or during, Hurricane Sandy.

Sediments ranged in textural class, and some contained shell fragments and/or gravels, reflecting deposition by overwash (Table 3-3).

Vegetation on these transects was relatively sparse (< 50%) and dominated by salt-tolerant, herbaceous species characteristic of a dunegrass community (Hill, 1986). Dominant species included *Andropogon virginicus* L., *Baccharis halimifolia* L., *Euthamia caroliniana* (L.) Green ex Porter & Britton, *Hypericum gentianoides* (L.) Britton, Sterns & Poggenb., *Juncus scirpoides* Lam., *J. dichotomus* Elliott, *Panicum amarum* Elliott, *P. virgatum* L., *Phragmites australis* (Cav.) Trin. Ex Steud., and *Solidago sempervirens* L. Frequent disturbance, salinity (through salt spray and overwash), and low fertility levels limit the establishment of more diverse plant communities (Ehrenfeld, 1990).

The washover fans (OW1 and OW4) in this study were both located on the seaward side of a set of relict inlets. This set of historical inlets, called the Fox Hill Levels, was sporadically breached and overwashed in the late 1800's (McBride, 1999). The landward side of this relict inlet, described as a back-barrier flat, is relatively level and formed as the inlet was filled by sedimentation. This area is more stable than the active washover fans and does not regularly receive overwash sedimentation. The OW2 and OW3 transects were located on isolated, aeolian sand masses, or wash-around mounds, on the back-barrier flat. These features are aeolian sand accumulations (dunes) that since forming, have been eroded or reworked into circular or ovate mounds on the surface of overwash flats and relict inlets that are near the mean high water elevation (Hayden et al., 1995; Krantz, 2010). The soils at the high positions of these transects were formed in aeolian sand overlying overwash deposits of the relatively level relict inlet surface. At the high positions, the upper portion of the profile was dominated by sands and did not contain shells or gravels. A lithologic discontinuity was observed within 35-80 cm of the soil surface, at a depth approximately equal to the difference in relief between the high and the mid and low topographic positions. Below this discontinuity and throughout the profiles of the mid and low positions, the sediments were more reflective of overwash processes (and the sedimentation of a former inlet) (Leatherman, 1985). Textures ranged from coarse to fine sands and contained up to 8% gravels and shells (Table 3-3).

The surface ages of the dunes (high topographic positions), or washaround mounds, were estimated using historical aerial photography. In aerial photographs from 1952 there were no washarounds and little vegetation. The relict inlet appeared as a broad barrier flat. In the aerial photograph from 1966 there were washarounds (or dunes) present and these landforms grew and shifted somewhat between the 1966, 1972, and 1982 photographs, after which they appeared mostly stable. Based on the appearance of the dunes in the aerial photographs, the dune at OW2 was estimated to have a surface age of 43±3 years and the dune at the OW3 transect was estimated to have a surface age of 52±7 years (Table 3-2). The OSL dates collected from a depth of 53 cm at the high positions of OW2 and OW3 estimated soil ages of 167±33 and 148±23 years, respectively. The depths at which the OSL samples were collected were just below (at OW2H) or just above (at OW3H) the lithologic discontinuity in the soil profiles of the high positions. The OSL ages were determined from samples of the overwash sediments, and were probably a better indicator of the age of the mid and low surfaces, which are the result of sedimentation of the inlet, and not the aeolian dune forming processes that created the younger, high topographic positions. The OSL ages measured at these sites likely reflected the overwash and sedimentation of the inlet, which occurred after the inlet breaching and overwash events in the late 1800s (McBride, 1999).

Within the OW2 and OW3 transects there was a shift in vegetation, reflecting the proximity of the water table to the surface. Vegetation at the high topographic positions was sparse (20-40%) and characteristic of the *Hudsonia* Dunes Community (Hill, 1986). Dominant species included *Ammophila breviligulata* Fernald, *Eupatorium hyssopifolium* L., *E. caroliniana* (L.) Green ex Porter & Britton, *Hudsonia tomentosa* Nutt., *Panicum virgatum* L., and *Rubus* L. Vegetation at the lower positions was much denser and exhibited greater diversity of species. The dominant plant species at these sites, *Baccharis halimifolia* L., *Distichlis spicata* (L.) Greene, *Fimbristylis caroliniana* (Lam.) Fernald, *Fimbristylis castanea* (Michx.) Vahl, *Iva frutescens* L., *Phragmites australis* (Cav.) Trin. Ex Steud., *Schoenoplectus americanus* (Pers.) Volkart ex Schinz & R. Keller, *Setaria parviflora* (Poir.) Kerguélen, and *Spartina patens* (Aiton) Muhl., are characteristic of the Transitional Fresh Marsh Community (Hill, 1986). The plant community at the mid position was similar to the low, but with a shift towards less salt-tolerant plants and fewer obligate wetland species. Dominant species included *Andropogon glomeratus* (Walter) Britton, Sterns, & Poggenb., *A. virginicus* L., *Eupatorium capillifolium* (Lam.), *E. hyssopifolium* L., *Dichanthelium acuminatum* (Sw.) Gould & C.A. Clark var. *acuminatum*, *Juncus dichotomus* Elliott, *J. scirpoides* Lam., and *Panicum virgatum* L.

The remaining six transects were located in the barrier core, located behind the foredunes and extending to the marshes on the landward side of the island. The barrier core is made up of barrier flats and dune fields. These dunes and flats were once subjected to aeolian and/or overwash driven erosion and deposition, however, as a result of coastal progradation and the formation of new dunes, are now relatively shielded from these processes. The relative stability allows for the development of grassland, shrub thicket, and woodland and forest vegetation communities (Jungerius, 2008; Leatherman, 1979a; Morton et al., 2007).

The BC3 and BC4 transects were located on barrier flats, which are relatively flat, low areas formed on overwash sediments and/or the remnants of migrating dunes. Soil textures ranged from coarse to fine sands, with some horizons containing 1-2% gravels and shell fragments. Distinct changes in sand fractionation through the profile suggested a predominance of overwash processes in the formation of the barrier flats (Table 3-3).

Despite being non-tidal, the vegetation of the BC3 transect was characteristic of a Salt Marsh Community (Hill, 1986). Predominantly composed of *Spartina patens* (Aiton) Muhl., vegetation coverage was near 100% at the low position, but only 70% at the high. At the low position, the composition of grasses was slightly more mixed, with *Echinochloa walteri* (Pursh) A. Heller, *Schoenoplectus americanus* (Pers.) Volkart ex Schinz, and *Setaria parviflora* (Poir.) Kerguélen accounting for slightly less than half the vegetation coverage. These species are all obligate or facultative wetland species according to the US Army Corps of Engineers' National Wetland Plant List (Lichvar et al., 2014). Though predominantly composed of *Spartina patens*

(Aiton) Muhl., the high position also had a few small *Diospyros virginiana* L., *Morella pensylvanica* (Mirb.) Kartesz, and *Vaccinium corymbosum* L. plants. These shrub species are less tolerant of wetter conditions, which is probably why they were not present at the mid or low positions. The decrease in plant cover at the high sites is likely due to the limited plant available water and drier conditions occurring with a deeper water table in a sandy soil.

The vegetation community of the BC4 transect was best described by the Shrub Succession Community of Hill (1986). At the high position, dominant species were mostly herbaceous grasses and vegetation coverage was about 60%. Dominant species were mostly facultative or facultative upland plants, including *Andropogon virginicus* L., *Dichanthelium acuminatum* (Sw.) Gould & C.A. Clark var. *acuminatum*, *Eupatorium hyssopifolium* L., *Panicum amarum* Elliott, and *P. virgatum* L., *Schizachyrium scoparium* (Michx.) Nash, and *Triplasis purpurea* (Walter) Chapm. Moving to wetter positions, plant cover increased to 100% and species diversity increased as well. In addition to the plants observed at the high position, there were also a number of facultative wetland and obligate wetland species, including *Chasmanthium laxum* (L.) Yates, *Dichanthelium scabriusculum* (Elliott) Gould & C.A. Clark, *Juncus dichotomus* Elliott, *J. scirpoides* Lam., *Leersia virginica* Willd., and *Mikania scandens* (L.) Willd. There was a higher proportion of vine, shrub, and tree species in the mid and low positions, including *Baccharis halimifolia* L., *Morella cerifera* (L.) Small, *Pinus taeda* L., *Rubus* L., *Smilax rotundafolia* L., and *Vitis rotundifolia* Michx.

Transects BC1, BC2, BC5, and BC6 were located in stabilized dune fields. The high topographic positions were located at or near the dune crests, which were moderately well to excessively drained. The low position of these transects were located in dune slacks, very poorly drained, depressional areas between dunes. The soil profiles were reflective of multiple depositional processes (Table 3-3). The upper portion of the profiles ranged from sands to fine sands, free of gravels and shells, and had textures evident of aeolian deposition and dune formation. The lower profile showed greater evidence of overwash sedimentation with the presence of some gravels and/or shells, generally less than 1%. Buried surfaces occurred at or below 1 m and were high in organic carbon (30-190 g kg^{-1}), contained fragments of plant parts, and had much finer textures, fine sandy loams to silty clay loams. These buried surfaces likely represent the old marsh surface that was buried during overwash and island migration (Oertel and Kraft, 1994).

The BC1 and BC2 transects were typical of the Shrub Succession Community, but both had a dramatic shift in species composition, vegetation coverage, and species diversity with topography. At the high positions, plant cover was relatively sparse, 20-40%, and mostly facultative or facultative upland species. Stunted *Pinus taeda* L. was the dominant species, with some *Andropogon virginicus* L., *Hudsonia tomentosa* Nutt., *Panicum virgatum* L., and *Schizachyrium scoparium* (Michx.) Nash. Plant cover at the mid and low positions was 100%. At the mid position there were some shrub species that were not present at the high or low positions, including *Baccharis halimifolia* L., *Morella cerifera* (L.) Small, *M. pensylvanica* (Mirb.) Kartesz, and *Vaccinium corymbosum* L. In addition to the grasses seen at the high position there was also *Dichanthelium acuminatum* (Sw.) Gould & C.A. Clark var. *acuminatum*, *Hydrocotyle umbellate* L., *Juncus scirpoides* Lam., and *Panicum amarum* Elliott. The low positions of BC1 and BC2 were composed of only herbaceous grasses, predominantly obligate and facultative wetland species. Dominant species included *Andropogon virginicus* L., *Dichanthelium scabriusculum*, *Mikania scandens* (L.) Willd., *Pluchea odorata* (L.) Cass., *Polygonum puncatum* Elliott, *Ptilimnium capillaceum* (Michx.), *Schoenoplectus americanus* (Pers.) Volkart ex Schinz & R. Keller, *Setaria parviflora* (Poir.) Kerguélen, and *Solidago sempervirens* L.

The BC5 and BC6 transects were both Woodland Communities, predominantly comprised of trees, shrubs, and vines (Hill, 1986). The BC5 transect was dominated by *Pinus taeda* L. and *Diospyros virginiana* L., with an increasing proportion of *Acer rubrum* L., *Amelanchier canadensis* (L.) Medik., *Ilex opaca* Aiton, *Morella cerifera* (L.) Small, and *Vaccinium corymbosum* L. in the lower parts of the transect. These species were more dominant across the entire BC6 transect. While still present, *Pinus taeda* L. and *Diospyros virginiana* L. made up a smaller proportion of the vegetation at BC6.

The ages of the surfaces in the barrier core (transects BC3, BC4, BC1, BC2, BC5, and BC6) were estimated using OSL techniques. Ages ranged from 101-228 years (Table 3-2). In addition to the OSL dates, organic sediment obtained from the buried marsh surfaces of transects in the stabilized dune fields was dated using radiocarbon dating methods. These dates suggested a much older age for the marsh surface, ranging from 140 to 880 years (Table 3-2). Radiocarbon dates obtained for soil organic matter in a bulk soil sample is more reflective of the mean residence time of organic material in the buried soil, and may substantially overestimate the time of burial (Wang et al., 1996). Radiocarbon dates of distinct wood or plant fragments gave much younger results. Since the date was obtained from a single plant, the resultant ages may have been somewhat more reflective of the actual time of burial. However, the age of the plant is unknown and could be a factor in interpreting these results.

There was likely a significant period of time between the initial burial of the marsh and the stabilization of the dunes on top, with multiple depositional events in between. Insufficient time between depositional events may have prevented substantial accumulation of organic matter, and those buried surfaces may not be readily visible in the soil profile. Additionally, reworking of the sand, by wind and/or water, may have eliminated evidence of previous organic matter accumulations. The gap in time between the marsh burial (estimated by radiocarbon methods) and stabilization of the current surface (estimated using OSL) lends further evidence to the idea of multiple modes of deposition suggested by the textural contrasts seen above the buried marsh surface. The marsh surface was buried during a large overwash event, and later reworking of the sand by wind formed the dunes seen today. These dunes are no longer active, and are protected by younger dune ridges that have formed closer to the ocean along with ongoing coastal progradation. In this study, the OSL ages were used in the development of soil chronofunctions, since they most accurately represented the age of the current surface and duration of soil development.

Changes in vegetation communities among the different landforms suggested some degree of ecological succession (Odum, 1969). As coastal progradation proceeds, washover fans and dunes become more stable, and the frequency of burial and influence of sea spray decreases, allowing for the establishment of more mature plant communities (Maun and Perumal, 1999). This transition isn’t strictly a function of time, as a number of abiotic stresses (frequency of disturbance, salinity, and nutrient availability) occur along the same directional gradient. The combination of these changes allows for the change in vegetation across the chronosequence (Maun and Perumal, 1999; Sykora et al., 2004; Tackett and Craft, 2010). As plant communities become more established, primary productivity increases along with organic inputs to the soil, which can increase nutrient availability as well as increase weathering rates (due to increased organic acids) (Jones et al., 2008; Lichter, 1998). Increased nutrient availability, particularly through the establishment of nitrogen fixing species (notably *Morella cerifera* and *M. pensylvanica*) has been shown to have dramatic effects on species composition in barrier island ecosystems, allowing for expansion of shrub thickets and forests (due to greater nitrogen availability), which reduces the cover and diversity of grass species (increased shading limits growth) (Brantley and Young, 2008). Average annual total nitrogen deposition (primary source of nitrogen in the absence of nitrogen fixing plants and microbes) on Assateague Island was 14.5 kg N $ha^{-1}yr^{-1}$ (National Atmospheric Deposition Program, 2014), whereas fixed nitrogen inputs of up to 118 kg N $ha^{-1}yr^{-1}$ from leaf litter in *Morella cerifera* shrub thickets has been documented on Hog Island, VA (Brantley and Young, 2008). Increased soil nutrient availability can increase plant biomass production, and therefore organic carbon inputs to the soil. Increased soil carbon and nitrogen availability has been shown to also increase microbial biomass (Rajaniemi and Allison, 2009). While increased nitrogen availability in soil and organic inputs (decomposition substrates) can result in higher decomposition rates, this relationship is not always straightforward, as other environmental factors can override soil and litter nutrient controls (Conn and Day, 1997).

3.4.2 Soil Morphology and Pedogenesis as a Function of Time

As expected, soil development was limited across all landforms and landscape positions. In order to segregate the effects of soil moisture, we compared soils located at similar topographic positions of each of the transects to assess soil profile development over time. Since these sandy soils have a high hydraulic conductivity and low water holding capacity, the depth to the water table changes with topography across the landscape. Due to the young age and low mafic mineral contents of the soils, redoximorphic features (e.g., organic accumulation, redox concentrations, and redox depletions) typically used to indicate drainage condition were not always present. Frequency and duration of saturation (cumulative saturation) at given depths (determined from water table data collected at each of the sites), in addition to morphological indicators of soil wetness, were used to assign soil drainage classes based on the criteria set forth by NRCS (Soil Survey Division Staff, 1993) (Table 3-1). Very poorly drained soils were ponded or saturated near the surface for most of the year. Soils had an O or A horizon at the surface and low chroma colors (< 2) occurred immediately below the surface horizon. Poorly drained soils were saturated in the upper 25 cm for most of the year. These soils generally had surface A horizons with mineral or mucky mineral textures and low chroma colors starting within the upper 30 cm of the profile. Somewhat poorly drained soils were typically not hydric, but the water table is within 50 cm of the surface for significant portions of the year. Low chroma (< 2) matrix colors typically occurred below 30 cm. The water table generally occurred deeper than 50 cm in moderately well drained soils, and rarely rose above 1.0 m in excessively drained soils. Accordingly, low chroma matrix colors occurred at much deeper depths. The presence and thickness of Oe, Oi, and A horizons in somewhat poorly, moderately well, and excessively drained soils is more a function of soil surface stability and vegetation and could not always be used as indicators of drainage class.

At the high positions, soils were somewhat poorly to excessively drained (that is, the upper horizons were essentially always aerobic). While the horizon sequence of a profile was relatively simple, there were noticeable differences in the morphology of the surface horizons across the chronosequence, namely in the formation and development of surface A horizons (thickening and darkening) and Bw horizons (Table 3-4 and Fig. 3-3).

The progressively darker colors observed in the surface horizons across the chronosequence were the result of increased organic carbon at or near the surface in older soils (Table 3-4). At the youngest sites, located on the active washover fans, organic matter accumulation was minimal. Frequent depositional events limited the establishment of vegetation, and therefore also limited the addition and accumulation of organic matter. At OW1 (Fig. 3-3a), very slight accumulations of organic

Table 3-4. Soil profile descriptions of selected soils at high (moderately well drained and excessively drained) topographic positions at Assateague Island National Seashore, MD, USA.

Site	Horizon	Depth	Texture[†]	Matrix Color	RMF[‡]	Organic Carbon	Other Features[§]
		cm				g kg^{-1}	
OW1H	CA	0-5	S	2.5Y 5/1.5		0.91	<1% OSF, 10YR 4.5/2, SC
	C1	5-31	S	2.5Y 5/2		0.57	
	C2	31-44	S	10YR 4/2		0.80	<1% gravels
	Cg	44-58	S	2.5Y 5/1.5		0.41	5% OSF, 10YR 4/2
	Ab	58-62	S	10YR 3/2		7.08	30% organic fragments <1% gravels
	C'g1	62-83	S	10YR 4/1.5		0.69	
	C'g2	83-144	S	2.5Y 4.5/1		0.16	
	C'g3	144-161	COS	2.5Y 4/0.5		0.39	12% gravels 1-2% shell fragments
	C'g4	161-183	S	2.5Y 4.5/0.5		0.19	4% gravels 1-2% shell fragments
	C'g5	183-198	S	2.5Y 4.5/0.5		0.21	
OW3H	AC	0-3	S	10YR 3.5/1.5		2.74	
	Bw1	3-12	S	10YR 4.5/2.5		0.55	
	Bw2	12-36	S	10YR 5/3		0.34	
	Bw3	36-54	S	10YR 6/3		0.22	
	Bw4	54-74	S	10YR 6/3	1-2%, 10 mm, D, F3M, 10YR 5/6	0.06	
	2Bw5	74-80	S	10YR 5/3		0.38	
	2Cg	80-123	S	10YR 5/1.5		0.30	

Site	Horizon	Depth	Texture[†]	Matrix Color	RMF[‡]	Organic Carbon	Other Features[§]
		cm				g kg^{-1}	
	2Cg/Ab	123-158	S	2.5Y 5/1		0.35	
	2C'g1	158-184	S	2.5Y 4.5/1		0.43	
	2C'g2	184-198	S	2.5Y 3.5/1		0.64	
BC3H	AC	0-6	S	10YR 3/1		5.45	
	CA	6-14	S	10YR 3.5/2	<1%, 2 mm, D, F3M, 7.5YR 4/6, RPO	2.11	
	C1	14-26	S	10YR 5/2	1%, 2 mm, D, F3M, 7.5YR 4/6, RPO	0.71	
	C2	26-50	S	2.5Y 5.5/2	5%, 10-50 mm, P, F3M, 10YR 5/6, 7.5YR 5/6, and 5YR 5/6, MAT	0.49	
	Cg	50-59	S	2.5Y 5.5/1		0.26	
	Cse1	59-73	S	2.5Y 4.5/1		0.16	1% FeS masses, 5-20 mm, N 2.5
	Cse2	73-112	S	2.5Y 5/1.5		0.81	
	Cse3	112-135	FS	2.5Y 4.5/1.5		0.58	
	Cse4	135-238	S	2.5Y 4.5/1		0.44	
	2Aseb	238-250	FS	5Y 3.5/1		1.13	
BC2H	CA	0-19	S	10YR 4.5/2		1.63	Surface Cover: <0.5 cm pine needles, variable in thickness and presence

Site	Horizon	Depth	Texture†	Matrix Color	RMF‡	Organic Carbon	Other Features§
		cm				g kg^{-1}	
	Bw1	19-29	S	2.5Y 6/3	1%, <2 mm, D, F3M, 10YR 5/6	0.26	
	Bw2	29-63	S	10YR 5.5/2.5	3%, 5-20 mm, D, F3M, 10YR 3/4 and 10YR 3/6, RPO and MAT	0.16	2 mm bands of FS, 10YR 2/1
	Cg	63-77	S	2.5Y 4.5/1.5	3%, 5-20 mm, D, F3M, 10YR 3/4	0.15	
	2Cg/Ab	77-123	FS	10YR 4/1.5		2.04	A part: 2-10 mm thick, discontinuous, 2.5Y 3/1, MK S
	2Cse1	123-159	S	2.5Y 4/1		0.63	OSF, 10YR 3.5/1.5
	2Cse2	159-185	COS	2.5Y 4.5/1		0.19	<1% gravels
	2ACseb	185-198	S	2.5Y 3/1		2.20	<5% organic fragments, 10YR 2/2
	3Aseb	198-214	L	2.5Y 3/0.5		39.21	30% organic fragments, 10YR 2/2 and 7.5YR 2.5/3
	3Oa	214-220	MUCK	10YR 2/2		189.50	
BC5H	Oi	0-2.5	SPM	7.5YR 2.5/2		485.75	Surface cover: 2 cm pine needles and pine cones
	Oe	2.5-6	MPM	60% 5YR 2.5/1 40% 2.5YR 2.5/2		245.80	
	AE	6-19	FS	10YR 4/2		3.10	
	A	19-30	FS	7.5YR 3/1.5		2.11	
	Bw1	30-77	S	10YR 5.5/3		0.21	
	Bw2	77-98	S	10YR 6/2.5		0.07	

Site	Horizon	Depth	Texture[†]	Matrix Color	RMF[‡]	Organic Carbon	Other Features[§]
		cm				g kg^{-1}	
	Bw3	98-145	FS	10YR 4/2.5		0.29	
	C	145-171	S	2.5Y 5/2		0.10	
	Cse	171-198	FS	2.5Y 4/0.5		0.16	
	2Ab1	198-216	FSL	5Y 3/1		45.66	35% organic fragments, 10YR 3/2
	2Ab2	216-232	MK LFS	10YR 2/1		67.12	40% organic fragments
	3Cg	232-268	FS	10YR 4/1.5		1.34	

[†] Texture classes: COS = coarse sand, S = sand, FS = fine sand, LFS = loamy fine sand, FSL = fine sandy loam, L = loam, SICL = silty clay loam, MK = mucky, MUCK = muck, MPT = mucky peat, MPM = moderately decomposed plant material, SPM = slightly decomposed plant material

[‡] Contrast classes: F = faint, D = distinct, P = prominent; F3M = iron (Fe^{3+}) masses; MAT = in the matrix, RPO = on surfaces along root channels

[§] OSF = organic stains; SC = on surfaces along root channels

Fig. 3-3. Soil profiles of selected soils at high topographic positions at Assateague Island National Seashore, MD. (a) OW1H, surface age 13±1 years (aerial photographs), (b) OW3H, surface age 52±7 years (aerial photographs), (c) BC3H, surface age 120±20 years (OSL), (d) BC2H, surface age 148±27 years (OSL), (e) BC5H, surface age 190±37 years (OSL).

Fig. 3-3(cont.). Soil profiles of selected soils at high topographic positions at Assateague Island National Seashore, MD. (a) OW1H, surface age 13±1 years (aerial photographs), (b) OW3H, surface age 52±7 years (aerial photographs), (c) BC3H, surface age 120±20 years (OSL), (d) BC2H, surface age 148±27 years (OSL), (e) BC5H, surface age 190±37 years (OSL).

matter led to the formation of a CA horizon, with only a subtle color change relative to the parent material (typically 2.5Y 5/2) (Table 3-4). Buried surfaces (Ab horizons) described deeper in the profile suggest that with longer periods of stability, darker A horizons with greater organic matter contents had previously developed in these locations. On the more stable landforms where soils have had more time to develop, AC and A horizons with darker colors (lower Munsell value), redder hues, and increased organic matter were described (Figs. 3-3b, 3-3c and 3-3d). At the oldest sites, BC5 and BC6, sufficient organic matter accumulation at the surface led to the development of Oi and Oe horizons above thick (10-25 cm) A horizons. The thicker O and A horizons (Fig. 3-3e) at the older sites were reflective of increased carbon inputs associated with a more mature and better established vegetation community with greater biomass production, and a longer time period over which organic matter has accumulated (Jones et al., 2008; Tackett and Craft, 2010). Among the high topographic positions, organic carbon stocks increased exponentially across the chronosequence (Fig. 3-4). Soil organic carbon stocks in the youngest sites were low, but become more substantial in the older, forested soils (BC5H and BC6H). Nielsen et al. (2010) measured average carbon stocks (0-100 cm) of 13.3 kg C m^{-2} in older (approximately 3000 years) beach ridge soils of Denmark. The relatively low carbon stocks at the sites on Assateague Island (compared to the Denmark study and soils globally) likely reflect the young age, sometimes very dry conditions, and low nutrient availability in the soils. Warmer temperatures (relative to other studies) may increase organic decomposition rates, lowering organic carbon accumulation in the Assateague soils.

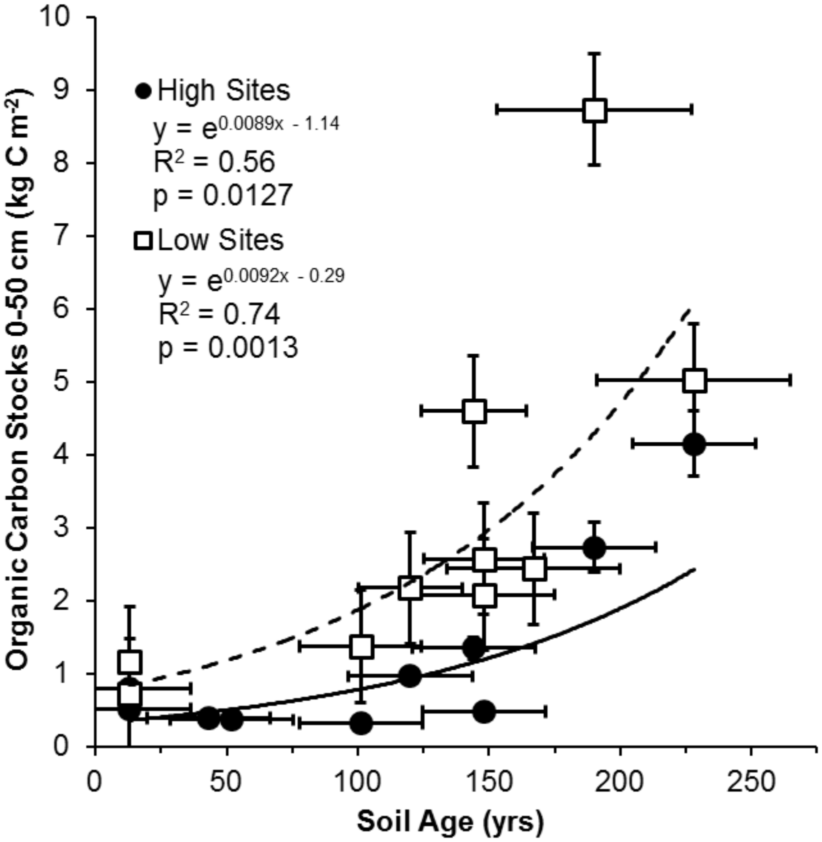

Fig. 3-4. Soil organic carbon stocks (0 to 50 cm) at high (moderately well and excessively drained) and low (poorly and very poorly drained) topographic positions from ten transects at Assateague Island National Seashore, MD, USA. Soil ages were estimated using comparisons of historical aerial photography (soils less than 60 years) and Optically Stimulated Luminescence (OSL) dating (soils over 60 years). Error associated with age estimates are shown, but are in some cases too small to be visible in the figure. Average carbon stocks of three replicate samples is shown, error bars represent the standard error of the mean.

Over the entire chronosequence, the average carbon accumulation rate at the high sites was 0.020±0.009 kg C m^{-2-}yr^{-1}. Typically, organic carbon accumulation is initially slow as vegetation becomes established. As vegetation communities grow and develop, primary productivity increases and organic carbon inputs to the soil increase, causing greater organic carbon accumulation rates (Jones et al., 2008; Odum, 1969; Tackett and Craft, 2010). Given the young age of these soils and the potential limitations for plant growth, the increase in carbon accumulation rates associated with plant community succession may not yet be apparent. On a beach ridge chronosequence in Denmark, carbon accumulation rates of 0.0485 kg C m^{-2}yr^{-1} were measured over the first 200 years of soil development, after which rates decreased to 0.0065 kg C m^{-2}yr^{-1} (Nielsen et al., 2010). Soil organic carbon tends to reach a steady state as accumulation rates slow. Work by Protz et al. (1984) on a beach ridge chronosequence in Hudson Bay, Ontario, Canada showed organic carbon increases at a linear rate until approximately 3000 years, after which organic matter remains at a steady state or decreases. Other studies have shown organic matter levels stabilize even earlier, after 2000 years, on Lake Huron shorelines in Ontario, Canada (VandenBygaart and Protz, 1995), after 400 years on Lake Michigan, MI, USA dunes (Lichter, 1998), and after only 60 years on Atlantic coastal dunes in the United Kingdom (Jones et al., 2008). Decreases in organic matter accumulation rates and stabilization of organic carbon stocks has been attributed to stabilization of organic inputs with established plant communities, increased grazing (lowering inputs), and increased decomposition rates (associated with the establishment of microbial and fungal communities) (Brantley and Young, 2008; Jones et al., 2008). Variations in the time required to reach a steady state may be due to differences in climate, vegetation, and soil parent materials or nutrient availability. Carbon stocks among the relatively dry soils in this study continue to increase across the chronosequence, and given the relatively short duration of this chronosequence, less than 250 years, stocks do not appear to have reached a steady state.

At the better drained positions (high sites) subsoil development was limited to the formation of weak Bw horizons in the older transects (Table 3-4). Bw horizons had a slightly redder hue (10YR) and brighter chroma (2-3) relative to the unweathered parent material (typically 2.5Y 5/2). There was no increase in clay or textural change due to pedogenic processes in Bw horizons. Redder hues and brighter chromas in B horizons are generally associated with an increase in iron oxide minerals (Bigham et al., 2002). However, iron oxide contents, measured as DCB extractable Fe, in the soils were very low (maximum measured value was 2.56 g kg^{-1}, mean was 0.28 g kg^{-1} for all horizons measured). Slight increases in DCB Fe content were observed in some of the subsoil horizons (Fig. 3-5), however, this relationship was not always straightforward. Relatively higher concentrations of DCB Fe corresponded with subtle increases in chroma in oxidized horizons (Bw and C horizons (Fig. 3-6a)), however there was no clear relationship between hue and DCB Fe in subsoil horizons (Fig. 3-6b). Low iron concentrations and organic carbon and iron relationships have been associated with incipient podsolization processes in siliceous sandy soils (Nielsen et al., 2010). Redder hues observed in Bw and C horizons seemed to be more closely related to organic matter content (Fig. 3-6d). Bw and C horizons with higher organic matter contents tended to have lower chromas

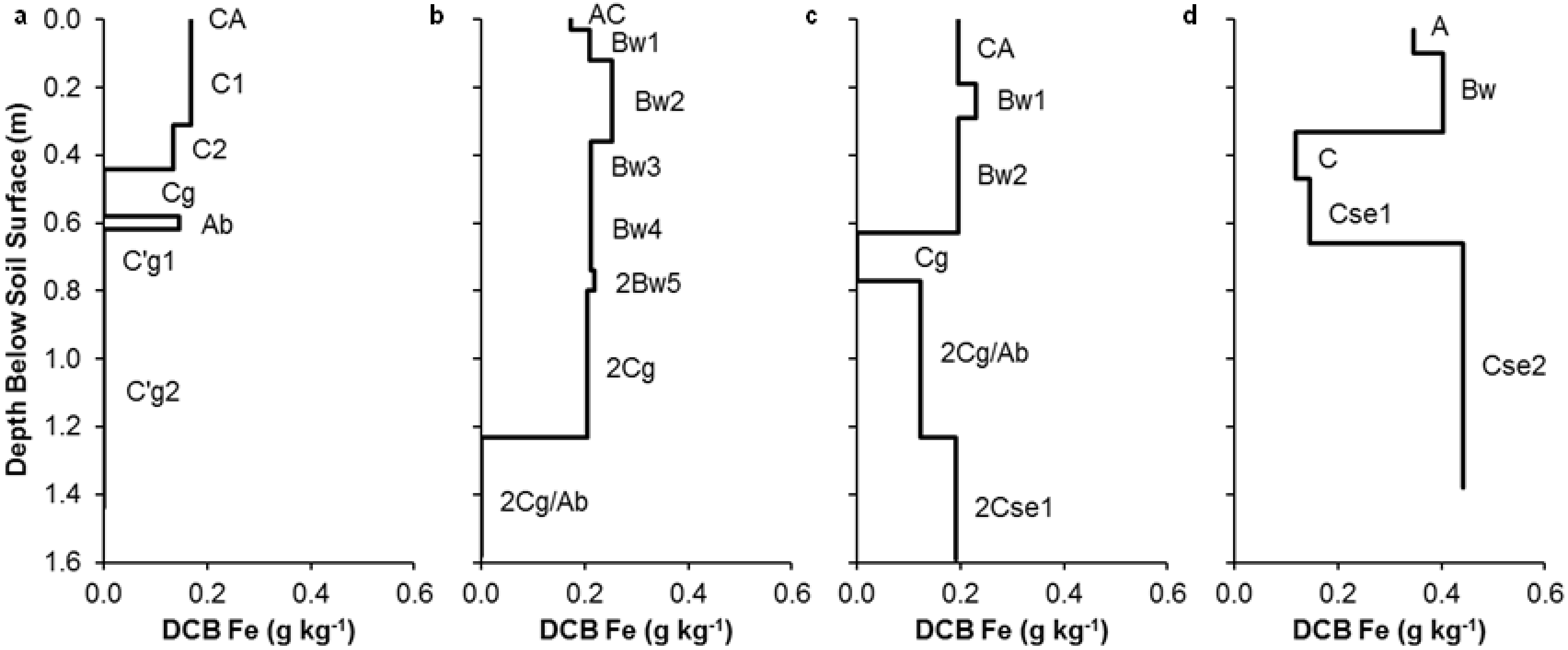

Fig. 3-5. Dithionite extractable iron (DCB Fe) content for selected soil profiles at Assateague Island National Seashore, MD, USA. (a) OW1H, surface age 13±1 years (aerial photographs), (b) OW3H, surface age 52±7 years (aerial photographs), (c) BC2H, surface age 148±27 years (OSL), (d) BC6H, surface age 228±37 years (OSL).

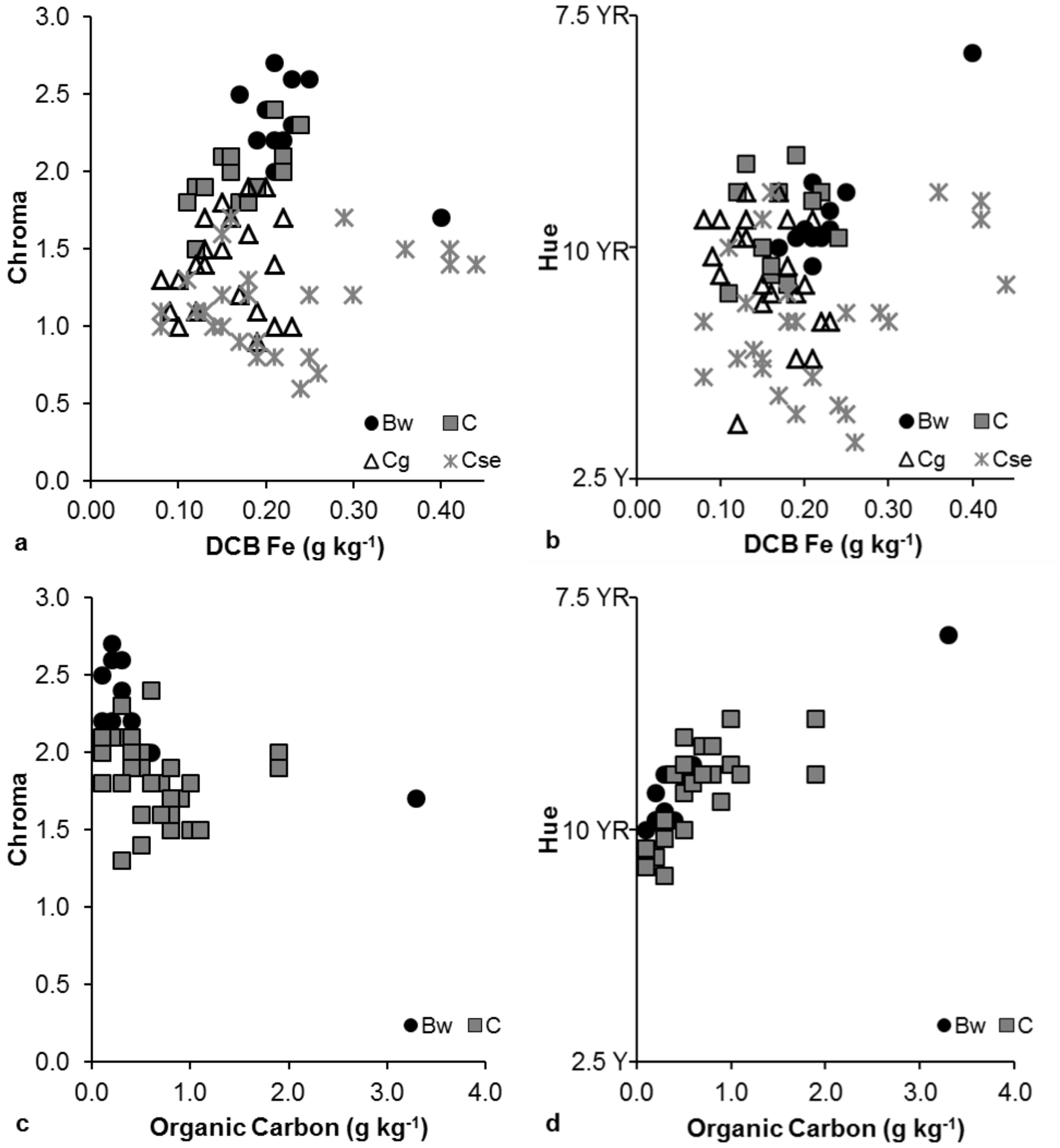

Fig. 3-6. Subsoil horizon colors, (a) chroma, and (b) hue as a function of dithionite extractable iron (DCB Fe), and (c) chroma, and (d) hue as a function of organic matter in soils at Assateague Island National Seashore, MD, USA.

(Fig. 3-6c), suggesting that the combination of redder hues and brighter chromas is the result of accumulations of both iron (hydro)oxides and organic matter.

Iron translocation can also be driven by fluctuating ground water, which may be a factor in these soils, given the proximity of the median water table to the soil surface. The Cg horizons, where saturated and reducing conditions occur for much of the year, had low Fe concentrations as soluble Fe^{2+} has been leached from the horizon. On the other hand, horizons containing sulfidic materials, designated with the suffix “se”, showed slight increases in iron (Figs. 3-5c and 3-5d). Iron in these horizons was likely not in the oxidized form (Fe^{3+}), but rather as reduced iron (Fe^{2+}) associated with iron sulfide minerals (FeS or FeS_2) (Fanning et al., 2010). Since iron (hydro)oxide minerals are not present in the reduced horizons, the chromas tend to be low (< 2), despite increases in DCB Fe concentration (particularly in Cse horizons) (Fig. 3-6a). Iron concentrations measured in Cse horizons (which contained sulfidic materials, including iron sulfide minerals) most likely did not reflect iron that had existed as Fe(III) (hydro)oxides in the soil, but rather iron that had been associated with iron sulfide minerals (as Fe^{2+}) and was oxidized after sampling and prior to analysis.

Despite these complications, there did appear to be a subtle accumulation of iron (hydro)oxides in the oxidized subsoil of the older soils. Relatively low DCB Fe contents and minimal accumulations of iron oxides in Bw horizons are attributed to the low proportion of iron bearing minerals in the parent material. Based on optical grain counts from four pedons from Assateague Island, mafic minerals generally make up 2 to 3% of minerals in the fine sand fraction (National Cooperative Soil

Survey, 2014). Similarly low mafic mineral contents (1 to 9%) have been reported for Virginia barrier island soils (Hatch and Edmonds, 1992; Peacock and Edmonds, 1992).

Given the young age of these soils, many pedogenic processes (e.g., formation and accumulation of significant amounts of clay or the development of structure) have not yet occurred. We used a simplified version of Harden’s Soil Development Index (SDI) (1982) focused on melanization (darkening associated with A/O horizon formation) and rubification (reddening associated with Bw horizon development), in an attempt to begin to quantify pedogenesis in these soils. Each of the properties evaluated (melanization and rubification) was first evaluated independently using the colors measured in the field to understand how these properties changed across the chronosequence. Among the relatively well drained topographic positions (high sites), melanization increased with soil age (Fig. 3-7a), reflecting the decrease in value (darkening) as a result of organic matter accumulation. While rubification tended to increase as a function of soil age, this relationship was not statistically significant (Fig. 3-7b). The general trend suggested that there was some degree of rubification (redder hues, brighter chromas) in the oxidized subsoils, likely due to the accumulation of iron (hydro)oxides and organic matter, however this change cannot be used as a strong indicator of soil age. We observed that surface horizons tended to have redder hues (particularly in forested sites) as the result of organic matter accumulations. The rubification index (calculated for the entire profile) likely reflected reddening due to organic matter and brighter chromas due to iron

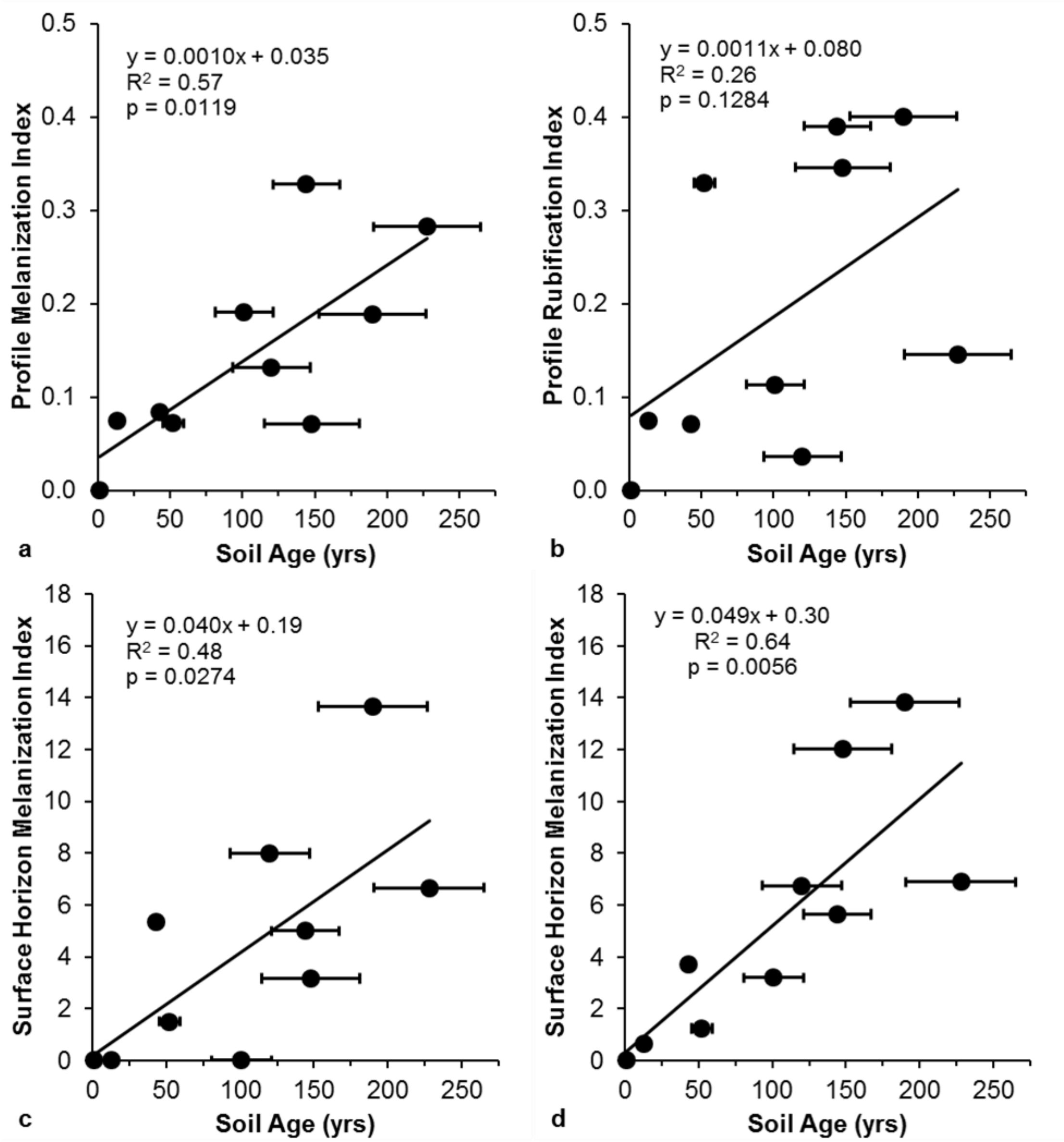

Fig. 3-7. Development of quantified soil properties in moderately well to excessively drained soils (high topographic positions) at Assateague Island National Seashore, MD, USA. (a) Profile melanization index and (b) profile rubification index calculated using the methods in the Soil Development Index (SDI) of Harden (1982). Soil colors were measured in the field using a Munsell Color Book. (c) Surface horizon melanization index calculated from soil colors measured in the field using a Munsell Color Book, and (d) surface horizon melanization index calculated from soil colors measured using a digital colorimeter. Surface horizon melanization index is calculated using surface and near-surface horizons with an accumulation of organic matter. Soil ages were estimated using comparisons of historical aerial photography (soils less than 60 years) and Optically Stimulated Luminescence (OSL) dating (soils over 60 years). Error associated with age estimates are shown, but are in some cases too small to be visible in the figure.

(hydro)oxides (Figs. 3-6a and 3-6d). Since rubification did not show a significant trend independently, we did not incorporate this component into a SDI.

In well drained locations (such as the high sites) melanization, or decreases in soil color value, was the best field indicator of soil age. Since melanization processes were occurring primarily in the surface and near surface horizons (A, AC, and CA horizons) we recalculated the index to consider changes in color value only in those horizons. In these calculations, melanization (Eq. 1) of A, AC, and/or CA horizons of the profile were multiplied by the horizon thickness, giving the horizon index value which was compared between profiles. In the case of multiple A, AC, or CA horizons near the soil surface, the horizon melanization indices were summed for the profile. In these calculations, the profile melanization index was not divided by total profile thickness, since we were not looking at color change over the whole profile depth. Including horizons thickness in the calculation allowed us to consider depth of melanization in addition to degree.

This surface horizon melanization index (includes surface and near-surface horizons with organic matter accumulations) was calculated using both the field and digitally measured soil colors. While both showed a significant relationship with age (for the high topographic positions), there was a much better fit when using the digitally measured colors (Figs. 3-7c and 3-7d). The digital measurements were made on homogenized samples, which may explain some of the differences seen between the measurement methods. Furthermore, digital measurements were made to the tenth of a unit of value, while field measurements were only made to half of a unit. The greater precision in the digital measurements likely improved the fit in the melanization trend, however the similar trends seen in the two methods suggests that that visual comparisons with the Munsell chart can also be used as a reliable indicator of relative soil development.

Comparison of the profile melanization and rubification indices of soils in this chronosequence and excessively and well drained soils formed on late-Pleistocene age dunes in southeastern MD (Condron, 1990) suggested that over a longer time period the melanization and rubification indexes follow a logarithmic curve as rates of change decrease (Fig. 3-8). These profile indices were calculated using field measured colors. Some of the soils in Condron’s study were Spodosols, and organic matter accumulation extended deep into the profile. To compare the two sites, melanization and rubification were considered over all mineral horizons within the soil as in Harden’s SDI (Harden, 1982). These metrics of soil development (melanization and rubification) likely have less use in comparing soil development beyond the initial stages of pedogenesis. Not only do these processes begin to change at a slower rate, limiting the resolution of the chronofunction, but other pedogenic processes (e.g., clay accumulation evidenced by textural changes and/or clay films, structural development, and changes in consistence) begin to take place in the soil. At that point, the morphological characteristics associated with those more dominant processes would have greater use in quantifying soil development for estimations of soil age or comparisons of soil profiles.

Older dune and beach sand soils typically show an initial increase in organic matter, followed by rubification (redder hues, brighter chromas) and the formation of

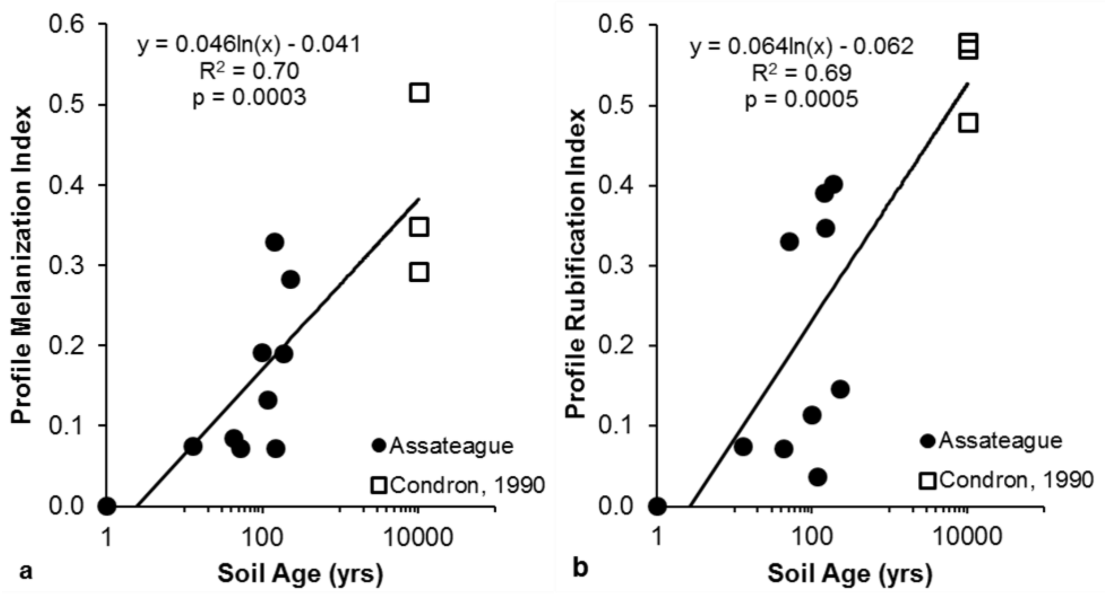

Fig. 3-8. Comparison of quantified soil properties from ten moderately well to excessively drained soils at Assateague Island National Seashore, MD, USA and three late Pleistocene age dune soils in southeastern MD described by Condron (1990), (a) profile melanization and (b) profile rubification calculated from soil colors measured in the field using a Munsell Color Book. Soil ages at Assateague sites were estimated using comparisons of historical aerial photography (soils less than 60 years) and Optically Stimulated Luminescence (OSL) dating (soils over 60 years). Age of late Pleistocene dune soils were estimated using radiocarbon dating (Condron, 1990). Due to scale, error associated with estimations of soil age could not be shown.

argillic or spodic horizons. Miles and Franzmeier (1981) described the development of clay lamellae and eventually argillic horizons across a Indiana sand dune chronosequence of soils ranging from 3500 to 20,000 years. A Lake Huron dune chronosequence described by VandenBygaart and Protz (1995) in Pinery Provincial Park, Ontario, Canada (soils ranging from 100 to 4700 years) showed Bw horizon formation within 1000 years of soil development and weak argillic horizons were described in soils older than 3800 years. In other sand dune chronosequences, spodic horizon formation is the dominant process (as opposed to clay accumulation). In a Lake Michigan beach ridge chronosequence ranging from 25 to 4150 years, incipient B horizon development was observed between 150 and 200 years, with evidence of podzolization processes within 400 years (Lichter, 1998). Similarly, a beach ridge sequence (ranging from 22 to 2965 years) in Denmark studied by Nielsen et al (2010) described slight Fe and Al accumulations in the subsoil (weak B horizon development) after 200 years. Spodosols formed within 1500 to 1700 years of soil development, with substantial ortstein cementation after 2400 to 3400 years. Studies from the coast of the Hudson Bay (soil profiles ranging from 100 to over 5000 years) show weak B horizons developing within 750 years, and spodic horizons developing after 2000 years (Protz et al., 1984). Condron (1990) described well developed spodosols in moderately well and somewhat poorly drained late Pleistocene age sand dunes in Maryland (located on the mainland near Assateague Island). However, at excessively drained sites incipient Bt horizons were present (Condron, 1990). Differences in the pedogenic processes and the rate at which they occur could be attributed to variations in climate, parent material (weatherable mineral content and particle size), and drainage class among the chronosequences.

Previous studies of older chronosequences, and our observations of the well-drained soils in the Assateague chronosequence, would suggest that given sufficient time and landform stability, barrier island soils could follow similar trends, developing weak argillic and/or spodic horizons. However differences in parent materials, climate, and soil moisture may influence their development. Previously cited sand dune and beach ridge chronosequence studies have been located in colder climates, and soils were often formed in parent materials with much higher proportions of weatherable minerals. Although the youngest of the soils studied by Protz et al. (1984) and Nielsen et al. (2010) were similar in age to soils in the Assateague chronosequence, they showed somewhat higher organic matter contents in surface horizons. Colder climates may have limited organic matter decomposition, leading to more rapid soil organic carbon accumulation relative to the Assateague soils of similar ages. The subtle color changes observed in the Assateague chronosequence were similar to those observed in previous studies, despite the much lower weatherable mineral content at Assateague. Mineral weathering was likely limited by colder temperatures in previous studies, whereas at Assateague, weathering was limited by lack of weatherable minerals in the parent material. The weathering resistant mineralogy of the Assateague soils may restrict or greatly slow weathering rates, so that the diagnostic horizons observed in other chronosequences may not form at the same rate (or ever). The weatherable mineral content of the parent material (as well as other factors) may also dictate whether clay illuviation or podzolization processes dominate in a given soil. Given the dynamic nature of the barrier islands and their landforms, it is uncertain if a given soil surface would actually remain stable long enough for argillic or spodic horizons to develop.

There were substantial differences between the trends observed in the better drained positions and those observed in the poorly drained soils, suggesting a strong water table interaction. Thin A horizons were present on the youngest sites and progressively thicker and darker A and O horizons with increased organic carbon were observed on the older soils (Table 3-5 and Fig. 3-9). Across the chronosequence, organic carbon stocks increased exponentially, suggesting the establishment of vegetation and higher rates of organic carbon input (Fig. 3-4). The average organic carbon accumulation rate across low sites of the chronosequence was 0.046±0.015 kg C $m^{-2}yr^{-1}$. This is higher than average accumulation rates measured at high sites, but more similar to the rates (0.0485 kg C $m^{-2}yr^{-1}$) measured by Nielsen et al. (2010) (discussed earlier). It is expected that accumulation rates would slow down as a steady state was reached, but it does not appear that the organic carbon levels for the poorly drained soils have reached a maximum within the 228 years of this chronosequence.

The changes in profile color (melanization and rubification) observed over time in the high positions were not observed at the low positions (Fig. 3-10). The lack of age-related trends is attributed to the interaction and dominating effect of soil moisture. Melanization generally occurs along with organic matter accumulation. However, at the low sites, the melanization index did not increase with organic

Table 3-5. Soil profile descriptions of selected soils at low (very poorly to somewhat poorly drained) topographic positions at Assateague Island National Seashore, MD, USA.

Site	Horizon	Depth	Texture[†]	Matrix Color	RMF[‡]	Organic Carbon	Other Features[§]
		cm				g kg^{-1}	
OW1L	A	0-1.5	S	10YR 2/1		35.96	30% masking of sand grains by organic matter
	CA	1.5-9	S	10YR 5.5/3		7.33	2% OSF, 10YR 2/1, SC
	C	9-20	S	10YR 5.5/2		1.12	2% OSF, 10YR 2/2, SC
	Cg	20-23	FS	2.5Y 3.5/1		1.12	
	Ab	23-26	S	10YR 2/2		8.20	
	C’g	26-29	FS	2.5Y 5.5/1		2.21	2% OSF, 10YR 4/2, SC
	Aseb	29-32	S	10YR 3/1.5		8.23	30% organic fragments
	Cse	32-71	S	2.5Y 4.5/1		0.16	H_2S odor
	C’’g1	71-131	S	2.5Y 4/1		0.24	1-2% gravels <1% shell fragments 0.5-1.0 cm bands FS, 10YR 2/1
	C’’g2	131-164	S	2.5Y 4.5/1		0.10	
	ACb	164-185	S	2.5Y 3.5/0.5		0.34	5% shell fragments
	C’’’g	185-218	S	2.5Y 4.5/1		0.25	
BC3L	A	0-1.5	MK S	10YR 3/2		95.39	
	AC	1.5-7	S	10YR 4/2		6.37	
	Cg1	7-22	S	2.5Y 5.5/1.5		0.56	1-2 cm bands FS, 2.5Y 3/1 OSF, 10YR 3.5/4
	Cg2	22-33	S	2.5Y 4/1		0.25	
	Cg3	33-101	S	2.5Y 4.5/1		0.10	
	Cse1	101-115	S	2.5Y 3/1		0.10	

Site	Horizon	Depth	Texture[†]	Matrix Color	RMF[‡]	Organic Carbon	Other Features[§]
		cm				g kg^{-1}	
	Cse2	115-182	S	2.5Y 4.5/1		0.09	
	Cse3	182-224	S	2.5Y 2.5/1		0.10	
	2Aseb	224-238	LFS	N 3		2.81	
OW3L	Oa1	0-3	MUCK	7.5YR 3/2		238.70	
	Oa2	3-6	MUCK	10YR 2.5/2		185.20	
	CA	6-14	COS	10YR 5.5/2		3.88	1-2% gravels 1-2% shell fragments
	Cg1	14-23	COS	2.5Y 5/1.5	1%, <5 mm, F3M,10YR 4/6, RPO 4%, <5 mm, F3M, 10YR 5/4	0.62	1-2% shell fragments 1% gravels
	Cg2	23-103	S	5Y 4.5/1		0.54	1% shell fragments
	Cg3	103-138	S	5Y 4/1		0.52	
	Cg4	138-174	FS	5Y 3.5/1.5		0.38	1% gravels
	Ab	174-238	LFS	5Y 3.5/0.5		3.04	
BC2L	Oa	0-2.5	MUCK	10YR 2/2		156.35	
	AC	2.5-5	FS	10YR 4/2		2.75	
	Cg1	5-18	S	2.5Y 5.5/1.5		0.98	
	Cg2	18-25	S	2.5Y 4.5/2		0.40	
	Cg3	25-39	S	2.5Y 4/2		0.61	
	2CAb	39-56	FS	10YR 3/1.5		2.26	1-2 cm bands FS, 2.5Y 3/1
	2Cg	56-92	S	2.5Y 4.5/1		0.34	
	2Cse1	92-127	COS	2.5Y 4.5/1		0.10	1% gravels
	2Cse2	127-147	COS	2.5Y 4/1		0.16	1% gravels

Site	Horizon	Depth	Texture[†]	Matrix Color	RMF[‡]	Organic Carbon	Other Features[§]
		cm				g kg^{-1}	
	3Ab1	147-164	L	5Y 3/1		63.12	Organic fragments, 10YR 3/3 OSF 10YR 2/1
	3Ab2	164-171	L	2.5Y 2.5/1		52.46	Organic fragments, 10YR 3/3 and 10YR 3/4
	3Aseb1	171-183	L	2.5Y 3/1		42.40	Organic fragments, 10YR 3/3 and 10YR 3/4
	3Aseb2	183-198	FSL	10YR 2.5/1.5		22.77	
BC5L	Oe	0-13	MPT	5YR 2.5/2		457.55	Surface cover: 0.5 cm pine needles and leaves
	A	13-20	FS	10YR 2.5/1.5		9.96	
	Cg1	20-30	FS	2.5Y 4.5/2		0.89	3-4% OSF, 7.5YR 2.5/3 and 10YR 3/1.5 H_2S odor
	Cg2	30-56	FS	2.5Y 4.5/1.5		0.59	H_2S odor
	Cg3	56-82	FS	2.5Y 4.5/1		0.26	H_2S odor
	2Ab1	82-99	MK SICL	7.5YR 2.5/2		141.70	
	2Ab2	99-109	FSL	7.5YR 2.5/1		44.57	
	3Cg	109-157	FS	10YR 4.5/1.5		1.10	
	3Cse1	157-177	FS	2.5Y 3.5/1		1.24	
	3Cse2	177-198	S	2.5Y 3.5/1		0.24	<1% gravels

[†] Texture classes: COS = coarse sand, S = sand, FS = fine sand, LFS = loamy fine sand, FSL = fine sandy loam, L = loam, SICL = silty clay loam, MK = mucky, MUCK = muck, MPT = mucky peat, MPM = moderately decomposed plant material, SPM = slightly decomposed plant material

[‡] Contrast classes: F = faint, D = distinct, P = prominent; F3M = iron (Fe^{3+}) masses; MAT = in the matrix, RPO = on surfaces along root channels

[§] OSF = organic stains; SC = on surfaces along root channels

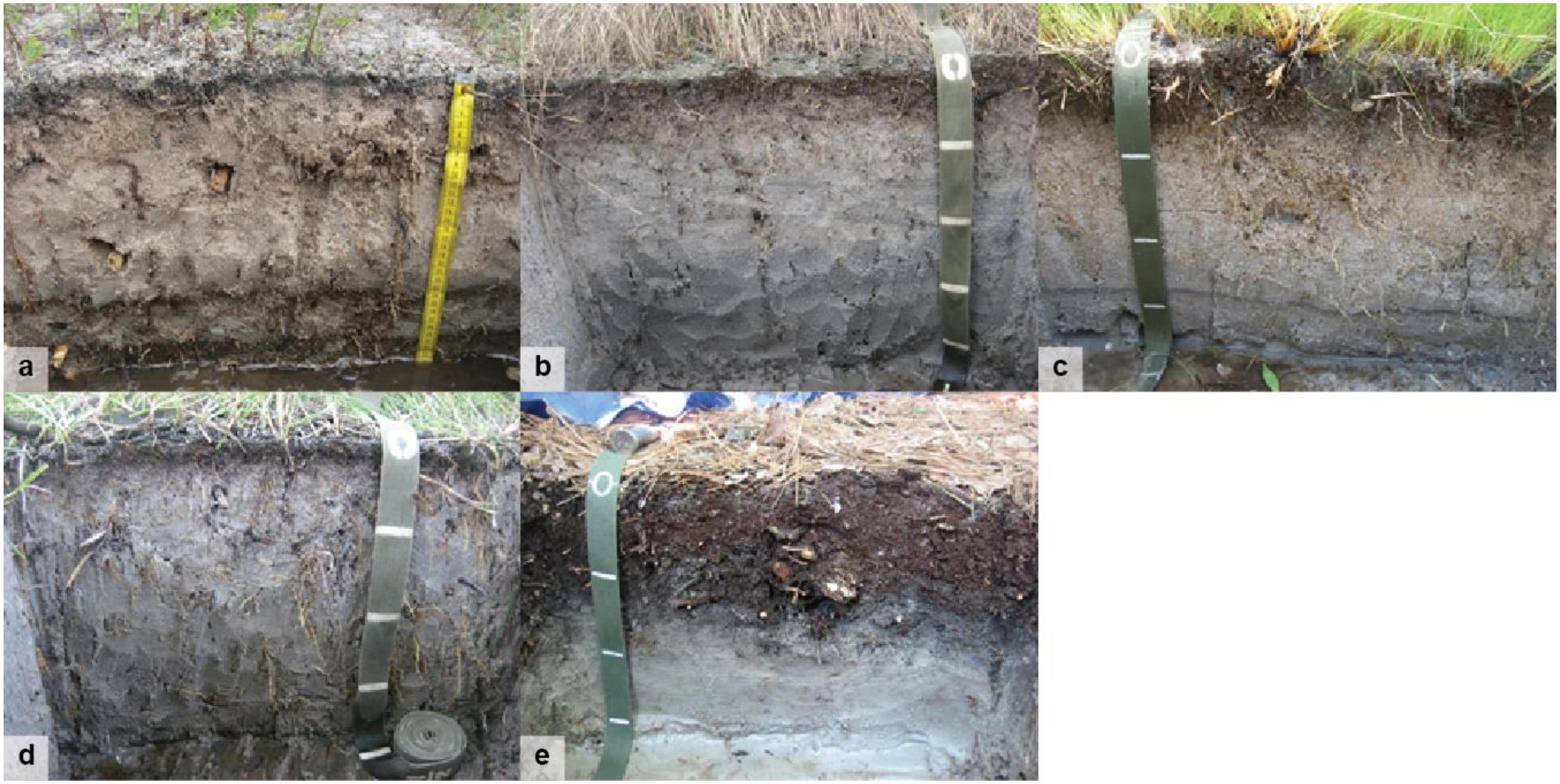

Fig. 3-9. Soil profiles of selected soils at low topographic positions at Assateague Island National Seashore, MD, USA. (a) OW1L, surface age 13±1 years (aerial photographs), (b) BC3L, surface age 120±20 years (OSL), (c) OW3L, surface age 148±23 years (OSL), (d) BC2L, surface age 148±27 years (OSL), (e) BC5L, surface age 190±37 years (OSL).

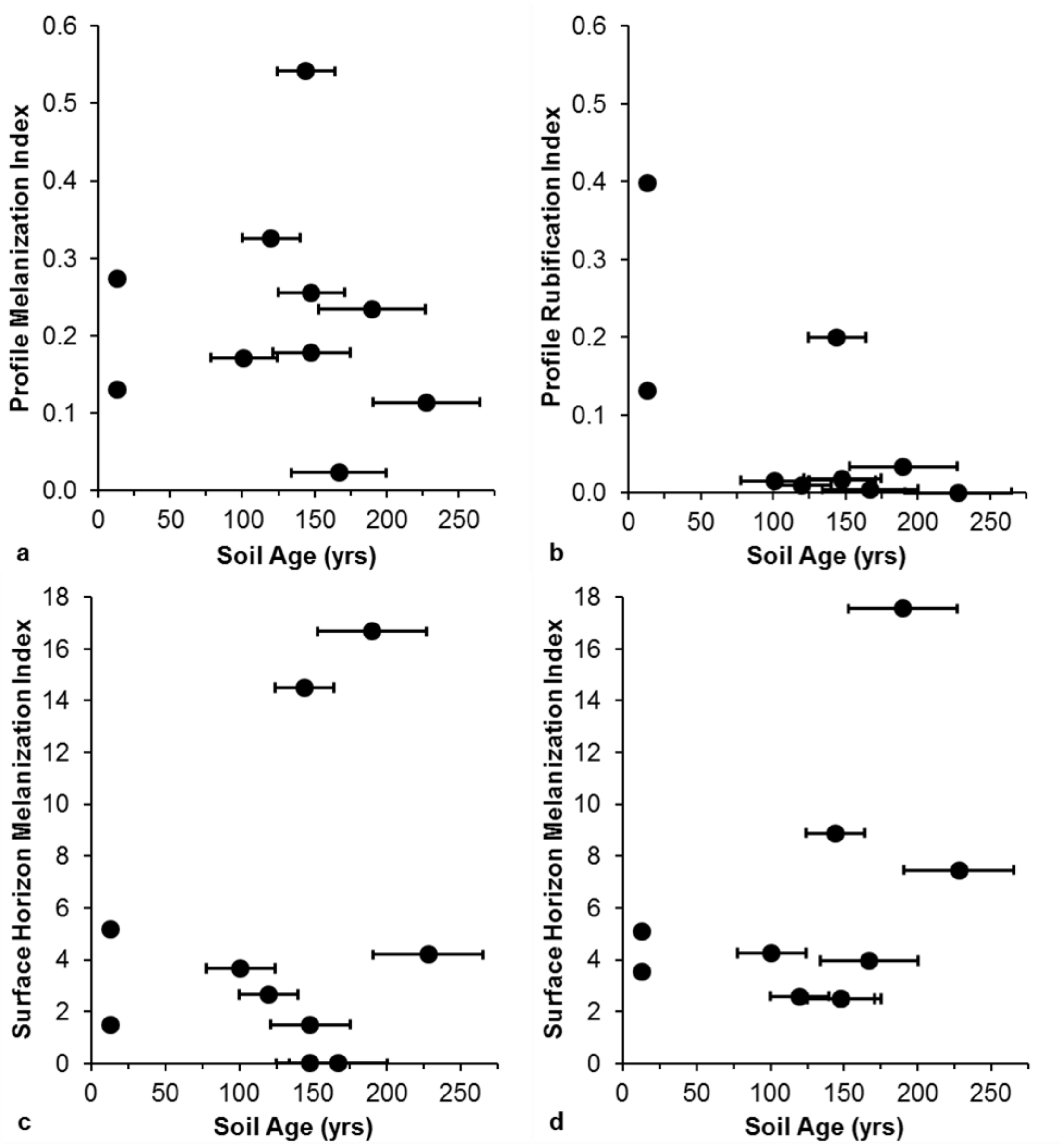

Fig. 3-10. Development of quantified soil properties in very poorly and poorly drained soils (low topographic positions) at Assateague Island National Seashore, MD, USA. (a) Profile melanization index and (b) profile rubification index calculated using the methods in the Soil Development Index (SDI) of Harden (1982). Soil colors were measured in the field using a Munsell Color Book. (c) Surface horizon melanization index calculated from soil colors measured in the field using a Munsell Color Book, and (d) surface horizon melanization index calculated from soil colors measured using a digital colorimeter. Surface horizon melanization index is calculated using surface and near-surface horizons with an accumulation of organic matter. Soil ages were estimated using comparisons of historical aerial photography (soils less than 60 years) and Optically Stimulated Luminescence (OSL) dating (soils over 60 years). Error associated with age estimates are shown, but are in some cases too small to be visible in the figure.

carbon contents (and soil age) (Figs. 3-10a, 3-10c, and 3-10d). Soil color and organic matter relationships were, in part, influenced by soil texture (Schulze et al., 1993). Schulze et al. (1993) showed that for sandy soils (such as these) Munsell value decreases rapidly as organic matter contents increase to 15 g kg^{-1} (approximately 9 g kg^{-1} organic carbon) and then change less rapidly with further increases. Similarly, we found that as organic carbon increased beyond 10 g kg^{-1}, changes in value were minimal (Fig. 3-11). At the low positions organic carbon contents in surface horizons ranged from 5.7 to 298 g kg^{-1}, so despite increases in organic carbon, the effect on soil color was no longer apparent. Soil organic carbon in soils at the low positions may have reached and exceeded a threshold where added soil organic carbon no longer darkens the color (Wills et al., 2007). Furthermore, rubification of the subsoil and formation of Bw horizons was not observed at the wetter sites (Fig. 3-10b). Rather than the slight accumulation of iron oxides (as seen at the high positions), the subsoils of the low sites were reduced and depleted of iron, resulting in low chroma matrix colors (chromas < 2). Low chroma horizons (Cg and Cse horizons), indicating near permanent saturated and reducing conditions, were observed immediately below surface horizons in the low topographic positions (Table 3-5 and Fig. 3-9).

3.4.3 Effect of Saturated and Reducing Conditions

Redoximorphic features (e.g., redox concentrations, redox depletions, reduced matrixes, and depleted matrixes) are soil morphological features formed by the reduction, movement, and oxidation of iron and/or manganese compounds. These

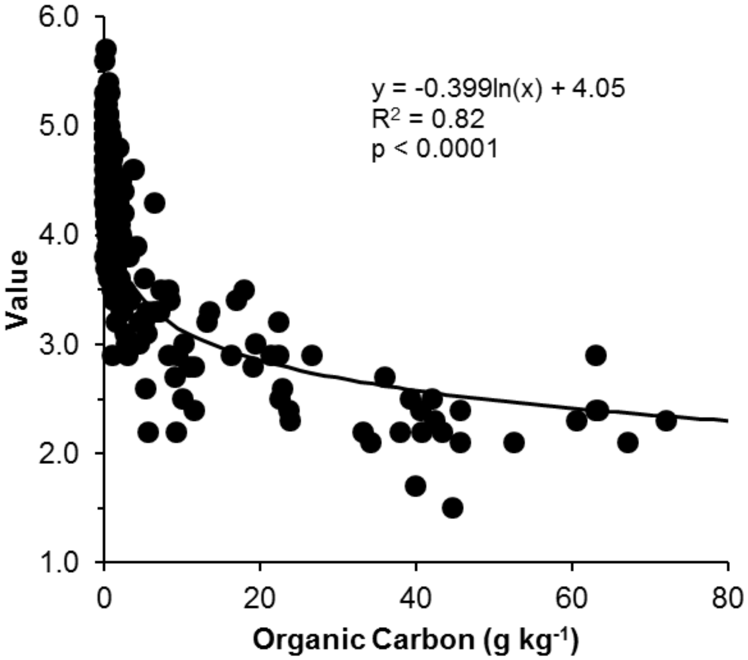

Fig. 3-11. Munsell color value of mineral soils as a function of organic carbon. Soils were sampled at Assateague Island National Seashore, MD, USA. Color was measured using a digital colorimeter (Konica-Minolta Chroma Meter CR300, Minolta Corporation, Ramsey, NJ).

features are commonly used to indicate the frequency and duration of saturated conditions in the soil. However, due to the low available iron in the sandy parent materials, redox concentrations were not prevalent features in these soils, despite relatively shallow water tables and frequently saturated conditions. Redox concentrations form as soluble Fe^{2+} is oxidized, forming Fe(III) (hydro)oxide minerals. Where present in Assateague Island soils (less than half of soils described), redox concentrations occurred as iron masses. Their abundance was typically 1-2% and concentrations had hues of 7.5YR to 10YR, values 3-5, and chromas of 4-6. Fluctuations in water tables and reducing conditions may have led to the oxidation of iron and formation of concentrations during drier parts of the year, followed by iron reduction and dissolution of concentrations during wetter periods. Horizons containing redox concentrations were almost always above the median water table and the average frequency of saturation in these horizons was about 29% annually. When the soil is saturated, soluble Fe^{2+} has the potential to be quickly leached from these sandy soils because of their high hydraulic conductivity. Given the low concentrations of iron, more complete reduction and leaching of iron may occur faster and under less saturated conditions than observed in other soils.

Depletions were only described in 2 of the 30 soils. Depletions form as iron is reduced to soluble Fe^{2+} and translocated. The resulting low chroma colors were the sand grains unmasked by Fe(III) (hydro)oxide coatings, which otherwise typically give soil a yellow, brown, or red hue. Similar to concentrations, depletions were observed in horizons above the median water table. Depletions had hues of 2.5Y to 10YR, values 4.5-5, and chromas of 1.5-2. Rather than isolated depleted zones, horizons that were saturated for much of the year had depleted matrixes, with hues of 2.5Y (or yellower) and chromas less than 2. In these horizons, soluble Fe^{2+} has been largely leached from the soil. Horizons less frequently saturated had slightly higher chromas, 2 or greater. The higher chroma colors observed in oxidized horizons (often Bw horizons) were due to slight accumulations of iron (hydro)oxides and organic matter. Once Fe^{2+} is leached out of the profile, it is no longer available to form redox concentrations under oxidizing conditions. Given the low extractable iron concentrations in these soils, iron may have been leached out of the profile relatively rapidly, explaining why concentrations were not regularly observed in conjunction with the low chroma matrix colors. These low chroma matrix colors (chromas less than 2) seemed to be a more permanent and reliable indicator of the frequency and duration of saturation, regardless of current conditions[1]. Low chroma matrix colors were observed in subsoil horizons across all topographic positions; however they occurred deeper in the subsoil at the better drained positions, reflecting the deeper water tables at these sites.

Reduced iron (Fe^{2+}) can be identified in the pore water of saturated soil horizons by observing soil reaction with α,α’-dipyridyl dye (Childs, 1981). When soluble Fe^{2+} is present, as under reducing conditions, the soil will turn pink or red through the formation of a ferrous α,α’-dipyridyl complex. Despite near continuous saturation in many of the horizons, relatively few gave a positive reaction with the

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[1] Morphological features indicative of drainage class and hydric soils are detailed further in Chapter 5 of this dissertation.

dye. The negative reaction could indicate oxidizing conditions (all iron is in the Fe^{3+} form) or reducing conditions where Fe^{2+} is not present. In these soils, Fe^{2+} concentrations may be too low to generate a reaction with the dye, although it has been shown that concentrations of Fe^{2+} as low as 3 to 5 µg mL^{-1} will generate are reaction with α,α'-dipyridyl in sandy soils (Vasilas et al., 2013). It is also possible that Fe^{2+} may be unavailable, either precipitated with sulfide (S^{2-}) or leached from the profile due to sustained saturated and reducing conditions (Childs, 1981; Griffin, 2013).

Within a transect, the low sites (poorly and very poorly drained soils) had larger organic carbon stocks than their better drained counterparts of the same age (Fig. 3-4). Organic-enriched surface horizons were thicker and darker in color at the lower and wetter transect positions (Tables 3-4 and 3-5 and Figs. 3-3 and 3-8). Organic horizons, predominantly Oa horizons, were observed at the surface in many of the low and some of the mid positions, where only A horizons were observed in better drained soils of the same age. Wetter conditions (and greater plant water availability) at the lower topographic positions can increase plant biomass production, increasing carbon inputs (Craft, 2001). Faster establishment of vegetation in the low positions (due to wetter, more favorable conditions) may explain the earlier steepening of the organic carbon accumulation curve relative to the high sites (Fig. 3-4) (Jones et al., 2008). A shallower water table also increases the frequency and duration of saturated and reducing conditions. Under anaerobic conditions, organic matter decomposition rates are slowed, leading to greater accumulation of organic matter (Craft, 2001; Grootjans et al., 1998; Jones et al., 2008). As a result of higher carbon inputs and slower decomposition rates, organic matter accumulated at the lower topographic positions more readily than at the high positions.

The presence of soluble sulfide was observed in the field by the occurrence of H_2S odors (Schoeneberger et al., 2012; USDA-Natural Resources Conservation Service, 2010). Sulfide minerals were detected in the field by reaction with H_2O_2. The addition of H_2O_2 to sulfidic soil materials resulted in an increase in value (and occasionally, reddening of hue) as iron monosulfide (FeS) or pyrite (FeS_2) minerals were oxidized (Schoeneberger et al., 2012). Reaction with pyrite was generally slower as it is a more stable mineral. These observations were confirmed in the laboratory by monitoring the change in soil pH under moist, aerobic conditions (e.g., Fig. 3-12. Sulfidic materials in soils will undergo a significant drop in pH as sulfide minerals are oxidized and sulfuric acid is formed (Fanning et al., 2002). To be designated as sulfidic materials, the pH must, under moist and oxidized conditions, decrease by at least 0.5 units to a value of 4.0 or less within 16 weeks or until pH reaches a nearly constant value (Soil Survey Staff, 2010). Soil horizons meeting the criteria for sulfidic materials were designated with the morphologic horizon suffix "se".

Sulfidic materials were observed in the subsoil of many of the soils and across all landforms (Tables 3-4 and 3-5). These horizons occurred below the depth of permanent saturation, where soil redox conditions were sufficiently low to cause reduction of sulfate to sulfide. The Fe^{3+} of iron (hydro)oxides is chemically reduced to form FeS and FeS_2 by dissolved sulfides (H_2S) or biologically reduced along with sulfate (SO_4^{2-}) during the oxidation of organic matter (Fanning et al., 2010).

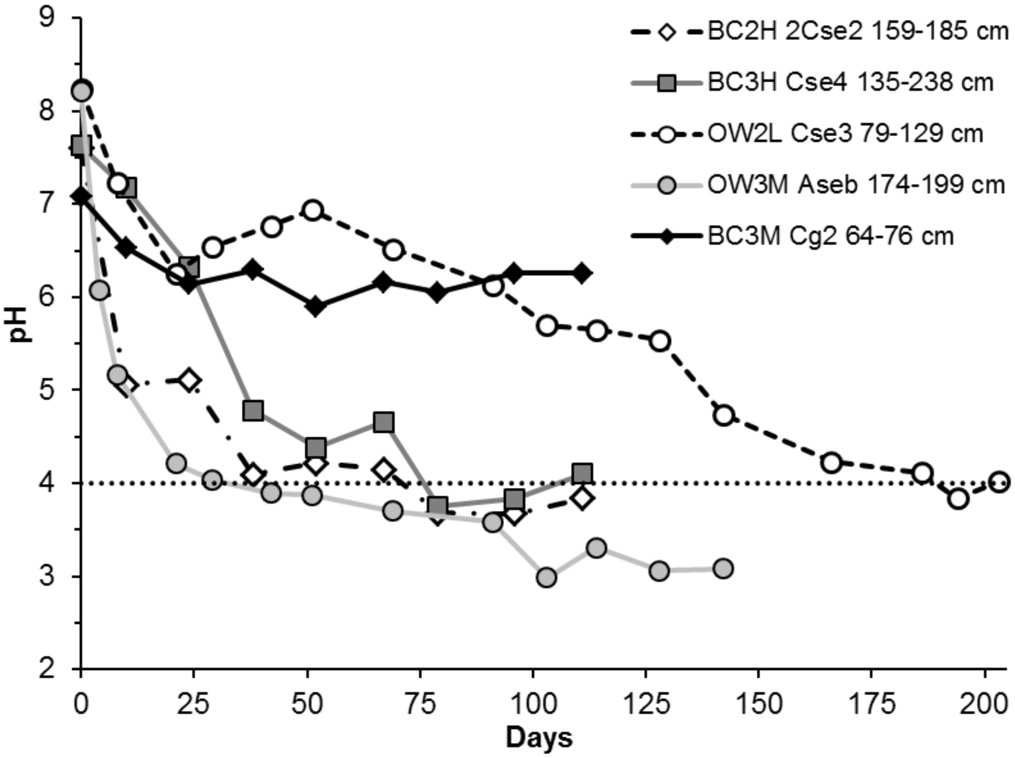

Fig. 3-12. pH of selected soil samples following moist incubation. Soils were sampled on Assateague Island National Seashore, MD, USA following moist incubation. To be designated as sulfidic materials, under moist and oxidized conditions, the pH must decrease by at least 0.5 units to a value of 4 or less within 16 weeks (112 days) or until pH reaches a nearly constant value (Soil Survey Staff, 2010).

The presence of sulfides in these systems also indicates a marine or brackish water influence. Since the wetlands associated with these soils are non-tidal, marine water additions occur somewhat irregularly, through sea spray, overwash and surface flow, influx of saline ground water, and/or flooding from the bay (Hall, 2005). Measurements of soil pore water electrical conductivities showed at least some degree of marine water influence at all of the sites (Table 3-1). Among the four sites where water was ponded for portions of the year, average electrical conductivity was 3.6 dS m^{-1} (as salinity this would be 1.9 ppt, which would be considered oligohaline). Across all sites, average soil pore water electrical conductivity ranged from 0.2 to 8.9 dS m^{-1} (Table 3-1). Seasonal variation in electrical conductivity (average range of 5.6 dS m^{-1} over the year) suggests that marine water intrusion occurred in pulses, generally associated with large storm events (Hall, 2005). For example, electrical conductivity at all of the sites increased an average of 3.4 dS m^{-1} in the sampling period immediately following Hurricane Sandy in October 2012. Temporal variability of electrical conductivity observed in this and other studies at Assateague Island suggests that marine water from periodic events, such as overwash, flooding, and/or groundwater intrusion, are a much larger source of salinity and sulfur relative to atmospheric inputs (e.g., sea spray) (Hall, 2005). Average atmospheric deposition of sulfate on Assateague Island (2000 through 2012) was 13.1 kg ha^{-1} (precipitation weighted average concentration was 1.28 mg L^{-1}) (National Atmospheric Deposition Program, 2014). Climatic conditions (e.g., rainfall, evapotranspiration rates) following salt water intrusion likely effects the persistence of salinity and therefore, sulfur availability in the soil (Greaver and Sternberg, 2007). Spatial and temporal variability in the presence of sulfides may, at least partially, be explained by differences between sites in the occurrence and duration of saturated and reducing conditions, and the relative frequency and seasonality of events causing marine water intrusion.

3.4.4 Taxonomic Classification

Currently there are two separate suites of soils used in mapping Assateague Island (Table 3-6) (Soil Survey Staff, 2014b). Soils in the northern part of the island, located in Maryland, were mapped as being in the mesic soil temperature regime. The southern part of the island is located in Virginia and the soils mapped there are classified as thermic. Otherwise, these two sets of soils are similar in their characteristics, particularly for the non-tidal soils, which would be mapped in the barrier core and overwash areas of focus in this study. The non-tidal soils in both suites represent a catena or toposequence, ranging from poorly drained (Askecksy / Camocca), moderately well drained (Brockatonorton / Fisherman), and excessively drained (Acquango / Assateague) soils.

Soil Temperature Regime

According to the U.S. Soil Taxonomic System (Soil Survey Staff, 2010) the mesic regime has a mean annual soil temperature at 50 cm of 8^{o}C or greater and less than 15^{o}C. The thermic regime has mean annual soil temperatures of 15^{o}C or greater and less than 22^{o}C. Where measured (sites BC1M, BC5M, and OW2M, and all positions along transects BC2, BC6, and OW3), mean annual soil temperatures at 50

Table 3-6. Series and taxonomic classification of soils currently mapped on Assateague Island (spans the states of Maryland and Virginia).

State	Series Name	Drainage Class†	Taxonomic Class	Salinity Class‡
MD	Acquango	ED	Mixed, mesic Typic Udipsamments	Nonsaline to slightly saline
MD	Brockatonorton	MW	Mixed, mesic Aquic Udipsamments	Nonsaline to moderately saline
MD	Askecksy	PD	Siliceous, mesic Typic Psammaquents	Nonsaline to very slightly saline in A horizon, nonsaline in rest of profile
MD	Saltpond	VP, tidal flooding	Sandy, mixed, mesic Haplic Sulfaquents	Slightly to strongly saline
MD	Purnell	VP, tidal flooding	Sandy, mixed, mesic Histic Sulfaquents	Moderately to strongly saline
VA	Assateague	ED	Mixed, thermic Typic Udipsamments	none given
VA	Fisherman	MWD	Mixed, thermic Aquic Udipsamments	none given
VA	Camocca	PD	Mixed, thermic Typic Psammaquents	variable according to frequency of flooding
VA	Backbay	VP, irregular tidal flooding (wind tides)	Fine-loamy, mixed, active, nonacid, thermic Histic Humaquepts	none given
VA	Chincoteague	VP, tidal flooding	Fine-silty, mixed, active, nonacid, thermic Typic Sulfaquents	Strongly saline

† Drainage Classes: ED = Excessively drained, MW = Moderately well drained, PD = Poorly drained, VP = Very poorly drained.

‡ Salinity Classes based on the electrical conductivity of a saturated soil paste extract: Nonsaline, < 2 dS/m; Very slightly saline, 2 to < 4 dS/m; Slightly saline, 4 to < 8 dS/m; Moderately saline, 8 to < 16 dS/m; Strongly saline, ≥ 16 dS/m (Schoeneberger et al., 2012).

cm ranged from 15.0 to 17.3^{o}C in 2012 and from 14.5 to 16.9^{o}C in 2013 (Fig. 3-13). Greater seasonal temperature fluctuation occurred at sites with less vegetation cover and those with little to no organic or leaf litter cover at the surface. Forested sites had greater shading (due to increased canopy cover) and thicker organic horizons and leaf litter accumulations which insulated the soil. These sites had cooler temperatures in the summer and warmer temperatures in the winter when compared to the non-forested sites (data not shown). Mean annual soil temperature at the BC6 transect was lower than transects BC2 and OW3 in both 2012 and 2013, however this difference was less than 2^{o}C (Table 3-7). Since our data set is relatively small (12 soils) and spans only a two year period, it is uncertain if the differences in mean annual soil temperatures between transects has a meaningful significance, despite the statistical significance.

The average annual soil temperature (across all Assateague sites) was significantly greater than 15^{o}C in 2012 ($p = 0.0001$), and nearly so in 2013 ($p = 0.0641$) (Fig. 3-13 and Table 3-7). In 2012 air temperatures were 1.8 degrees above the 42 year average and 1.2 degrees above the average of the last 10 years, while in 2013 the air temperature was 0.4 degrees below the 42 year average and 1.0 degree below the average of the last 10 years (Table 3-7). These soils clearly lie near the boundary between thermic and mesic. However, given that even in a year with slightly below average air temperatures (2013) most of the sites still had a mean annual soil temperature equal to or greater than 15^{o}C, the soils on Assateague Island probably would be better classified within a thermic soil temperature regime, rather than mesic.

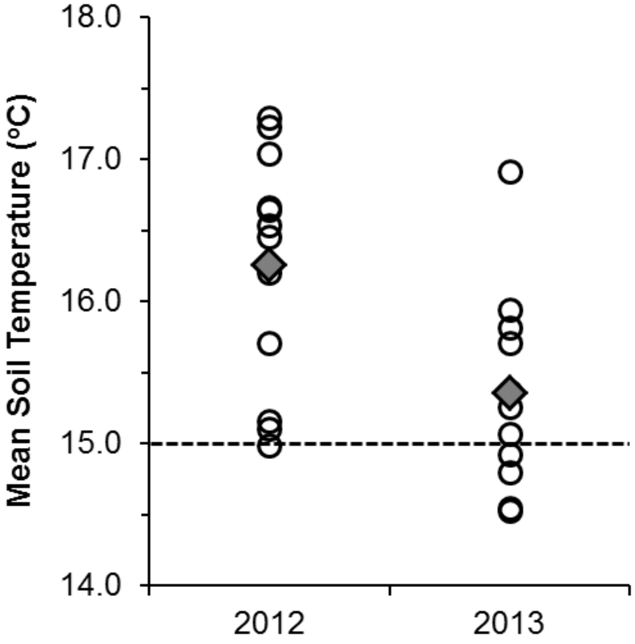

Fig. 3-13. Mean annual soil temperature (50 cm depth) for 12 sites at Assateague Island National Seashore, MD, USA in 2012 and 2013. Average for all sites in each year is indicated with gray diamond symbols. The dashed line shows the 15°C boundary between mesic (< 15°C) and thermic (≥ 15°C) temperature regimes.

Table 3-7. Mean annual air and soil temperatures measured at Assateague Island National Seashore, MD in 2012 and 2013. Temperatures were recorded every 90 minutes by data loggers located near the study sites (Assateague). Additional temperature data and historical climate records were obtained from a National Weather Service Remote Automatic Weather Station located on Assateague Island (RAWS).

	2012[†]	2013[†]
	----- °C -----	
Assateague Mean Air Temperature	15.3	13.9
RAWS Mean Air Temperature	15.7	13.5
Difference from 42 Year Mean (1969-2011)[‡]	+1.8	-0.4
Difference from 10 Year Mean (2002-2011)[‡]	+1.2	-1.0
Mean Soil Temperature (at 50 cm)		
All Sites (n=12)	16.3	15.4
BC2 (n=3)	17.0 a	16.4 a
BC6 (n=3)	15.1 b	14.7 b
OW3 (n=3)	16.5 a	15.3 ab

[†] Within years, mean annual soil temperature for transects (BC2, BC6, and OW3) followed by the same letter are not significantly different ($\alpha = 0.05$).

[‡] Difference between the RAWS Mean Air Temperature for the year of interest and the long term mean air temperature for the same station.

The mesic soil series mapped in Maryland (Acquango, Brockatonorton, and Askecksy) are also mapped on barrier islands in Delaware and parts of New Jersey (Soil Survey Staff, 2014b). Without measurements of soil temperatures on barrier islands in Delaware and New Jersey, we cannot determine how far north the mesic/thermic boundary occurs, and therefore are uncertain if these soil series should be reclassified as thermic, or if the thermic soil series already developed (Assateague, Fisherman, and Camocca) should simply be used in Maryland, in addition to being used in Virginia and states further south.

Mineralogy

Soil series mapped on Mid-Atlantic barrier islands are classified either as having mixed or siliceous mineralogy (Table 3-6). Soils in a siliceous family have greater than 90% silica minerals (including quartz, chalcedony, or opal) and other resistant minerals in the sand and coarse silt fractions (0.02 – 2.0 mm) (Soil Survey Staff, 2010). Soils in mixed mineralogy families are not dominated by any one particular group of minerals, and in these cases, mainly are recognized because they contain greater than 10% weatherable minerals (mostly feldspars, but also other minerals such as pyroxenes, amphiboles, etc.). In the Psamments sub-order (most soils mapped on the non-marsh portions of Mid-Atlantic barrier islands), mineralogy can affect the great group classification. Psamments with greater than 90% resistant minerals in the sand and coarse silt fractions are classified as Quartzipsamments (Soil Survey Staff, 2010). Otherwise, great group classification of Psamments is based on soil temperature or moisture regimes. In the Mid-Atlantic region, soils not meeting the criteria for Quartzipsamments would be classified as Udipsamments.

Mineralogy data in the National Cooperative Soil Characterization Database for the soil series mapped in the Maryland portion of Assateague Island is limited to six soil profiles (two pedons each from the Acquango, Brockatonorton, and Askecksy series) (National Cooperative Soil Survey, 2014). Four of these pedons were sampled as part of this project in cooperation with NRCS Soil Survey staff (BC5H, mapped as Acquango; BC5L, mapped as Askecksy; BC2H, mapped as Brockatonorton; and BC2L, mapped as Askecksy). In these six pedons, resistant mineral content ranged from 90-94% in the particle size control section (25-100 cm) based on optical grain counts performed at the National Soil Survey Laboratory, in Lincoln, NE (National Cooperative Soil Survey, 2014), placing these soils in Quartzi- great groups or siliceous families (Soil Survey Staff, 2010). Grain counts were made on the fine sand fraction of the sampled horizons from the pedons mapped as Acquango and Brockatonorton, which in these soils comprised 21 to 56% of the sample by weight. Given that these soils had sand textures (less than 2% silt and clay) and in most of the soils the medium sands were the dominant particle size fraction (42 to 70%) it is somewhat uncertain if the mineralogy of the fine sands alone gave a good estimation of the overall mineralogy. Optical grain counts were made on the fine and medium sand fractions of the horizons from pedons mapped as Askecksy. Resistant mineral contents were greater in the medium sand fraction (95 to 98%) than in the fine sand fraction (79 to 93%) of these two pedons, suggesting that mineralogy is not uniform across sand fractions. Given the particle size distribution, inclusion of both the medium and fine sand fractions is likely more representative of the soil mineralogy.

There is a slightly larger data set for the Assateague, Camocca, and Fisherman soils in Virginia (mineralogy data is available for three pedons of each series). For each of these pedons, mineralogy data is available for one horizon from within the particle size control section. Grain counts were made on sand grains passing through a 40 mesh sieve (0.42 mm), which includes most of the medium sands, and all of the fine and very fine sands (Peacock and Edmonds, 1992). Only one sample had a resistant mineral content greater than 90% (95%, Assateague series), and the remaining eight pedons ranged from 75 to 89% (National Cooperative Soil Survey, 2014; Peacock and Edmonds, 1992). These pedons were sampled on the southern portion of Assateague Island (five pedons) and Chincoteague Island (four pedons), a barrier island located in the bay between the southern end of Assateague Island and mainland Virginia. The resistant mineral content in pedons sampled on Assateague Island tended to be slightly greater, ranging from 83 to 95%, than samples from Chincoteague Island, ranging from 75 to 81% (National Cooperative Soil Survey, 2014).

There may be differences in the depositional environments on Assateague Island and Chincoteague Island, and between the different portions of Assateague Island which could impact the soil mineralogy. Given the limitations of the data set, both in number of samples and sampling methods, it is unclear if there are significant differences in the mineralogy between sampling areas. Clearly, there is uncertainty in the mineralogical content of these soils affecting the taxonomic classification and highlights the need for further investigation into the soil mineralogy. Since the soils in this study were sampled in Maryland where, based on available mineralogy data, resistant mineral content was greater than 90%, the soils described have been classified in Quartzi- great groups or siliceous families. However, we recognize that this is based on a limited data set and some questions regarding mineralogy may remain.

Taxonomic Classification of Pedons and Affiliated Soil Series

Based on our assessment that these soils are in a thermic temperature regime and on the assumption that they have siliceous mineralogy, the soils in this study should be classified within a catena of siliceous, thermic Psamments or Psammaquents. Ironically, series have not been established for these classes because the established thermic soil series have been designated as having mixed mineralogy (Assateague, Fisherman and Camocca series). The mesic soils have been designated as having either siliceous (Askecksy) or mixed (Acquango, Brockatonorton) mineralogy. One way to address this might be to establish a new catena of siliceous, thermic soils. An alternate approach would be to reclassify the mesic catena currently used in Maryland to be siliceous and thermic. However, if we were to follow this latter path, there remain a number of classification problems related to the particular properties of the soils that do not fall within the range in properties of these soil series (beyond differences in mineralogy and temperature regime) given in the Official Soil Series Descriptions (OSDs) (Soil Survey Staff, 2014a).

The OSDs for the Askecksy, Brockatonorton, and Acquango series do not currently recognize the range of morphologies and properties that we observed in these soils. The major omissions or necessary changes to the current mapping concepts include:

- Inclusion of non-tidal very poorly drained and somewhat poorly drained soils. Currently only poorly drained, moderately well drained, and excessively drained soils are recognized. Very poorly drained soils are only recognized in tidally influenced settings.
- Recognition of sulfidic materials and Cse horizons, especially occurring within 50 cm of the soil surface which would lead to classification of Sulfaquents.
- Recognition of non-tidal, very poorly, poorly, and somewhat poorly drained Haplic Sulfaquents.
- Recognition of soil salinity classes greater than non-saline in non-tidal settings.
- Recognition of O horizons, particularly on more stable landforms. When present, Oa and Oe horizons were described in very poorly and poorly drained soil series, and Oe and Oi horizons were described in somewhat poorly drained and drier soils.
- Recognition of mucky mineral A horizons in poorly and poorly drained soil series.
- Recognition of Bw horizons (hue 10YR, value 4-6, chroma 2-3) in moderately well drained and drier soils in stable landforms.

- Expansion of the range of colors in C horizons in moderately well drained soils (hues as red as 10YR, chromas as low as 2).
- Inclusion of finer textures and mucky mineral textures in buried A horizons.

Many of the discrepancies between the current OSDs and our soil descriptions and observations can be satisfied by changing or expanding the range of characteristics given in the OSDs of the currently recognized series. However, we propose that in some cases, new soil series are needed to adequately capture the range of properties and distinguish between soils on Mid-Atlantic barrier islands (Table 3-8).

The catena of series currently mapped on Assateague Island (both Maryland and Virginia) include very poorly (tidally influenced), poorly, moderately well, and excessively drained soils. On barrier islands, the depth of the water table varies across the landscape with topography, and occurs along a spectrum. Despite the absence from the set of soils used in mapping Assateague Island, we described non-tidal very poorly and somewhat poorly drained soils. The very poorly, poorly, and somewhat poorly drained soils typically occurred along a continuum with organic matter accumulations thinning in the drier positions. Very poorly drained soils had Oa horizons or A horizons with relatively high organic matter contents (mucky mineral). In poorly drained soils, surface horizons were mineral or mucky mineral. The very poorly and poorly drained soils were hydric. The somewhat poorly drained soils were generally non-hydric, and hydromorphic features (matrix color chromas less than 2) occurred deeper than 30 cm, but above 50 cm. Given that the somewhat poorly drained soils were generally non-hydric, we suggest a series be established to separate

Table 3-8. Currently recognized and proposed taxa for Mid-Atlantic barrier island soils based on observations and descriptions of soils at Assateague Island National Seashore, MD, USA.

Series	Classification	Drainage Class[†]	Concept of Series and Typical Horizon Sequence[‡]	Pedons Included[§]	Changes Needed / Characteristics to be Included	How to Accommodate
Askecksy	Typic Psammaquents	PD	• Hydric • Non-tidal • Predominantly herbaceous vegetation • Located in interdunal swales and depressions • Horizon Sequence – Younger: Oa or A, Cg Older: Oe, Oa, A, Cg May have buried surface horizons (Ab or Oa) and/or Cse horizons (below 50 cm)	OW2M OW3L OW3M BC1M BC3L BC2L BC2M BC5L* BC6L* BC6M*	• Salinity greater than nonsaline • Inclusion of very poorly drained soils • Presence of Oa and Oe horizons • Mucky texture modifiers in A horizons • Presence of Cse horizons (below 50 cm) • Finer textures and mucky texture modifiers in buried A horizons	Change range of characteristics
Fox Hill (proposed)	Haplic Sulfaquents	VP-PD	• Hydric • Non-tidal • Located in interdunal swales and depressions • Sulfidic materials within 50 cm of the surface • Horizon sequence – Younger: Oa or A, AC, Cse Older: Oe, Oa, A, Cse May have buried surface horizons (Ab or Oa)	OW1L OW2L OW4L BC1L BC4L*	• Salinity: nonsaline or greater • Presence of sulfidic materials within 50 cm • May have buried surface horizons	New series

Series	Classification	Drainage Class[†]	Concept of Series and Typical Horizon Sequence[‡]	Pedons Included[§]	Changes Needed / Characteristics to be Included	How to Accommodate
Bayberry (proposed)	Typic Psammaquents	SP	• Generally not hydric • Located on dune fields, barrier flats, and overwash fans • Horizon sequence – Younger: A, AC, C, Cg Older: Oi, Oe, A, AC, C, Cg May have buried surface horizons (Ab or Oa) and/or Cse horizons (below 50 cm)	OW1M BC3M BC4M OW4H BC5M*	• Salinity: nonsaline or greater • Presence of Cse horizons (below 50 cm) • May have buried surface horizons	New series
La Galga (proposed)	Haplic Sulfaquents	SP	• Generally not hydric • Located on dune fields, barrier flats, and overwash fans • Sulfidic materials within 50 cm of the surface • Horizon sequence – Younger: A, AC, C, Cg, Cse Older: Oi, Oe, A, AC, C, Cse May have buried surface horizons (Ab or Oa)	OW4M BC6H*	• Salinity: nonsaline or greater • Presence of sulfidic materials within 50 cm • May have buried surface horizons	New series

Series	Classification	Drainage Class[†]	Concept of Series and Typical Horizon Sequence[‡]	Pedons Included[§]	Changes Needed / Characteristics to be Included	How to Accommodate
Brockatonorton	Aquic Quartzipsamments	MW	• Located on dune fields, barrier flats, and overwash fans • Horizon sequence – Young: A or AC, C Older: Oi, A or AC, Bw, C, Cg May have buried surface horizons (Ab or Oa) and/or Cse horizons (below 50 cm)	OW1H OW2H OW3H BC1H BC3H BC4H BC2H*	• Presence of Oi horizons in older soils • Presence of Bw horizons • C horizons with hues as red as 10YR • C horizons with chromas as low as 2 • Presence of Cse horizons (below 50 cm) • Presence of buried surface horizons	Change range of characteristics
Acquango	Typic Quartzipsamments	ED	• Located in dune fields at summit positions • Horizon sequence – Younger: AC, C, Cg Older: Oi, A, AC, Bw, C, Cg May have buried surface horizons (Ab or Oa) and/or Cse horizons (below 1 m)	BC5H*	• Salinity: nonsaline or greater • Presence of Oi horizons in older soils • Presence of Bw horizons Presence of Cse horizons (below 50 cm) • Presence of buried surface horizons	Change range of characteristics

[†] Drainage classes: ED = excessively drained, MW = moderately well drained, SP = somewhat poorly drained, PD = poorly drained, VP = very poorly drained.

[‡] Typical horizons sequences are given for soils on younger (less stable) landscapes dominated by herbaceous vegetation and older (more stable) landscapes dominated by trees and shrubs. All horizons listed are not always present, but is meant as a generalized typical sequence.

[§] Pedons denoted with an asterisk (*) are located on older (more stable) landscapes with dominated by trees and shrubs (rather than dominantly herbaceous vegetation).

these soils from those in lower and wetter topographic positions. We do not suggest including the somewhat poorly soils in a moderately well drained series (such as Brockatonorton), since saturated and reducing conditions occurred much closer to the soil surface in the somewhat poorly drained soils.

Among the very poorly to somewhat poorly drained soils, soils were classified into two taxonomic families, Typic Psammaquents and Haplic Sulfaquents. On Assateague Island (MD), these soils would currently be mapped as the Askecksy series, a poorly drained, sandy, mesic Typic Psammaquent. Since the interior (non-marsh) portions of the barrier island are non-tidal, the Askecksy series does not recognize the potential of sulfidic materials within the soil profile. However, we described sulfidic materials (designated with the suffix “se”) in many of the soils. When sulfidic materials are present within the upper 50 cm of the soil profile, the soils are classified as Sulfaquents. Taxonomically, these soils would fit into the Saltpond series, which is currently used in mapping tidal marshes in Delaware. According to the OSD, the Saltpond series occurs on low-lying dunes and dunes on washover fans, but also experiences twice daily flooding. We propose that two new soil series are needed to recognize the non-tidal, very poorly and poorly drained Haplic Sulfaquents and the non-tidal, somewhat poorly drained Haplic Sulfaquents that we described in the barrier core and overwash zones of barrier islands.

According to Soil Taxonomy (Soil Survey Staff, 2010) a soil is designated as containing sulfidic materials if the pH drops at least 0.5 units to less than 4 within 16 weeks of moist, aerobic incubation. However, the low buffering capacity of these sandy soils may have caused a faster or more dramatic drop in pH than might have been seen in finer textured soils with similar sulfide concentrations, and actual sulfide concentrations may be relatively low (Balduff, 2007; Fanning and Rabenhorst, 2008). Balduff (2007) found that sandy soil materials with chromium reducible sulfide concentrations as low as 0.16 g S^{-2} kg^{-1} had a sufficient drop in pH to be classified as sulfidic materials. However, finer textured soils with similar sulfide concentrations did not show the same drop in pH. Assuming a 1:1 molar relationship between Fe^{2+} and S^{2-}, a rough estimation of sulfide content was made using the DCB extractable Fe concentrations (where measured). This would assume that all the DCB Fe existed as iron monosulfide (FeS) in the soil. In Cse horizons in soils at Assateague Island, estimated sulfide content ranged from 0.0 to 0.25 g kg^{-1} soil. Based on the sometimes slow reactions observed with H_2O_2 (as discussed earlier) much of the sulfide may have been in the more stable pyrite (FeS_2) form, and soil sulfide concentrations could have been higher, as much as 0.51 g kg^{-1}. In either case, sulfide contents in these soils were relatively low, especially when compared to other soils containing sulfidic materials. Concentrations of chromium reducible sulfides (disulfides) have been measured in tidal marsh and subaqueous mineral soils of Maryland ranging from 0.9 to 13.3 g S^{2-} kg^{-1} soil, and as high as 47.9 g S^{-2} kg^{-1} soil in organic soils (Balduff, 2007; Hussein and Rabenhorst, 1999). Classifying these soils as Sulfaquents may imply sulfide concentrations (and the potential implications or limitations for land use) much greater than are actually present in these soils[2]. Further investigation is

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[2] Neutralization of the potential acidity with a soil sulfide concentration of 0.51 g kg^{-1} would require 1.59 g $CaCO_3$ per kg of soil (2.4 Mg ha^{-1} with a soil depth of 10 cm, average bulk density 1.5 g cm^{-3}),

needed to evaluate the sulfide concentrations and variability among these soils. Additionally, reevaluation of the criteria for sulfidic materials may be needed, particularly as pertaining to sandy soils[3].

The soils described in the barrier core and overwash areas were non-tidal, however they were not completely freshwater systems. Average electrical conductivity of the soil pore water among all sites for February 2012 through January 2013 was 4.0 dS m^{-1} (standard deviation = 2.3 dS m^{-1}). Monthly measurements at individual sites ranged from 0.1 to 28.2 dS m^{-1}, with the highest values occurring immediately following Hurricane Sandy in October 2012. Given the variability in marine water inputs, both spatially and temporally, and the limited duration of our data set, we cannot be certain if the values we measured are reflective of long term average electrical conductivity in these soils. Furthermore, at the mid and high topographic positions soil pore water samples were from a depth of 1.0 m. We do not know if electrical conductivity measurements at this depth are representative of the entire soil profile or if electrical conductivity is as high within the plant rooting zone. It is possible, particularly at the high topographic positions, that the electrical conductivity was higher in the deeper, more frequently saturated horizons, while less

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which is relatively low compared to rates required for neutralization of active acid sulfate soils in other studies (Fanning and Burch, 2000; Offiah and Fanning, 1994)

[3] It is interesting to note that in the 1st edition of Soil Taxonomy, sulfidic materials were defined based upon chemical compositions - “containing 0.75 percent or more sulfur (dry weight), mostly in the form of sulfides and that have less than three times as much carbonate (CaC03 equivalent) as sulfur”. The intent of this definition was to capture those materials that would become acidic upon oxidation. In the 2nd edition of Soil Taxonomy, the definition was changed (to the current one) which eliminated the chemical composition requirements in lieu of directly measuring the change in pH during moist incubation under oxidizing conditions.

frequently saturated horizons closer to the surface (within the rooting zone) had a lower electrical conductivity as salts have been leached downward. However, the data do show that the barrier island soils were not completely freshwater systems. Direct comparisons cannot be made between the electrical conductivity of a saturated paste extract (EC_e) and the electrical conductivity of the soil pore water, but our data indicated that electrical conductivity in these soils may be greater than suggested by the OSDs. For example, soils in the Askecksy series are described as being very slightly saline to nonsaline (EC_e less than 4 dS m^{-1}) in the A horizon and nonsaline (EC_e less than 2 dS m^{-1}) throughout the rest of the profile (Soil Survey Staff, 2014a). Based on our measurements of the pore water and observations of halophytic plants, we believe that periodic salt water intrusion and resultant soil salinity is a factor in these soils that should be noted within the OSD because of its potential impact on plant growth.

Across all drainage classes, some of the soils had greater organic matter accumulations (manifested in A and/or O horizons) than what may be inferred from the OSDs. Organic matter accumulation was a function of both soil age and soil moisture. The older sites tended to be forested and in these soils, organic accumulations were substantially greater and horizon morphology was quite different from their non-forested counterparts (e.g., Figs. 3-3a, 3-3b, 3-3c, and 3-3d vs. Fig. 3-3e, Figs. 3-9a, 3-9b, 3-9c, and 3-3d vs. Fig 3-9e, and Tables 3-4 and 3-5). The contrast is particularly obvious in the excessively drained soils. The Acquango official series description does not accommodate Oe or Oi horizons or weak Bw horizons, all of which were observed at BC5H, an excessively drained, forested soil

(Table 3-4 and Fig. 3-3e). Based on vegetation descriptions given in the OSD for Acquango, it seems to describe soils occurring in non-forested and sparsely vegetated, younger (less stable) dunes and foredunes, where organic matter accumulations and subsoil development would be minimal. The range of characteristics across the catena could be expanded to recognize the increased organic matter observed in the relatively older soils (Oi, Oe, Oa, and A horizons with mucky mineral textures). Additionally, the potential presence of Bw horizons (hue 10YR, value 4-6, chroma 2-3) and C horizons (not Cg) with 10YR hues and chromas as low as 2 in moderately well drained and drier soils, should be recognized. Expansion of these criteria would combine soils that morphologically appear quite different, but by soil standards are all quite young and have limited development. This would result in very young soils with minimal profile development being included in the same series as soils with strongly developed O and A horizons, and even weak Bw horizons. The alternative approach would be to split these soils into separate series based on their age and organic accumulations. However this would result in twice as many soil series on barrier islands. A “young” and “old” soil series for very poorly and poorly drained Typic Psammaquents (Askecksy), somewhat poorly drained Typic Psammaquents (proposed new series), moderately well drained Aquic Quartzipsamments (Brockatonorton), excessively drained Typic Quartzipsamments (Acquango), very poorly and poorly drained Haplic Sulfaquents (proposed new series), and somewhat poorly drained Haplic Sulfaquents (proposed new series) would increase the number of soil series used on Mid-Atlantic barrier islands to 12.

Further consideration is needed to determine if the spatial extent of these soils justifies the need for additional series.

Buried surfaces described in the range of characteristics for the Askecksy, Brockatonorton, and Acquango series are similar to buried surfaces described on the washover fans, back-barrier flats, and barrier flats, but not the remnant marsh surfaces described in the soils on dune fields in the barrier core. The OSDs note the possible presence of Ab horizons, but these horizons have textures of loamy fine sand or coarser. The remnant marsh surfaces described on Assateague Island had greater carbon accumulation and finer textures. In some cases the buried surfaces were organic horizons, or mineral textures with mucky modifiers. Clay and silt percentages were also greater. We suggest that the range of characteristics for buried A horizons be expanded to include the higher organic contents and finer textures found in some of these buried surfaces.

3.5 CONCLUSIONS

Soil development in the dunal deposits of Assateague Island was best expressed in the accumulations of organic matter in surface horizons and subtle changes in subsoil colors. These modest changes reflected the young age of the soils and relatively weathering resistant mineralogy of the parent materials. While development was limited, study of these soils does give some insight into early pedogenic processes. Characteristics and development of the soil was a function of time (represented by landform stability) and soil moisture (represented by topography). These factors were also related to the plant community, which often could be used as a predictor of soil characteristics. Greater carbon stocks and more developed A and O horizons were observed at sites with more productive plant communities (e.g., dense herbaceous communities in very poorly drained soils and mature forest communities on older, more stable soils).

Soils forming in washover fan deposits, where deposition of new sediment is a relatively common occurrence, are young and show relatively little development. Depositional events are periodically “restarting” the pedogenic clock, and soils simply have not had time to form stronger expressions of pedogenesis. The dynamic nature of these landforms also limits the establishment of vegetation. With low plant biomass production, organic carbon inputs to the soil are minimal.

Shifts in vegetation (from sparse herbaceous communities to maritime forests) coincided with increases in biomass production, resulting in greater accumulation of organic carbon in the soil. Increased organic matter in the soil can set up a positive feedback loop, as improved soil conditions (higher nutrient availability) allow for more favorable conditions for these later successional species. With greater organic matter inputs and more time for formation, soils on these stable landforms have developed organic enriched surface horizons (A and O horizons). This process of ecological succession and organic matter accumulation seems to occur faster in the poorly and very poorly drained soils within a given landform. Greater water availability (due to a shallower water table) increases plant biomass production and therefore, organic carbon inputs to the soil are greater. Additionally, organic carbon decomposition rates are slowed under saturated and reducing conditions. The very poorly and poorly drained soils have greater organic carbon stocks, and thicker and darker organic-enriched surface horizons relative to better drained soils of similar age.

Slight accumulations of iron (hydro)oxides and organic matter in oxidized subsoil horizons are visible in the form of weak Bw horizons in the older soils (greater than 148 years). Organic acids, released from plants, can increase weathering rates of primary minerals. However, the soils on Assateague Island are sandy and contain very few mafic minerals, so primary mineral weathering and secondary mineral formation and accumulation (generally evidenced by color changes and increased clay in the subsoil) is limited. Only slight color changes (reddening of hue and increased chroma) are observed in oxidized horizons of older soils. In horizons that are frequently saturated, available iron is reduced and soluble Fe^{2+} is leached out of the profile. As a result, the soil matrix has a low chroma because the sand grains are not coated by iron (hydro)oxides or organic compounds. The low available iron also limits the formation of redox concentrations in periodically saturated horizons.

While the pedogenic processes occurring in these soils are limited, we were still able to develop chronofunctions to characterize development. In well drained soils, melanization and organic carbon stocks (0-50 cm) increased with soil age. There was an increase in rubification with soil age, but this trend was not statistically significant. Based on comparisons with other sandy soil chronosequences, we can expect that rates of organic carbon accumulation and melanization will slow as organic carbon reaches a steady state in the soil. However, we are uncertain at what point this will occur, or if greater carbon accumulation rates (as documented in other sandy soil chronosequences) will occur before the steady state is reached. In poorly drained soils, organic carbon stocks are increasing at a faster rate than measured in the drier soils, suggesting that plant community succession in these soils has advanced further than in the better drained positions. Because of the higher organic carbon contents in the surface horizons, there was no apparent trend in melanization across the chronosequence of poorly drained soils. In these soils it appears a threshold had been exceeded, where there is no longer a direct relationship between organic carbon content and darker soil color (melanization). In general, soil development is a function of both age and water table depth, and any attempts to estimate or predict pedogenic rates or processes must consider both of these factors.

Study of the soils at Assateague Island National Seashore also raises a number of questions regarding the current taxonomic classification and mapping of soils on Mid-Atlantic barrier islands. Previously, little data was available on these soils, and we found that the soil series established for Mid-Atlantic barrier islands do not adequately address the range in characteristics that we observed in these soils. We saw a greater range in surface and subsoil horizons properties then had been previously documented, particularly the presence of organic surface horizons, mineral A horizons with greater organic carbon contents, and weak Bw horizons. Additionally, the soils in the Maryland portion of Assateague Island likely occur in the thermic temperature regime, rather than mesic (as they are currently mapped and classified). Despite providing greater insight into the characteristics and properties of these soils, there are a few classification issues that remain unresolved. We found that these soils, despite being non-tidal systems, do have a marine water influence. The electrical conductivity (salinity) of the soil pore water may influence the vegetation present. It also provides a source of sulfate, which can be reduced to sulfide under reducing conditions. The variation in water chemistry seasonally and across the island raises a number of questions regarding the classification of these soils and sulfidic materials in sandy soils. Also not fully resolved is the mineralogical classification of these soils, which based on the limited mineralogy data available could be placed in either siliceous or mixed mineralogy classes depending on the particular pedon of interest and analytical methods.

CHAPTER 4: ORGANIC CARBON DYNAMICS IN SOILS OF MID-ATLANTIC BARRIER ISLAND LANDSCAPES

4.1 ABSTRACT

Geomorphic processes associated with coastal wetlands often result in high carbon accumulation rates and relatively large carbon stocks. Barrier islands are an important component of coastal ecosystems and freshwater and brackish wetlands on these islands provide an important habitat for a number of animal and plant species. However, organic carbon dynamics in these landscapes have received relatively little attention. The objective of this study was to document the accumulation of organic carbon and understand the factors influencing soil carbon dynamics on barrier islands. Ten topographic transects were established on different landforms on Assateague Island National Seashore, MD. Soil carbon stocks, carbon inputs, and decomposition rates were compared among landforms (representing differing degrees of landform stability and soil age) and drainage conditions. Carbon stocks (0-1.0 m) ranged from 0.49 to 18.8 kg C m^{-2}, and increased in magnitude with soil age. Higher carbon stocks in the older soils were partly attributed to the increased time over which carbon had accumulated. Additionally, a shift from herbaceous dominated to forest dominated plant communities led to greater carbon inputs in older soils. Carbon stocks were also greater in the very poorly and poorly drained soils (relative to drier soils) where high levels of carbon inputs (plant biomass) exceed decomposition rates, which were slowed under anaerobic conditions. While rates of carbon accumulation are somewhat low compared to other more productive systems, barrier island soils have the

potential to store large amounts of organic carbon as organic-rich surface horizons are buried during overwash events.

4.2 INTRODUCTION

The accumulation of organic matter is often one of the first processes in soil formation, and soil organic matter often reaches a steady state faster than other soil properties (Birkeland, 1999). Organic matter accumulates when organic material incorporated in the soil, primarily through additions of plant biomass, exceeds losses, which occur through decomposition. Soil organic stocks are made up of humic substances (highly resistant organic compounds formed by secondary synthesis reactions) and non-humic substances (organic residues, or the unaltered remains of plants, animals, and microorganisms). Non-humic substances, consisting of carbohydrates, proteins, peptides, fats, waxes, and other recognizable biochemical compounds, can be easily broken down by microorganisms and do not persist in the soil for long periods of time (Sparks, 2003). Most soil organic matter (80-100%) is made up of humic substances, which are much more resistant to microbial attack and can persist in the soil for long periods of time (Sylvia et al., 2005). Growing concern over increasing atmospheric CO_2 levels has led to a greater interest in quantifying carbon stocks and fluxes, particularly in soils, because of the large proportion of carbon stored in soils (Schlesinger, 1997). Wetland soils have the potential for greater carbon storage and more rapid sequestration rates relative to other terrestrial soils, however they also have the potential to become a large source of greenhouse gases (CO_2 and CH_4) because of the large reserve of carbon held in these soils (Bridgham et al., 2006; Kayranli et al., 2010).

Most plant biomass is added to the soil and serves as the primary organic carbon input in soils (Schlesinger, 1997). Net primary productivity is controlled by abiotic and biotic factors, including hydroperiod (duration and frequency of saturation), nutrient availability, climate (solar radiation, air/soil temperature), salinity, soil acidity, as well as a number of other factors. While plant biomass production tends to be higher in wetlands relative to other ecosystems worldwide, there is a great deal of variability among different wetland types attributed to differences in water source, dominant vegetation, and soil type (Craft, 2001; Schlesinger, 1997). Processes regulating plant productivity are also influential on organic matter decomposition rates. Organic matter decomposition is carried out primarily by soil microbes, which use organic carbon for growth of cellular biomass (respiration). Under aerobic conditions, microbes use oxygen as the terminal electron acceptor in the oxidation of carbon compounds. Oxygen diffusivity is greatly lowered in saturated soils, and under prolonged periods of saturation (such as occurs in wetland soils) oxygen can be depleted by microbial activity. Without available oxygen, microbes utilize other electron acceptors (NO_3^-, Mn(IV) oxides, Fe(III)(hydro)oxides, SO_4^{2-}, or CO_2) in the oxidation of carbon compounds (anaerobic respiration). Anaerobic respiration is less thermodynamically favorable than aerobic respiration, and under slower decomposition rates organic matter accumulates in the soil. Higher accumulation rates can result in the formation of thick organic surface horizons and/or dark, organic-rich mineral surface horizons (Collins and Kuehl, 2001).

Barrier islands are an important and incredibly dynamic component of coastal zone ecosystems (Ritter et al., 2002). They are aligned parallel to the mainland shore and are completely separated from the mainland by bays, salt marshes, or a combination of wetland environments. Composed of unconsolidated marine sediments, the islands are typically elongate, ranging in size up to several kilometers long and less than a few kilometers wide (Davis, 1994). At the interface between marine and terrestrial ecosystems, barrier islands provide a key habitat for aquatic and terrestrial species that are dependent upon both ecosystems for portions of their life cycle and/or food sources. Freshwater ponds and wetlands found throughout the islands are a critical part of this habitat (Hall, 2005).

While there is considerable interest in soil carbon dynamics, particularly in wetlands (Bridgham et al., 2006; Kayranli et al., 2010; Sollins et al., 1996), studies of soil carbon on barrier island landscapes are relatively limited (e.g., Berendse et al., 1998; Brantley and Young, 2010; Tackett and Craft, 2010). Barrier islands tend to be quite young (Mid-Atlantic barriers are estimated to be 5000-7000 years old), and because of the particular geomorphic processes common to these landscapes, the soils are often much younger (generally less than 1000 years old) (Davis, 1994; Oertel and Kraft, 1994). While many soil development processes (such as the accumulation and translocation of clay, iron, and carbonates) occur over many thousands of years, the accumulation of organic matter is somewhat unique in that it reaches a steady state within a relatively short time frame (the first few thousand years of development, or even sooner) (Birkeland, 1999). Across a range of environments, soil organic matter tends to increase relatively quickly initially, after which the rate of increase tends to slow and carbon stocks remain relatively constant after approximately 3000 years (Schlesinger, 1990).

In regions and landscapes where soil burial is a common geomorphic process, buried soils can be a significant reservoir of sequestered carbon (even those with low carbon concentrations) because of the large volume of soil, compacted bulk densities due to burial, and extensive geographic distribution across the landscape (Chaopricha and Marín-Spiotta, 2014). Organic matter accretion and burial processes have been cited as a primary reason for high carbon sequestration rates in coastal wetlands (Brevik and Homburg, 2004). There are a number of geomorphic processes affecting barrier island landforms, such as island migration, storm overwash, inlet dynamics, and aeolian sand movement, which can result in sometimes frequent depositional or erosional events. These processes have the potential to bury or expose soils and organic carbon, making these soil geomorphic processes important in consideration of carbon cycling in these landscapes.

While barrier island soils are generally thought of as being limited in terms of soil development, their young age provides an opportunity to study organic matter during this rapid early stage of accumulation. Controls on organic matter accumulation in barrier island landscapes have received little attention in the literature, despite the potential of these systems for rapid carbon sequestration because of their young age (particularly in the freshwater wetlands). The frequency and magnitude of burial events could allow for high sequestration rates to be maintained over a longer period of time than seen in more stable soil environments (Brevik and Homburg, 2004). The objective of this study was to document the accumulation of organic carbon and understand organic carbon dynamics in soils on barrier islands. In addition to providing greater insight into the role of these landscapes in carbon cycling, we also hope to gain a better understanding of factors affecting rates of early soil carbon accumulation.

4.3 MATERIALS AND METHODS

4.3.1 Study Area, Site Selection, and Site Descriptions

The study was conducted at Assateague Island National Seashore, MD (Fig. 4-1). Assateague Island is located along the eastern coast of Maryland and Virginia, and is jointly managed by the National Park Service, U.S. Fish and Wildlife Service, and the State of Maryland. As publicly owned land, the island is somewhat protected from human manipulation, allowing for better study of natural conditions and processes. The island is typical of Mid-Atlantic barrier islands being approximately 60 km long and generally less than 2 km wide (maximum width 4.5 km). Average annual air temperature is 13.9^{o}C, and ranges from 2.7^{o}C in the winter months to 24.5^{o}C in the summer months (Western Regional Climate Center, 2013). Average annual precipitation is 1100 mm, with fairly even distribution over the year (Natural Resources Conservation Service - Water and Climate Center, 2013). This study was focused on non-tidal, fresh to brackish wetlands, so sites were selected on the barrier core and overwash landforms of the island. Based on reconnaissance studies of the island, hydric conditions and significant organic accumulations were not present in the foredunes and beaches, so these areas were not included in the study. We also omitted sites located on the tidal marshes, since our intention was to focus on the less studied non-tidal systems.

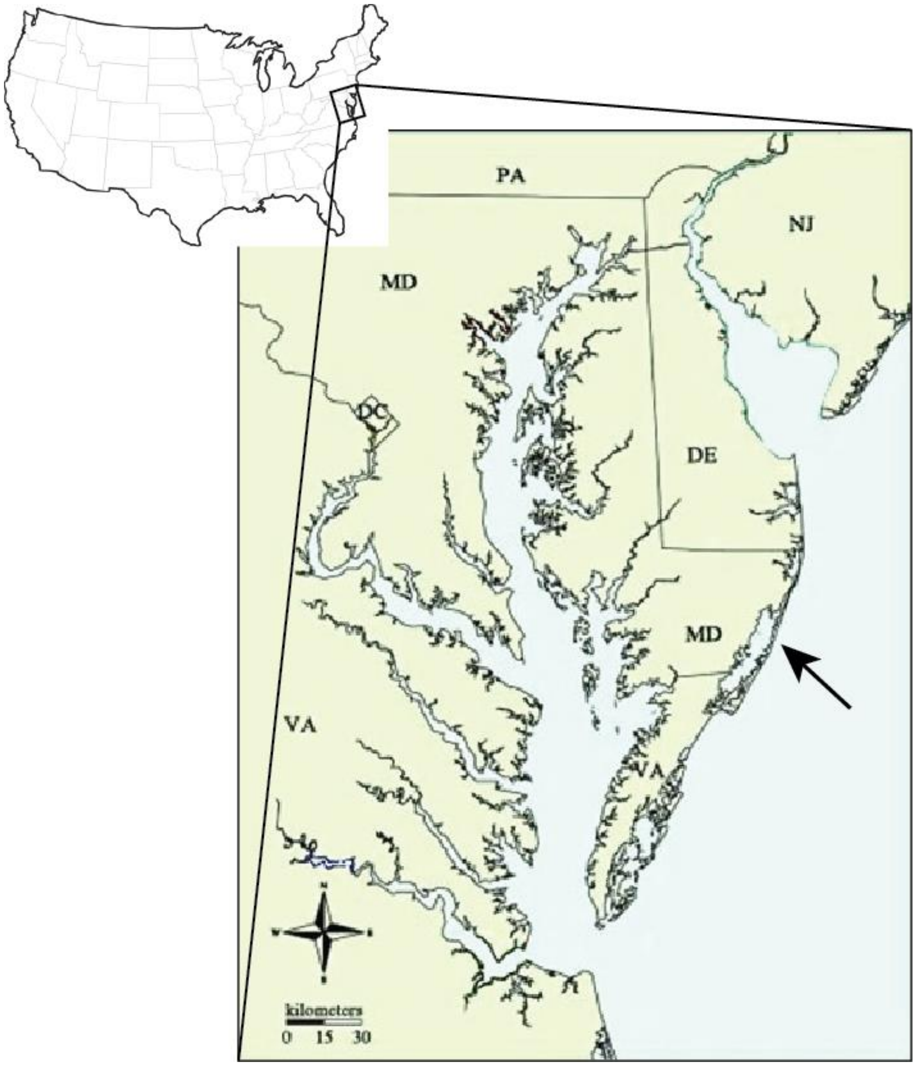

Fig. 4-1. Regional map of Maryland and surrounding states showing location of Assateague Island (indicated by arrow).

Ten study areas were selected to encompass the range of landforms and vegetation communities across the island landscape. Six study areas were located in the barrier core (BC) and four were in an overwash area (OW)[4]. At each area a topographic transect was established ranging from the most excessively or best drained soils at dune crests or summits to poorly or very poorly drained soils in swales and depressions. Along each transect, three topographic positions were identified, the high (somewhat poorly drained soils or drier), mid (somewhat poorly to very poorly drained soils), and low (poorly or very poorly drained soils) (Table 4-1). At the sites identified as somewhat poorly, poorly, and very poorly drained, soils were saturated in the upper 50 cm of the soil profile for significant portions of the year. Additionally, these soils had low chroma (< 2) matrix colors, indicative of saturated and reducing conditions, within the upper 50 cm of the surface. Very poorly, poorly, and somewhat poorly drained soils were distinguished from each other based on the proximity of the water table to the soil surface, frequency and duration of saturated conditions, and the depth at which low chroma (< 2) matrix colors were observed. In addition to having common to persistent saturation at or near the soil surface (3 to 12 months annually), very poorly drained soils often had organic horizons at the surface. Moderately well and excessively drained soils were much drier, with the water table rarely rising above 50 cm and low chroma matrix colors

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[4] Landforms and geomorphic characteristics are discussed in more detail in Chapter 3 of this dissertation.

Table 4-1. Characteristics of study sites at Assateague Island National Seashore, MD, USA.

Transect	Landform[†]	Topographic Position	Age[‡]	Drainage Class[§]	Median Water Table	Average Electrical Conductivity[¶]
					m	dS m^{-1}
BC1	Barrier Core –	Low	101	VP	-0.02	3.2 (2.1)
	Dune Field	Mid	101	VP	-0.14	4.7 (1.7)
		High	101	MW	-0.64	1.7 (2.1)
BC2	Barrier Core –	Low	148	VP	0.03	5.5 (4.1)
	Dune Field	Mid	148	VP	-0.09	6.2 (2.8)
		High	148	MW	-0.46	4.7 (2.1)
BC3	Barrier Core –	Low	120	VP	-0.05	5.1 (3.6)
	Barrier Flat	Mid	120	SP	-0.33	3.6 (2.9)
		High	120	MW	-0.66	3.7 (2.3)
BC4	Barrier Core –	Low	144	VP	-0.16	1.9 (2.4)
	Barrier Flat	Mid	144	SP	-0.37	1.6 (1.2)
		High	144	MW	-0.69	1.1 (1.6)
BC5	Barrier Core –	Low	190	VP	-0.07	5.6 (2.5)
	Dune Field	Mid	190	SP	-0.40	5.9 (3.4)
		High	190	ED	-1.20	0.2
BC6	Barrier Core –	Low	228	VP	0.07	5.7 (2.6)
	Dune Field	Mid	228	VP	-0.07	8.9 (5.1)
		High	228	SP	-0.37	6.4 (3.1)
OW1	Overwash –	Low	12	PD	-0.16	0.9 (2.2)
	Washover Fan	Mid	12	SP	-0.37	0.9 (1.5)
		High	12	MW	-0.55	1.0 (1.7)
OW2	Overwash –	Low	42	VP	0.00	6.3 (1.7)
	Back-barrier	Mid	167	PD	-0.13	4.2 (1.3)
	Flat	High	167	MW	-0.53	1.4 (1.5)
OW3	Overwash –	Low	54	VP	0.01	6.4 (0.7)
	Back-barrier	Mid	148	VP	-0.15	5.0 (0.5)
	Flat	High	148	MW	-0.65	2.0 (2.4)
OW4	Overwash –	Low	12	PD	-0.23	7.0 (8.0)
	Washover Fan	Mid	12	SP	-0.35	3.1 (2.3)
		High	12	SP	-0.44	4.9 (5.3)

[†] Landforms were defined using terminology of Schoeneberger and Wysocki (2012) and Morton et al. (2007).
[‡] Age of soil surfaces was determined by comparisons of historical aerial photos of Assateague Island (sites younger than 60 years) or by Optically Stimulated Luminescence (OSL) dating techniques.
[§] Drainage Classes: ED = Excessively drained, MW = Moderately well drained, SP = somewhat poorly drained, PD = poorly drained, VP = Very poorly drained. Given the young age of these soils, redoximorphic features (e.g., organic accumulation, redox concentrations) typically used in assigning drainage classes were not always present. Therefore, we used the frequency and duration of saturation at given depths in addition to morphological features in order to determine the drainage class.

[¶] Electrical conductivity (reported as temperature corrected specific conductance) of soil pore water was measured monthly from February 2012 through January 2013. Pore water was collected from 1.0 m deep piezometers at high and mid positions. At low positions, samples were collected from surface water (when present), 0.25 m, 0.5 m, and 1.0 m. Value presented is the average of all measurements at the low position. One standard deviation is given in parentheses. Water table at BC5H was almost always deeper than 1.0 m, so value given is not an average, but a single measurement.

occurring at deeper depths. Topographic relief across the transects was relatively small. Nevertheless, this did correspond to meaningful differences in water table depth and vegetation (species composition and density) because of the high hydraulic conductivity and low water holding capacity of these sandy soils.

Vegetation surveys were conducted at each of the transect positions in late summer 2012. Plant species present were identified and percent cover of each species was estimated in the area surrounding the site. In some instances plant communities varied dramatically across a relatively short transect due to differences in water availability associated with topography. Since we wanted to identify the plant species presence and density associated with water table depth and plant available water at each of the topographic positions, a standard sampling and surveying area could not be used for all of the transects and their respective topographic positions. Survey areas were delineated based on topography, vegetation, and soil characteristics at each position and differences between positions. Surveyed areas generally extended 3 to 10 m from the central point of the topographic position.

4.3.2 Site Instrumentation and Sampling

At each of the topographic positions, 2.0 m deep wells were installed with automatic recording data loggers to measure water table. Water table depths were measured at 12 hour intervals (6 am and 6 pm). Water level in a well was a measure of the total hydraulic head over the entire depth of the well. However, because these soils are sandy and have relatively constant hydraulic conductivity with depth, we assumed that conditions were generally hydrostatic. This was confirmed by periodic comparisons of well readings and free standing water depths. Since conditions were hydrostatic, well readings could be used as a measure of water table depth.

Piezometers were installed at all of the sites for sampling of soil pore water. Piezometers at high and mid positions were 1.0 m deep. At low positions, piezometers were 0.25, 0.5, and 1.0 m deep. When there was ponding at the surface (generally in late winter, spring, and following large storm events), surface water was collected at the low positions. Salinity was measured on water samples collected monthly February 2012 through January 2013 using a portable salinity meter (YSI Model 85, YSI Incorporated, Yellow Springs, OH).

In order to assess soil carbon stocks, three replicate 7.5 cm diameter soil cores were collected at each transect position to a depth of 50 cm using 60 cm aluminum tubes. Sharpened cores were pounded into the ground to 50 cm, and the height of the soil surface inside and outside of the cores was measured to account for any compaction. A small excavation (generally using an auger) was made around the core so the bottom of the core could be capped before it was removed from the soil. Empty space between the top of the core and the soil surface was filled with foam disks and newspaper and capped to limit disturbance and/or loss of soil during transport. Cores were frozen to limit biological activity and to facilitate extraction of continuous, intact soil cores. Soil morphology was described to a depth of 2.0 m according to the procedures of Schoeneberger et al. (2012). Soils were sampled by horizon for measurement of organic carbon in soil horizons below 0.5 m.[5]

Annual organic carbon inputs were estimated from a peak biomass harvest and litterfall collections. A biomass harvest was conducted in late summer 2012 to estimate peak herbaceous aboveground biomass of herbaceous plant species at each transect position. This method has been shown to generally underestimate APP (Kaswadji et al., 1990; Shew et al., 1981), however it was chosen because it would provide a relative comparison of APP and carbon inputs from aboveground herbaceous biomass among sites while minimizing disturbance. While plant species vary in their growth patterns, we assumed that sampling at this time would capture most species at their annual peak level of production based on previous studies conducted in nearby areas with similar vegetation (Dilustro and Day, 1997), and would best estimate aboveground biomass production for the year. At each topographic position, three 0.5 by 0.5 m plots were harvested of all aboveground herbaceous vegetation as close to the soil surface as possible. Live and dead standing plant material was separated and placed in labelled paper bags and dried at 65^{o}C to a constant weight. Biomass harvests were not conducted at the BC5 and BC6 transects because these transects are forested, and herbaceous vegetation coverage was minimal to non-existent.

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[5] Soil description and sampling methods and pedogenesis at Assateague Island National Seashore is discussed in more detail in Chapter 3 of this dissertation.

Litter traps were installed at all of the sites, with the exception of the BC3 transect. At BC3, there were no trees or shrubs at sites or in the surrounding area, and litterfall was not expected to significantly contribute to carbon inputs. Litter traps (0.5 m by 0.5 m) were constructed from fiberglass window screening. In drier transect positions, screening was placed directly on the soil surface and held in place with metal gardening stakes. For wetter locations, PVC frames were constructed to collect the litter in fiberglass screened baskets (0.5 m x 0.5 m and approximately 0.15 m deep). Baskets kept the litter off of the ground to prevent sample loss during ponding events or decomposition under moist conditions. Litterfall traps were installed in July 2012, and litter was collected seasonally (September 2012, December 2012, March 2013, June 2013, and July 2013). Litter was separated into leaf and wood components, placed in labelled paper bags, and dried at 65^{o}C to a constant weight.

Wooden garden stakes inserted in the soil were used to estimate relative decomposition rates using a standard decomposition substrate. This method is based on concepts similar to the cotton strip assay method of assessing relative decomposition rates (Harrison et al., 1988). Wooden garden stakes (12”L x 5/8”W x 1/16”T, approximately 7 g), made from New England White Birch (*Betula papyrifera*), were labelled, dried, weighed, and inserted into the soil so that the top of the stake was even with the soil surface. Four sets of five stakes each were installed at the high, mid, and low positions of three transects (BC2, BC6, and OW3) in December 2012. Sets of five stakes were extracted at each site in March, June, September, and December 2013. After collection sticks were gently rinsed, dried at 65^{o}C, and weighed to determine mass loss.

4.3.3 Laboratory Analysis

Sampled soil cores were extracted by cutting the length of the aluminum tube and then pushing the intact frozen soil core out of the tube. The length of the soil core was measured, horizons were identified, and horizon thickness was measured. The entire sample from each horizon was dried (at 65^{o}C to a constant weight) and weighed. Sampling of the entire horizon allowed for a precise determination of bulk density, since the volume of the horizon (cross-sectional area of the core multiplied by horizon thickness) and mass of the horizon was measured. This method corrects for potential errors introduced by compaction, since the same horizon thickness value is used in the calculation of soil bulk density and for determination of carbon stocks within the horizon on an aerial basis (horizon thickness multiplied by 1 m^{2} area). Samples were sieved to remove gravels, shell fragments, and larger roots and plant materials (> 2 mm). Gravel and shell fragments were weighed to determine the gravel-free bulk density; coarse fragment content was later incorporated into determination of soil carbon content on a mass per area basis.

A 2 g subsample of the dried, homogenized fine earth fraction was ground with a mortar and pestle to pass through a #60 mesh sieve (0.25 mm) and dried at 105^{o}C. Organic horizon samples were initially ground with a coffee grinder, and then with a mortar and pestle. Total carbon and nitrogen was measured by dry combustion at 950^{o}C using a LECO CHN-2000 analyzer (LECO Corporation, St. Joseph, MI) (Bremmer, 1996; Nelson and Sommers, 1996). Calcareous soil horizons were pre-treated with 5% sulfurous acid to remove calcium carbonates prior to organic carbon determinations (Balduff, 2007; Nelson and Sommers, 1996). Samples were identified as potentially calcareous by the presence of shells, reaction (effervescence) following treatment with 10% HCl, or a soil pH > 7. Carbon contents of soil horizons below 0.5 m were measured using the same method, and bulk density values estimated from soil core samples were used to calculate carbon stocks in those horizons.

Dried litter (leaf and wood material) samples were weighed to determine seasonal litterfall totals. The summer season total was the sum of the partial summer measurements from 2012 (mid-July through mid-September) and 2013 (mid-June through mid-July). For each topographic position, litter collected over the entire year was homogenized and ground using a Wiley plant mill with a 2 mm mesh screen. Approximately 2 g of the sample was ground in a coffee grinder and dried at 105^{o}C for one hour. Total carbon and nitrogen were measured by dry combustion at 950^{o}C using a LECO CHN-2000 analyzer (LECO Corporation, St. Joseph, MI) (Campbell, 1992). At sites where total collected leaf or wood litter was less than 10 g (dry weight total for the year), average percent carbon and nitrogen values were used for the calculation of carbon and nitrogen content. Herbaceous biomass samples (collected as live material) were dried, weighed, ground, and analyzed for total carbon and nitrogen according to the same procedure.

4.3.4 Estimation of Soil Age

Soil surface ages were estimated by two different methods. On the particularly young landforms (e.g. washover fans less than 60 years old) aerial photographs dating back to 1952 were examined to assess surface stability and estimate the age of soil surfaces. Large depositional events bury previous surfaces, restarting the soil development in the upper portion of the soil profile. The aerial photographs also provided documentation of changes in vegetation over the past 60 years at all of the sites.

Optically Stimulated Luminescence (OSL) dating has been used to estimate the age of relatively young, coastal deposits, and in areas where radiocarbon dating is not possible (Ballarini et al., 2003; Madsen and Murray, 2009). This technique was used to estimate surface age at all of the barrier core sites (BC) and two of the older overwash sites (OW2 and OW3). Samples were collected from the high position of the transect, with the exception of BC4, where the sample was collected at the mid position. A hole was dug to approximately 60 cm and a PVC tube (diameter 7.5 cm, length 10 cm) was hammered into the profile face (50-55 cm depth), capped, and sealed. Tubes were sent to the University of Georgia Luminescence Laboratory, Athens, GA for preparation and analysis.

4.4 RESULTS AND DISCUSSION

4.4.1 Plant Communities and Site Characteristics

Vegetation surveys were conducted in late summer 2012. Each of the sites were assigned to a Vegetation Association from the U.S. National Vegetation Classification System (Federal Geographic Data Committee, 2008) using descriptions and guides provided by the NatureServe Explorer Database (NatureServe, 2013) and Maryland Department of Natural Resources (Harrison, 2004) (Table 4-2). Variation in plant species composition and density can be attributed to a number of environmental factors, including frequency of disturbance (soil age), hydrologic conditions, nutrient availability, and water salinity (Ehrenfeld, 1990). Vegetation associations are grouped into general community types based on dominant physiognomic characteristics (Harrison, 2004). Herbaceous plant communities had greater than 25% cover by herbaceous (non-woody) plants and trees, shrubs, and dwarf-shrubs made up less than 25% of cover. Dwarf-shrublands were composed of low-growing shrubs (less than 0.5 m tall) and less than 25% cover by trees and tall shrubs. Dwarf-shrub species had greater than 25% cover, but individual shrubs were generally not touching. In shrubland communities, shrub species were usually taller than 0.5 m, and plant density ranged from relatively open to dense, closed canopies. Shrubs (including woody vine species) had greater than 25% cover. The understory was made up of herbaceous plants, but density varied among vegetation associations. Woodland and forest communities were dominated by trees, but stands were more open in woodlands (25 to 60% cover) than in forests (overlapping canopies, generally greater than 60%). Herbaceous plants were a more significant portion of the understory in the more open woodland communities than in the forests where the canopies tended to be closed.

The spatial patterning of vegetation types and the surface ages associated with each vegetation type suggested some degree of ecological succession. Vegetation on active washover fans tended to be relatively sparse and comprised of early colonizing, stress tolerant, herbaceous plants (Table 4-2). As washover fans and dunes stabilize and are better protected from sand burial and sea spray (as a result of coastal progradation and geomorphic processes) more mature plant communities can become

Table 4-2. Vegetation communities of study sites at Assateague Island National Seashore, MD, USA. Vegetation Associations were assigned from the U.S. National Vegetation Classification System (Federal Geographic Data Committee, 2008) and using association descriptions available on the NatureServe Explorer Database (NatureServe, 2013). Vegetation communities in Maryland are also described by Harrison (2004). Scientific and common names are given for each of the Vegetation Associations.

Site	Community Type	Vegetation Association	Common Name
BC1 L	Herbaceous	*Schoenoplectus pungens – Fimbristylis castanea*	Common Threesquare – Marsh Fimbry
BC1 M	Shrubland	*Morella cerifera* / *Hydrocotyle verticillata*	Wax Myrtle / Whorled Marshpennywort
BC1 H	Dwarf-Shrubland	*Hudsonia tomentosa* / *Panicum amarum var. amarulum*	Wooly Beach-heather / Coastal Panicgrass
BC2 L	Herbaceous	*Schoenoplectus pungens – Fimbristylis castanea*	Common Threesquare – Marsh Fimbry
BC2 M	Shrubland	*Morella cerifera – Baccharis halimifolia* / *Spartina patens*	Wax Myrtle – Eastern Baccharis / Saltmeadow Cordgrass
BC2 H	Woodland	*Pinus taeda* / *Morella cerifera* / *Spartina patens*	Loblolly Pine / Wax Myrtle / Saltmeadow Cordgrass
BC3 L	Herbaceous	*Spartina patens – Eleocharis parvula*	Saltmeadow Cordgrass – Dwarf Spikerush
BC3 M	Herbaceous	*Spartina patens – Eleocharis parvula*	Saltmeadow Cordgrass – Dwarf Spikerush
BC3 H	Herbaceous	*Spartina patens – Distichilis spicata –* (*Juncus roemerianus*)	Saltmeadow Cordgrass – Saltgrass – (Black Needlerush)
BC4 L	Shrubland	*Morella cerifera* / *Hydrocotyl verticillata*	Wax Myrtle / Whorled Marshpennywort
BC4 M	Shrubland	*Morella cerifera – Baccharis halimifolia* / *Spartina patens*	Wax Myrtle – Eastern Baccharis / Saltmeadow Cordgrass
BC4 H	Herbaceous	*Ammophila breviligulata – Panicum amarum var. amarum*	American Beachgrass – Bitter Panicgrass
BC5 L	Forest	*Pinus taeda* / *Morella cerifera* / *Vitis rotundifolia*	Loblolly Pine / Wax Myrtle / Muscadine
BC5 M	Forest	*Pinus taeda* / *Morella cerifera* / *Vitis rotundifolia*	Loblolly Pine / Wax Myrtle / Muscadine
BC5 H	Forest	*Pinus taeda* / *Morella cerifera* / *Vitis rotundifolia*	Loblolly Pine / Wax Myrtle / Muscadine
BC6 L	Forest	*Pinus taeda* / *Morella cerifera* / *Osmunda reglais var. spectablilis*	Loblolly Pine / Wax Myrtle / Royal Fern
BC6 M	Forest	*Pinus taeda* / *Morella cerifera* / *Osmunda reglais var. spectablilis*	Loblolly Pine / Wax Myrtle / Royal Fern
BC6 H	Forest	*Pinus taeda* / *Morella cerifera* / *Vitis rotundifolia*	Loblolly Pine / Wax Myrtle / Muscadine
OW1 L	Herbaceous	*Panicum virgatum – Spartina patens – Carex siliecea*	Switchgrass – Saltmeadow Cordgrass – Beach Sedge
OW1 M	Herbaceous	*Ammophila breviligulata – Panicum amarum var. amarum*	American Beachgrass – Bitter Panicgrass
OW1 H	Herbaceous	*Ammophila breviligulata – Panicum amarum var. amarum*	American Beachgrass – Bitter Panicgrass
OW2 L	Shrubland	*Baccharis Halimifolia – Iva frutescens* / *Spartina patens*	Eastern Baccharis – Maritime Marsh Elder / Saltmeadow Cordgrass
OW2 M	Herbaceous	*Morella cerifera* / *Panicum virgatum – Spartina patens*	Wax Myrtle / Switchgrass – Saltmeadow Cordgrass
OW2 H	Dwarf-Shrubland	*Hudsonia tomentosa* / *Panicum amarum var. amarulum*	Wooly Beachheather / Coastal Panicgrass
OW3 L	Shrubland	*Baccharis Halimifolia – Iva frutescens* / *Spartina patens*	Eastern Baccharis – Maritime Marsh Elder / Saltmeadow Cordgrass
OW3 M	Herbaceous	*Morella cerifera* / *Panicum virgatum – Spartina patens*	Wax Myrtle / Switchgrass – Saltmeadow Cordgrass

Site	Community Type	Vegetation Association	Common Name
OW3 H	Dwarf-Shrubland	*Hudsonia tomentosa* / *Panicum amarum var. amarulum*	Woolly Beachheather / Coastal Panicgrass
OW4 L	Herbaceous	*Panicum virgatum* – *Spartina patens* – *Carex silicea*	Switchgrass – Saltmeadow Cordgrass – Beach Sedge
OW4 M	Herbaceous	*Ammophila breviligulata* – *Panicum amarum var. amarum*	American Beachgrass – Bitter Panicgrass
OW4 H	Herbaceous	*Ammophila breviligulata* – *Panicum amarum var. amarum*	American Beachgrass – Bitter Panicgrass

established (Maun and Perumal, 1999). Vegetation cover and the proportion of shrub and tree species increased with soil age (Table 4-2 and Fig. 4-2a). The oldest sites were maritime forest communities with few herbaceous plant species. Similar ecological succession pathways have been observed in barrier island environments (Art, 1976; Au, 1974; Godfrey, 1976a), however a range of abiotic and biotic factors can influence the rate and direction of succession (Ehrenfeld, 1990; Olff et al., 1993; Sykora et al., 2004). As more mature plant communities become established, increases in plant biomass production can increase nutrient availability in the soil (through increased organic matter inputs to the soil) (Jones et al., 2008; Lichter, 1998). Nutrient availability is a major limiting factor for vegetation in barrier island environments (Ehrenfeld, 1990). In the absence of nitrogen fixing plants and microbes, atmospheric deposition is the only source of nitrogen on barrier islands (Ehrenfeld, 1990), which on Assateague Island averaged 14.5 kg N $ha^{-1}yr^{-1}$ from 2000 through 2012 (National Atmospheric Deposition Program, 2014). The establishment of nitrogen fixing species, notably *Morella cerifera* (wax myrtle) and *M. pensylvanica* (Northern bayberry), can further increase nutrient availability in soils, allowing for expansion of shrub thickets and forests, plant communities which may otherwise be uncompetitive in a nutrient poor environment (Brantley and Young, 2008; Olff et al., 1993). Brantley and Young (2008) measured fixed nitrogen inputs of 37 to 118 kg N $ha^{-1}yr^{-1}$ in leaf litter in *Morella cerifera* shrub thickets which substantially increased soil nitrogen relative to nearby grassland sites.

Within most transects, vegetation coverage tended to be sparser in drier (better drained) sites at dune crests compared to the dense, highly diverse herbaceous

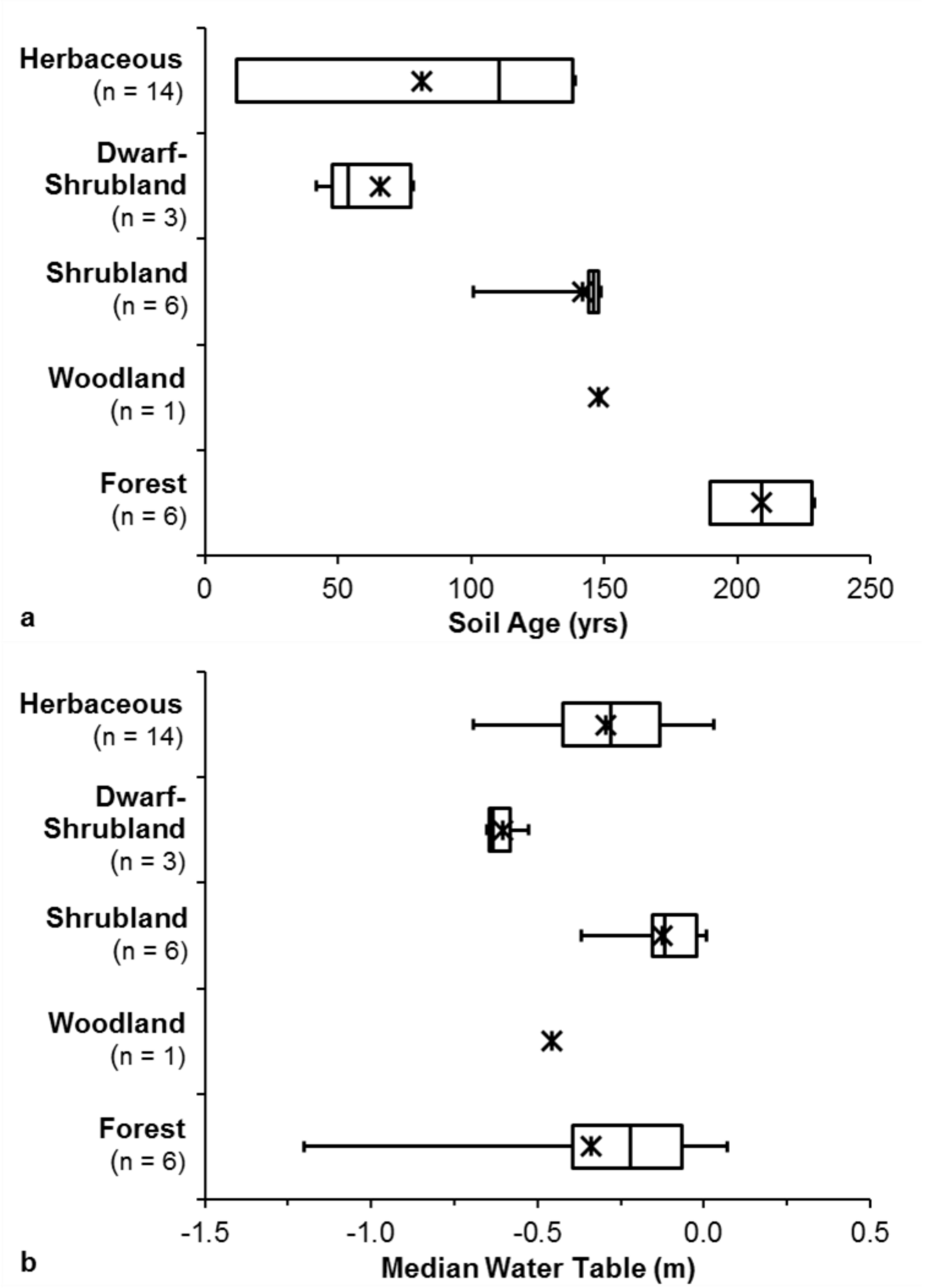


Fig. 4-2. Vegetation communities (generalized physiognomic types) of study sites at Assateague Island National Seashore, MD, USA, grouped by (a) soil age, and (b) median water table depth. The left and right sides of the box represent the 25th and 75th percentiles, respectively and the line inside the box is the median. Error bars show the range and the mean is represented by the star symbol.

communities in many of the lower (wetter) topographic positions. Species composition also changed within many of the transects, with a far greater proportion of obligate wetland and facultative wetland species in the lower topographic positions relative to the high positions. Differences in species composition were less apparent in the oldest transects, BC5 and BC6. At these transects, the plant communities, *Pinus taeda* (loblolly pine) dominated forests, were fairly uniform despite differences in the frequency and depth to saturation in the soil at each topographic position. While vegetation coverage and species presence was often influenced by water availability (proximity of the water table to the soil surface), each of the general physiognomic community types (herbaceous, dwarf-shrubland, shrubland, woodland, and forest) spanned a range of drainage conditions (Fig. 4-2b). These physiognomic community types do not consider the specific plant species present (e.g., obligate wetland herbaceous plants vs. obligate upland herbaceous plants).

While considered freshwater environments, there is a seasonal and temporally variable marine water influence in soils on Assateague Island (Hall, 2005). The average electrical conductivity of soil pore water (February 2012 through January 2013) ranged from 0.2 to 8.9 dS m^{-1} (Table 4-1). Among the four sites where water was ponded at the surface for portions of the year, average electrical conductivity was 3.6 dS m^{-1} (as salinity this would be 1.9 ppt, which would be considered oligohaline). Over the course of the year, electrical conductivity at individual sites varied significantly, on average 5.6 dS m^{-1}, suggesting that marine water intrusion occurs as pulses, generally associated with large storm events (Hall, 2005). Among all of the sites in this study, electrical conductivity of soil pore water increased on average 3.4

dS m^{-1} following Hurricane Sandy (October 2012). Influxes of marine water, and its persistence in the soil, likely influences the composition of plant species at a site, as well as biomass production (Ehrenfeld, 1990). Additionally, salinity levels can affect microbial communities and decomposition rates (Chambers et al., 2011; Rajaniemi and Allison, 2009).

4.4.2 Herbaceous Biomass Carbon Inputs

At the herbaceous, dwarf-shrubland, shrubland, and woodland sites, a biomass harvest was conducted as an estimate of peak standing biomass. Biomass harvests were not conducted at BC5 and BC6 since herbaceous plant species were sparse to non-existent in these forested transects. Herbaceous aboveground biomass (dry weight) ranged from 16 to 582 g m^{-2} among all sites (Fig. 4-3). Biomass was greatest at the wettest sites, which were the lower positions within a transect (Fig. 4-3), or sites where the median water table occurred relatively close to the surface (Fig. 4-4a). Sandy soils have a low water holding capacity, and water availability can be a major limiting factor for plant growth in these systems. Sites with a relatively shallow water table were more productive because plants were better able to access and utilize water for growth. There was no clear relationship between soil age and aboveground herbaceous biomass (Fig. 4-4b).

The average aboveground herbaceous biomass at sites on Assateague Island were similar to aboveground primary productivity measurements made along a Virginia barrier island dune chronosequence, where average productivity was 226 to 274 g $m^{-2}yr^{-1}$ (Dilustro and Day, 1997). Numerous studies have documented greater

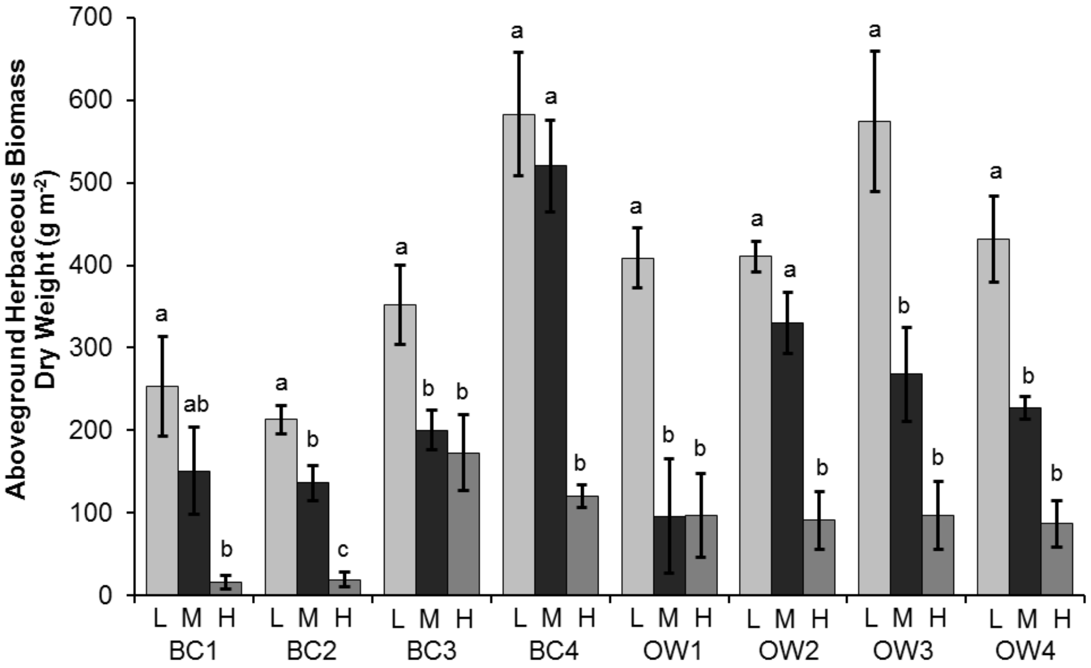


Fig. 4-3. Aboveground herbaceous biomass measured at study sites at Assateague Island National Seashore, MD, USA. Biomass was measured from a single harvest (n=3 for each transect position) conducted in late summer (approximate peak standing biomass). Transect positions, low (L), mid (M), and high (H), are indicated by shading. Biomass harvests were not conducted at the forested transects, BC5 and BC6, since herbaceous plant species were minimal to non-existent at these sites. Within a transect, biomass dry weights with the same letter are not significantly different (Tukey HSD, α=0.05). Error bars show the standard error of the mean (SEM).

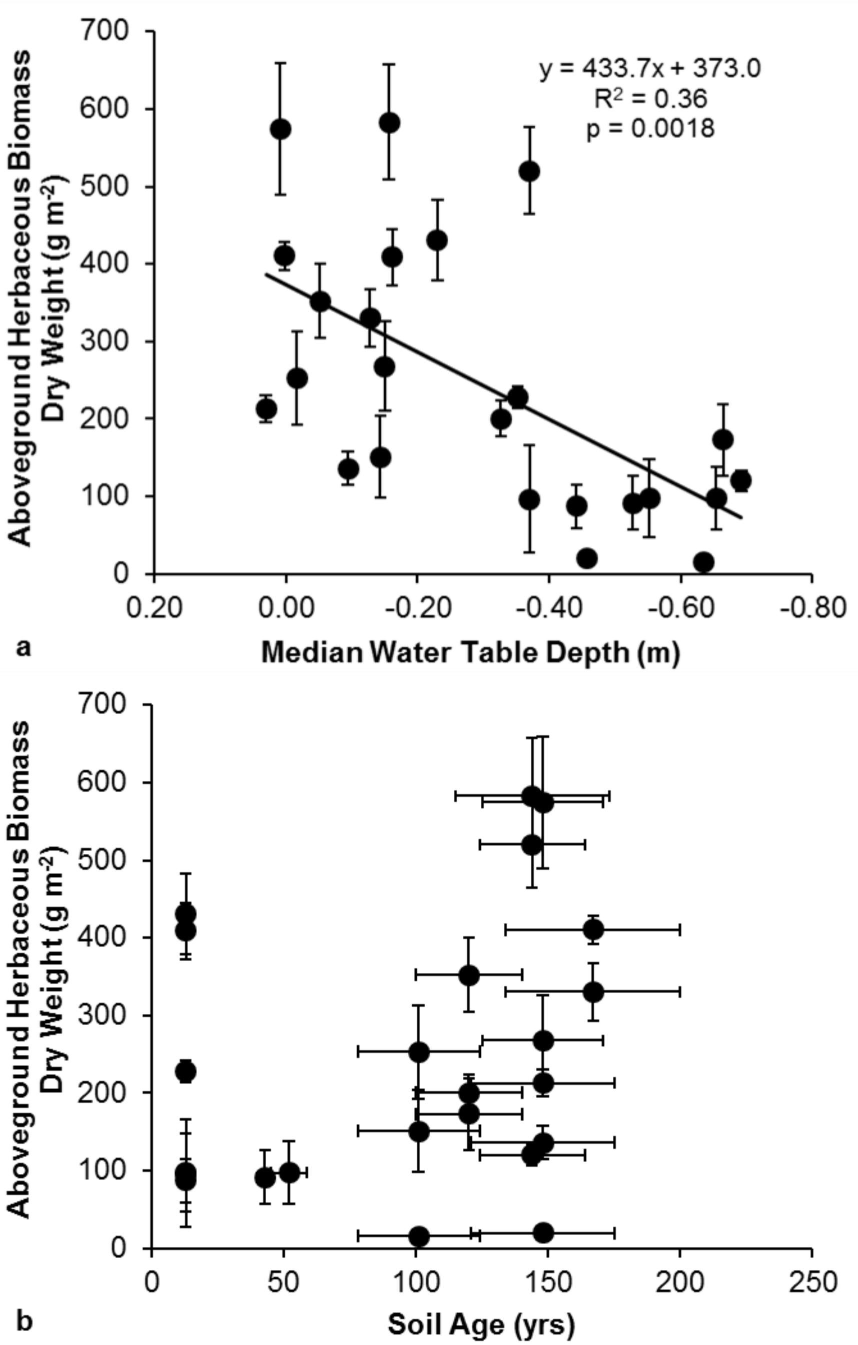


Fig. 4-4. Aboveground herbaceous biomass (dry weight) as a function of (a) median water table depth and (b) age, for 24 sites (3 topographic positions along 8 transects) in the barrier core and overwash zones of Assateague Island National Seashore, MD, USA. Aboveground biomass was measured in a biomass harvest conducted in late summer 2012. Error bars show the standard error of the mean. Water table depths at the sites were measured over a two year period from February 2011 through January 2013, standard error was too small to show on graph. Soil ages were estimated using comparisons of historical aerial photography (soils less than 60 years) and Optically Stimulated Luminescence (OSL) dating (soils over 60 years). Error associated with age estimates are shown, but in some cases too small to be visible in the figure.

levels of productivity in tidal marshes in Delaware, 516 to 1883 g $m^{-2}yr^{-1}$ (Roman and Daiber, 1984), Virginia, 399 to 1169 g $m^{-2}yr^{-1}$ (Reidenbaugh, 1983), and North Carolina, 214 to 1038 g $m^{-2}yr^{-1}$ (Shew et al., 1981). The lower values documented at our sites might be due to the differences in plant species composition, nutrient availability, and hydrology of marshes relative to the interior portions of the barrier island. Marshes are much wetter, and tend to have a greater influx of nutrients associated with diurnal tides (Craft, 2001; Mitsch and Gosselink, 2007). Among the very poorly drained soils (most similar in frequency of saturation to a tidal marsh), average live herbaceous biomass was 327 g $m^{-2}yr^{-1}$. This is still low compared to the ranges cited for tidal marshes, indicating that the limitations in nutrient availability and plant productivity associated with non-tidal wetlands (in comparison to tidal wetlands) likely had an effect on biomass production at these sites (Mitsch and Gosselink, 2007).

4.4.3 Litterfall Carbon Inputs

Litterfall was collected quarterly from July 2012 to July 2013 at all of the study sites with the exception of BC3. Vegetation at the BC3 transect was predominantly grasses, and there were no shrubs or trees in the area that would have been a source of litter. Total litterfall for the year (dry weight) varied widely among sites, ranging from less than 1 to 1395 g m^{-2} (Fig. 4-5). By dry weight, leaf litter tended to make up a greater proportion of the total litterfall, and ranged from <1 to 1087 g m^{-2}. At the forest and shrubland sites, leaf litter was 79% of the total litterfall on average, and in all but one site was the majority of litter collected. Wood litter (dry

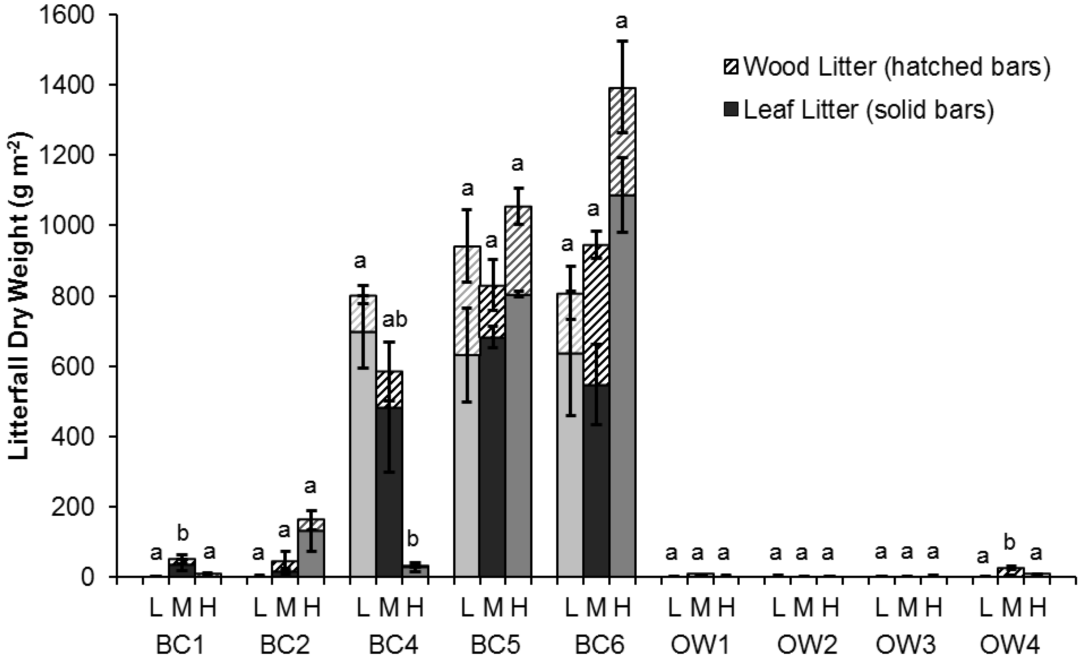


Fig. 4-5. Total litterfall collected from July 2012 to July 2013 at study sites at Assateague Island National Seashore, MD, USA. Litterfall was collected quarterly (n=3, for each collection at each transect position) and divided into leaf and wood materials. Transect positions, low (L), mid (M), and high (H), are indicated by shading. Litterfall was not collected at the BC3 transect since there were not trees or shrubs present. Within a transect, total litter dry weights with the same letter are not significantly different (Tukey HSD, α=0.05). Error bars show the standard error of the mean (SEM) for leaf and wood fractions.

weight) ranged from 0 to 398 g m^{-2} across all of the sites. In most of the transects, the total litterfall was not significantly different between the wetter and drier sites within the transect (Fig. 4-5).

Total litterfall was substantially greater at the forested sites (BC5 and BC6), ranging from 808 to 1395 g m^{-2}, than in the other vegetation communities. Similar litterfall rates, ranging from 695 to 965 g $m^{-2}yr^{-1}$ have been measured in 90-100 year old *Pinus taeda* (loblolly pine) stands in coastal South Carolina (Gresham, 1982). Litterfall among the shrubland and woodland communities was quite variable, ranging from 2 to 803 g $m^{-2}yr^{-1}$. Brantley and Young (2008) measured litterfall rates ranging from 381 to 899 g $m^{-2}yr^{-1}$ in shrub thickets on Hog Island, Virginia. The shrub communities in their study were dominated by *Morella cerifera* (wax myrtle), similar to the *M. cerifera* Shrubland communities in this study (Table 4-2, sites BC1M, BC2M, BC4L, and BC4M). The wide variation in litterfall rates among the shrubland plant communities was due to differences in species composition, plant maturity, and density of vegetation. Higher rates were measured on the *M. cerifera* dominated sites located in the barrier core than on the *Baccharis halimifolia* (Eastern Baccharis) dominated sites in the overwash areas. In dwarf-shrubland communities, plant coverage was relatively sparse, and accordingly, litterfall tended to be lower at these sites, ranging from 2 to 9 g $m^{-2}yr^{-1}$. Litterfall was also low in herbaceous plant communities (due to the lack of tree and shrub species), ranging from <1 to 30 g $m^{-2}yr^{-1}$. Litterfall collected at these sites was typically blown in from nearby trees and shrubs, usually located at higher parts of the transect or from the surrounding area. Litterfall was only collected over one year, so it is somewhat uncertain how reflective these rates are of the long term average. Hurricane Sandy hit the Mid-Atlantic coast in October 2012, and total litterfall at all sites might have been higher than average as a result of the storm (Gresham, 1982).

Unlike herbaceous biomass, at most sites annual litterfall did not vary within the transects (exceptions being transect BC1 and BC4) (Fig. 4-5), and litterfall did not show a clear trend with the depth to water table (Fig. 4-6a). Tree and shrub species tended to have deeper root systems than herbaceous grasses. Generally, roots were more common, larger in diameter, and extended deeper in the soils in the moderately well drained and drier soils under forest vegetation than in herbaceous, dwarf-shrubland, and woodland plant communities (see soil descriptions in Appendix A). Litterfall (a fraction of total biomass production) was not as sensitive to water table depth (relative to herbaceous biomass) because tree and shrub species were able to access soil water even in the drier soils. A much stronger relationship was seen between litterfall and soil age (Fig. 4-6b). The older sites had a greater proportion of tree and shrub species, and therefore, higher litterfall rates. Brantley and Young (2008) observed a decrease in litterfall rates among *Morella cerifera* (wax myrtle) shrub thickets ranging in age from 8 to 45 years. While this relationship seems contrary to our observations, we observed a continual shift in plant communities across the entire sequence. The oldest sites were maritime forest communities, dominated by *Pinus taeda* (loblolly pine), *Acer rubrum* (red maple) and other tree species. *M. cerifera*, which was common in the shrubland sites, was not present or made up a low proportion of the vegetation at the oldest sites. The continued increases in litterfall rates with soil age observed in this study is attributed to the

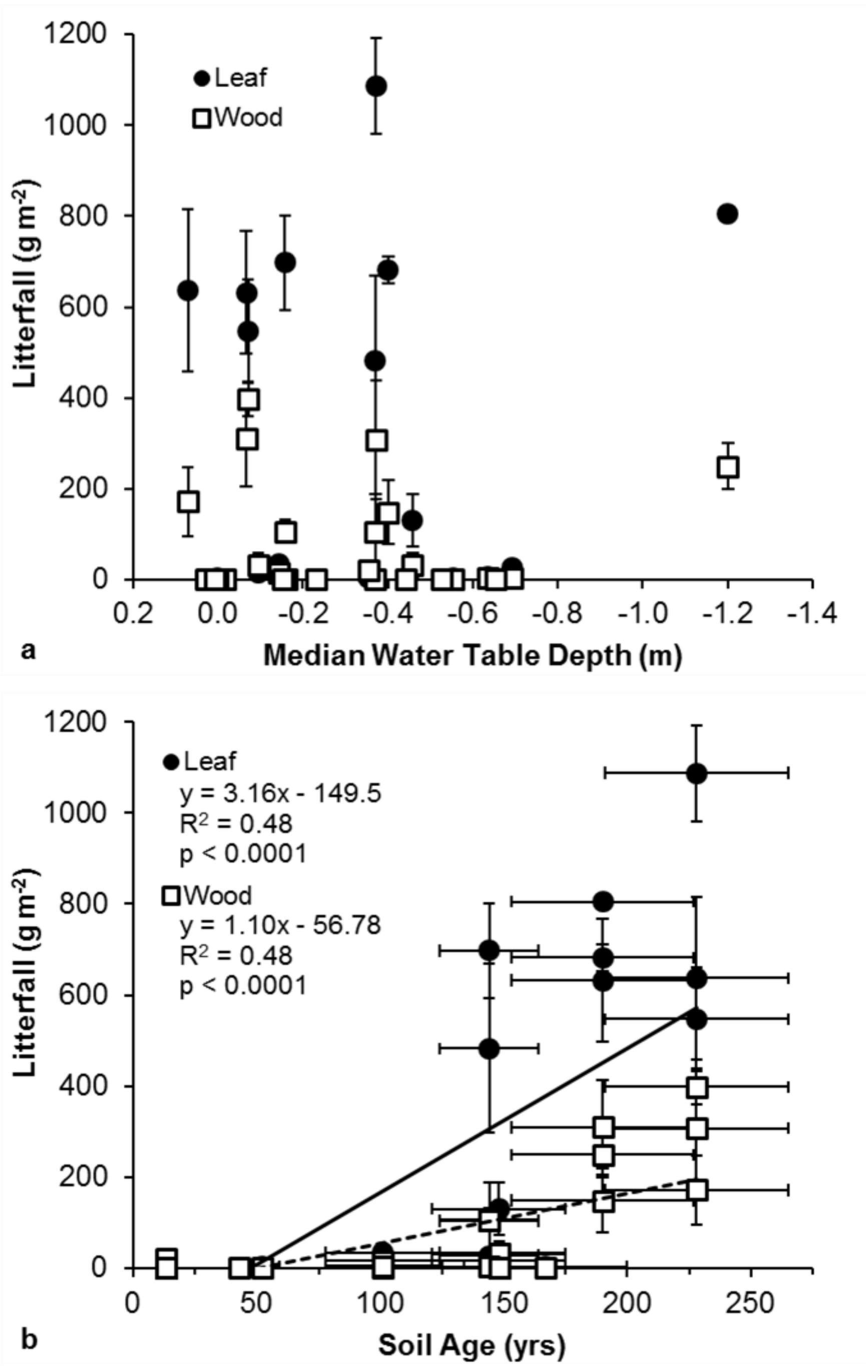


Fig. 4-6. Litterfall (dry weight) as a function of (a) median water table depth and (b) age, for 27 sites (3 topographic positions each along 9 transects) in the barrier core and overwash zones of Assateague Island National Seashore, MD, USA. Litterfall was collected quarterly from July 2012 to July 2013. Water table depths at the sites were measured over a two year period from February 2011 through January 2013. Standard error is too small to show on graph. Soil ages were estimated using comparisons of historical aerial photography (soils less than 60 years) and Optically Stimulated Luminescence (OSL) dating (soils over 60 years). Error associated with age estimates are shown, but are in some cases too small to be visible in the figure.

ongoing succession from herbaceous plant communities, to shrub dominated, and finally to tree dominated.

4.4.4 Total Carbon Inputs

Carbon content of plant material samples (herbaceous biomass, and leaf and wood litter) was measured estimate the total organic carbon inputs on an annual basis. Carbon inputs were reflective of the dry weights of the herbaceous biomass, leaf litter, and wood litter, and ranged from 7 to 689 g C $m^{-2}yr^{-1}$ (Fig. 4-7). Among the five general vegetation communities represented in this study (herbaceous, dwarf-shrubland, shrubland, woodland, and forest) total carbon inputs were greatest at the forest and shrubland sites, averaging 497 and 306 g C $m^{-2}yr^{-1}$, respectively (Table 4-3) Total carbon inputs tended to be higher at forest sites than at shrubland sites, but this difference was not statistically significant ($p = 0.0583$). The lowest carbon inputs were at the herbaceous and dwarf-shrubland sites, averaging 111 and 32 g C $m^{-2}yr^{-1}$, respectively (difference between herbaceous and dwarf-shrubland sites was not significant, $p=0.7651$). The average carbon inputs among shrubland sites was 306 g C $m^{-2}yr^{-1}$, however inputs ranged from 86 to 674 g C $m^{-2}yr^{-1}$ at these sites, owing to the wide range in plant species composition and density among the shrubland communities. Shifts in plant community composition with soil age tended to result in an increase in total carbon inputs. The proportion of carbon inputs attributed to herbaceous biomass vs. litterfall also shifted along the age sequence. While herbaceous biomass tended to increase with shallower water tables (Fig. 4-4a) this

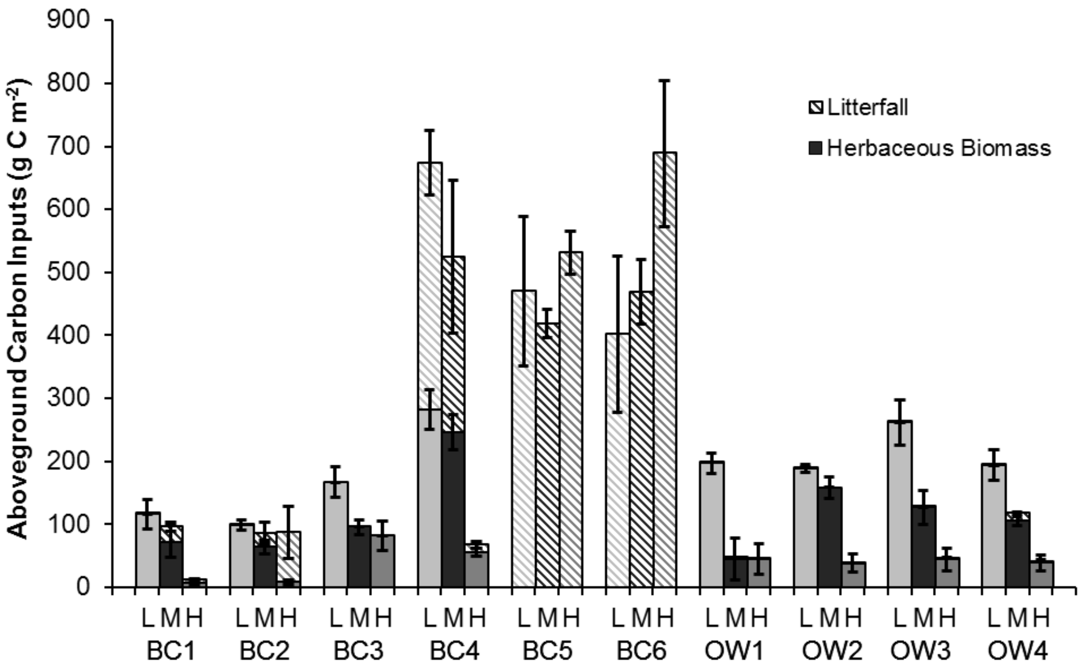


Fig. 4-7. Aboveground carbon inputs at sites along 10 topographic transects at Assateague Island National Seashore, MD, USA. Transect positions, low (L), mid (M), and high (H) are indicated by shading. Carbon inputs are divided between herbaceous biomass (solid bars) and litterfall (hatched bars). Error bars represent the standard error of the mean for each of the input types.

Table 4-3. Soil carbon inputs by plant community. Study sites were located at Assateague Island National Seashore, MD, USA. Carbon inputs are the average for each vegetation community, the standard error of the mean (SEM) is given in parentheses. Carbon inputs from each source (total, herbaceous biomass, leaf litter, and wood litter) followed by the same letter are not significantly different (Tukey HSD, α=0.05).

Vegetation Community	n	Aboveground Carbon Inputs[†]			
		Total	Herbaceous Biomass	Leaf Litter	Wood Litter
		--------------------------- g C $m^{-2}yr^{-1}$			---------------------------
Forest	6	497 (43) a	nd	367 (39) a	130 (19) a
Shrubland	6	306 (98) a	186 (39) a	99 (60) b	21 (10) b
Herbaceous	14	112 (14) b	109 (14) ab	2 (1) b	1 (1) b
Woodland[‡]	1	88	8	64	16
Dwarf-Shrubland	3	32 (10) b	30 (11) b	2 (1) b	1 (<1) b

[†] nd = not determined

[‡] Since there was only one woodland site, BC2 H, it was not included in statistical analysis.

was not the case for litterfall (Fig. 4-6a), because of the more extensive root structure and increased ability to access deeper water sources of shrub and tree species.

Within transects the relationship between total carbon inputs and median water table depth was dependent on the vegetation type at the sites (relative proportions of herbaceous, shrub, and tree species). At forested sites, carbon inputs did not vary with soil drainage class, however among the herbaceous plant communities greater total inputs were seen in the wetter soils (Fig. 4-8). Plant species comprising the dwarf-shrubland communities are mostly facultative or obligate upland species, and these communities were only described in moderately well and excessively drained soils. The shrubland sites tended to be concentrated in wetter soils (5 very poorly and poorly drained, 1 somewhat poorly drained), but varied widely in total carbon inputs and the proportion of each input type (herbaceous biomass, leaf litter, wood litter) due to differences in species composition, plant maturity, and plant density. Particularly high total carbon inputs were measured at the BC4L and BC4M sites (Fig. 4-7). High biomass production and litterfall at these sites was attributed to the nitrogen fixing contributions of *Morella cerifera* (wax myrtle), which had 10-20% cover, and a relatively open canopy that allowed for a dense understory of grasses and forbs. On the other hand, carbon inputs at OW2L and OW3L were mostly from herbaceous biomass. Dominant shrub species were *Baccharis halimifolia* (Eastern Baccharis) and *Iva frutescens* (maritime marsh elder). These shrubs were much smaller and total litterfall at these sites were minimal.

By focusing our measurements on biomass production by herbaceous (non-woody) plants (that will die over the winter) and senesced litter, we attempted to

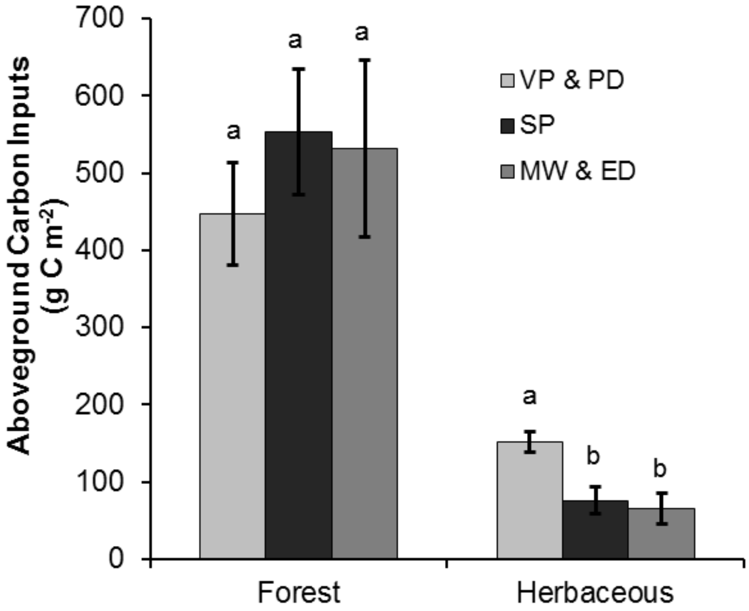


Fig. 4-8. Aboveground carbon inputs in very poorly and poorly (VP & PD), somewhat poorly (SP), and moderately well and excessively (MW & ED) drained soils in forest and herbaceous plant communities at Assateague Island National Seashore, MD, USA. Within each vegetation community, carbon inputs with the same letter are not significantly different (Tukey HSD, α=0.05). Error bars represent the standard error of the mean.

approximate aboveground production that would be incorporated into the soil annually. Our estimations of carbon inputs omitted belowground carbon inputs, which may be substantial in some plant communities. Ratios of belowground to aboveground primary productivity in salt marshes vary widely in the literature with average reported values of 1.5 in *Spartina alterniflora* (smooth cordgrass) marshes in Louisiana (Edwards and Mills, 2005), 5.5 in *S. alterniflora* marshes in Argentina (Negrin et al., 2012), and 7.2 in *S. alterniflora* and *S. patens* (saltmeadow cordgrass) Delaware Bay tidal marshes (Roman and Daiber, 1984). On the other hand, Coyle et al. (2008) measured the average aboveground primary productivity in *Pinus taeda* (loblolly pine) stands in South Carolina to be 2.7 times greater than belowground production. Similarly, Elsey-Quirck et al. (2011) found average aboveground productivity to be 3.0 times greater than belowground productivity in *Baccharis halimifolia* (Eastern Baccharis) shrubs in salt marshes in Delaware. Assuming litterfall is 60 to 70% of aboveground primary productivity in forest stands (Conner et al., 2011) and using the range of APP:BPP ratios for herbaceous (0.66-0.14) and trees and shrubs (2.7-3.0) cited in the literature we estimated potential belowground carbon inputs based on the aboveground inputs measured at each of the sites (Fig. 4-9). Total inputs at some sites were up to three times greater with the inclusion of potential belowground inputs. These estimates provide an indication of the potential magnitude of the belowground carbon inputs, however there is a great deal of uncertainty associated with these estimates. Variation in the relative proportions of root and shoot growth can vary widely with plant species, developmental stage, and resource availability (Coyle et al., 2008; Nadelhoffer and Raich, 1992; Reich, 2002), limiting

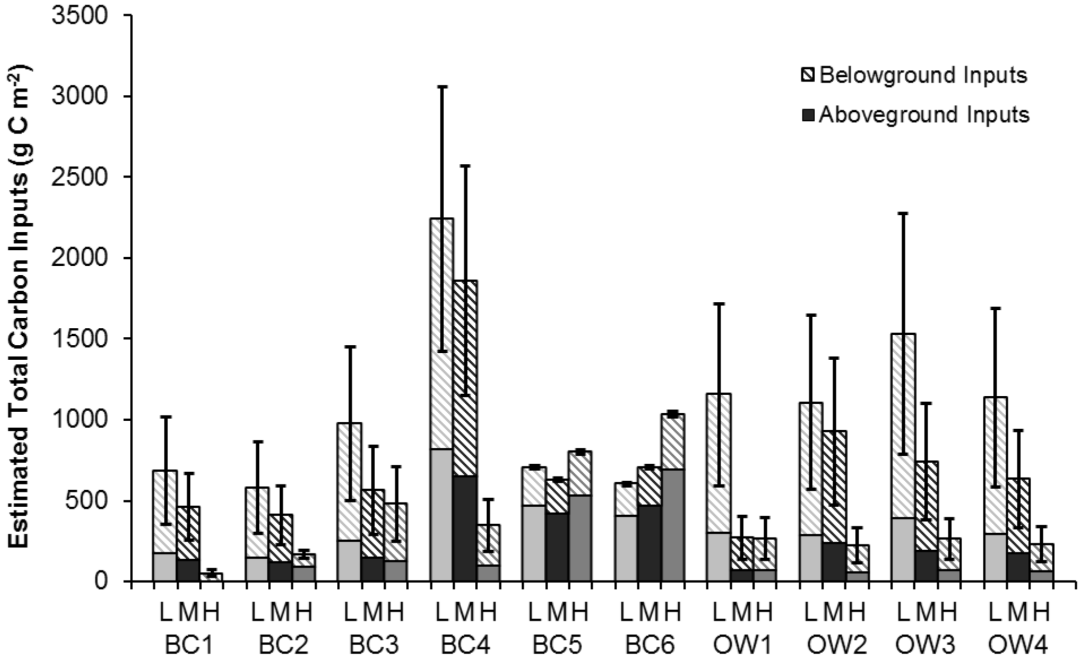


Fig. 4-9. Estimated total carbon inputs at sites along 10 topographic transects at Assateague Island National Seashore, MD, USA. Transect positions, low (L), mid (M), and high (H) are indicated by shading. Aboveground inputs were measured by a biomass harvest and litterfall collections. Belowground inputs were estimated using reported aboveground to belowground productivity ratios reported in other studies (Conner et al., 2011; Coyle et al., 2008; Edwards and Mills, 2005; Elsey-Quirk et al., 2011; Negrin et al., 2012; Roman and Daiber, 1984). Error bars represent the minimum and maximum values based on the range of ratios used in estimations.

our ability to use these ratios as an accurate indicator of actual belowground production. While our data for aboveground carbon inputs represent only a portion of the total carbon inputs, these are direct measures, and thus may provide a better estimate of relative input rates among sites.

Carbon inputs (as measured in this study) were comprised of three main components, herbaceous biomass, leaf litter, and wood litter. Herbaceous biomass included grasses and stems from annual and perennial herbaceous (non-woody) plants. Litterfall was divided into leaf litter, which included leaves and pine needles, and woody litter, which included sticks, branches, and pine cones. The C:N ratio of the wood litter ranged from 41 to 127 (average 89) and was significantly greater than ratios in the herbaceous biomass and leaf litter ($p < 0.0001$). In the herbaceous biomass and leaf litter, C:N ratios were lower, ranging from 33 to 85 (average 50, with no significant difference between the herbaceous biomass and leaf litter, $p = 0.9871$). The C:N ratios of plant tissues tend to be higher in woody materials where cellulose and lignin compounds make up a greater proportion of the plant. Nitrogen levels are generally higher in actively growing plant parts and reproductive parts, resulting in lower C:N ratios. Carbon to nitrogen ratios of herbaceous plant tissues can range from 10 to 80, depending on plant age, whereas average C:N ratios of evergreen leaves are 60 to 70, and wood tissues can have C:N ratios ranging from 130 to 400 (Singer and Munns, 2006). The inclusion of some plant reproductive parts (i.e., pine cones) with the wood litter might partially explain the somewhat lower than expected C:N ratios. It has also been shown that nitrogen fixing species, such as *Morella cerifera* (wax myrtle) tend to have lower C:N ratios. Brantley and Young

(2010) reported average C:N values of 26 in *M. cerifera* thickets. *M. cerifera* was present in many of the shrubland and forest communities, and the incorporation of those plant materials may have also contributed to the slightly lower C:N ratios for the woody litter. The range of C:N ratios within each component (herbaceous biomass, leaf litter, and wood litter) reflected the mixture of plant species among the sites and their respective nutrient status.

Aboveground carbon inputs were greatest at the forested sites (Fig. 4-7 and Table 4-3). At these sites, aboveground carbon inputs were primarily leaf and wood litter. Carbon inputs among these sites were fairly uniform within transects (i.e., not influenced by differences in median water table depth). Plant available water was not a limiting factor for tree and shrub growth because these species have deeper root systems and can access water held deeper in the soil, particularly in the better drained soils. Carbon inputs at the shrubland and woodland sites were a mix of herbaceous biomass and litterfall. The magnitude of carbon inputs from leaf and wood litter increased with soil age, as the proportion of shrub and tree species at the sites increased. In the shrubland sites, carbon inputs from herbaceous biomass were greater at the wettest sites, where shallow water tables allowed for plants to access water. Carbon inputs were lowest at the herbaceous and dwarf-shrubland sites. At these sites, total carbon inputs were primarily from herbaceous biomass, and also closely associated with soil water drainage. In the better drained soils, the water table was frequently below the reach of herbaceous plant roots and available water was low in the sandy droughty soils, restricting plant growth. Sites in the lower topographic positions (shallower median water tables) tended to have a greater density and diversity of plants and increased biomass because of increased access to available water.

4.4.5 Carbon Decomposition

Wooden garden stakes were used as a relative index of organic matter decomposition in three of the transects. The use of a standard substrate (the wooden stakes) evaluates differences in environmental controls on decomposition rates between the sites. The garden stakes were made from New England White Birch (*Betula papyrifera),* and had a C:N ratio of 400, which turned out to be much greater than the average C:N ratio of wood litter inputs measured at the Assateague sites. The high C:N ratio likely made the wooden stakes a less favorable carbon substrate for microbes and thus decomposition rates of the stakes may have underestimated decomposition rates of plant materials at these sites. Nevertheless, they did indicate relative differences in decomposition rates across transects and between sites.

Decomposition rates were compared at transects BC2, BC6, and OW3 based on weight loss of wooden garden stakes over the course of a year (December 2012 – December 2013). At all of the sites, weight loss over the first six months was minimal (Fig. 4-10). More significant weight loss was seen in the third (272 days) and fourth (364 days) collections. Colder temperatures likely limited decomposition rates in the early part of the year (Kirwan and Blum, 2011; Montagna and Ruber, 1980). Decomposition rates increased with warmer temperatures, resulting in the greater weight loss seen in the third and fourth collections (September and December). A comparison of decomposition studies by Montagna and Ruber (1980) suggests that

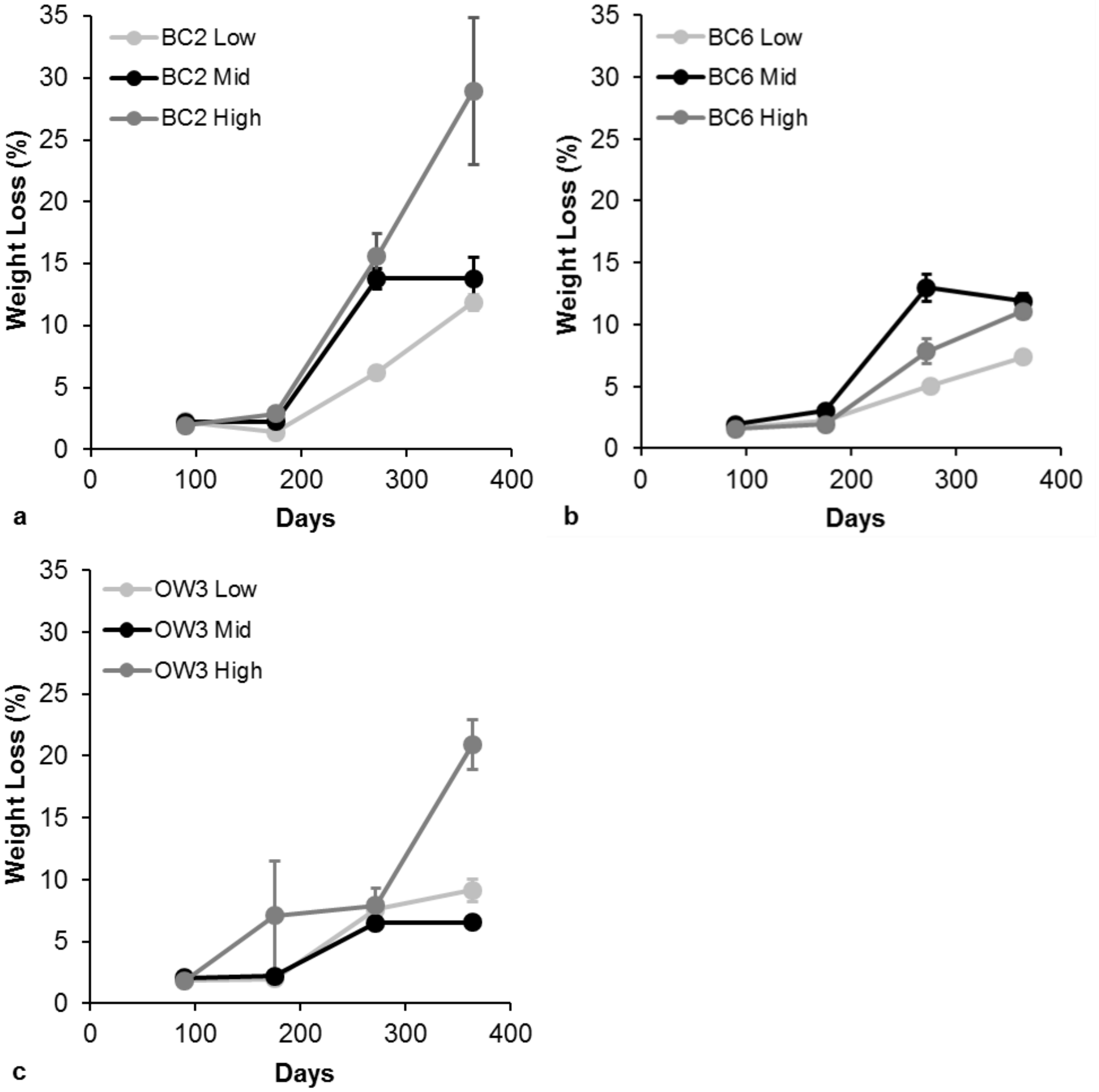


Fig. 4-10. Weight loss due to decomposition of wooden garden stakes in soils at the (a) BC2, (b) BC6, and (c) OW3 transects at Assateague Island National Seashore, MD, USA. Sticks were installed in December 2012 and removed over the course of the following year (March, June, September, and December). Weight loss is the average of five sticks for each collection period; error bars show the standard error of the mean.

the timing of organic matter additions may influence long term decomposition rates of a substrate. Organic matter showed higher initial loss rates in experiments started over the summer than in other seasons (likely due to warmer temperatures); however, loss rates remained higher for the remainder of the experiment (1 year). Herbaceous grass species, have a continual loss of leaves throughout the growing season, whereas litterfall from trees and shrubs often occurs in pulses, particularly during the fall season (Brantley and Young, 2010; Kaswadji et al., 1990; Shew et al., 1981). The timing of carbon inputs (reflective of the composition of the plant community), in addition to soil temperature, may play a role in influencing decomposition rates among sites with different plant communities.

Differences in decomposition rates among the sites were, at least in part, attributed to the frequency of saturation and development of anaerobic conditions. Relative decomposition rates (based on weight loss of wooden stakes) were greatest in better drained soils where aerobic conditions were prevalent (decreased frequency of saturation in the upper part of the soil) (Fig. 4-11). Under oxidized conditions microbial respiration (organic matter decomposition) is an aerobic process, but under prolonged periods of saturation, oxygen is depleted. Anaerobic respiration is a less favorable process and under these conditions decomposition rates are decreased. At lower positions, where the water table was frequently at or near the soil surface, reducing conditions occurred more frequently and for a longer duration, and anaerobic conditions resulted in slower decomposition rates. Conn and Day (1997) reported similar results in a litter bag decomposition study on a dune and swale chronosequence on Hog Island, Virginia.

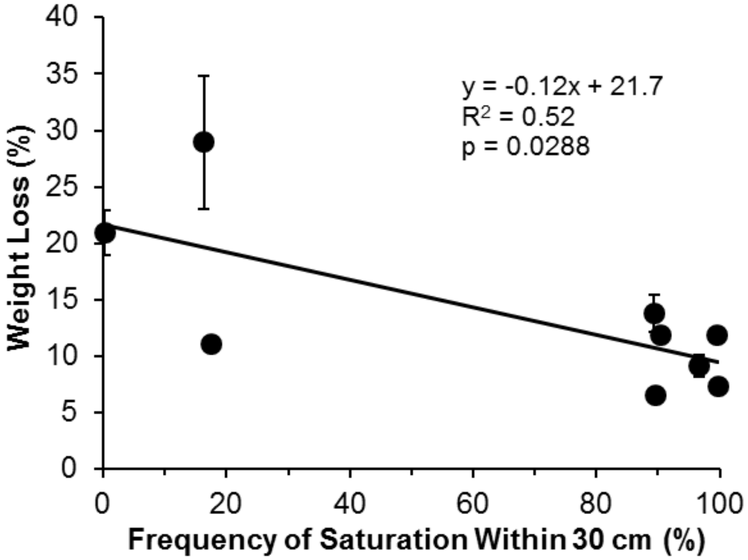


Fig. 4-11. Weight loss of wooden garden stakes as a function of frequency of saturation within 30 cm of the soil surface. Wooden stakes were inserted at nine sites (three topographic transects with three sites each) for one year at Assateague Island National Seashore, MD, USA. Weight loss serves as an indicator of relative decomposition rates among sites. Weight loss is the average of five sticks; error bars show the standard error of the mean. Water table depths at the sites were measured over a two year period from February 2011 through January 2013.

A significant interaction between transect and topographic position (p = 0.0047), suggests that there are other factors influencing decomposition rates (besides frequency of saturation). In young sandy dune soils, decomposition is primarily carried out by bacterial and fungal species (McLachlan and van Der Merwe, 1991). Microbial community composition has been shown to vary with age in early successional systems due to changes in energy and carbon inputs (both in the form of light and organic matter) and microecological interactions (Nemergut et al., 2007). Litter quality (e.g., nitrogen, phosphorus, and lignin contents, C:N ratio, lignin:N ratio, etc.) has been shown to play an important role in decomposition rates in coastal dune soils, however its influence is complex and cannot always be explained by a single factor (Conn and Day, 1997; Zhang et al., 2008). In general, herbaceous leaf litter decomposes more readily than leaves from deciduous and coniferous trees, and faster than bark and wood litter (Zhang et al., 2008). The proportion of wood and non-wood carbon inputs at each site likely has an effect on decomposition rates because of differences in litter quality. Factors affecting availability of organic carbon at each site, such as soil moisture, salinity, nutrient availability, plant species present, and plant density and productivity, can also affect microbial community biomass and composition (Rajaniemi and Allison, 2009). As these factors change, due to ecological succession or episodic events (overwash deposition) there can be changes in microbial community, and therefore, decomposition rates. The interaction of these factors and variation in their relative importance among sites can make it difficult to identify a single indicator driving decomposition rates. For example, Conn and Day (1997) found litter quality influenced decay rates in aerobic barrier island dune soils, but in nearby swales, differences in litter quality had little to no effect, and decay rate was regulated by environmental controls (e.g., frequency of saturation).

4.4.6 Soil Organic Carbon Stocks

Soil organic carbon stocks were calculated to a depth of 50 cm for each of the sites and ranged from 0.32 to 10.3 kg C m^{-2} (Fig. 4-12). Within a transect, carbon stocks were generally greater (with the exception of the BC6 transect) in lower (wetter) topographic positions. There were also significant differences in the carbon stocks between transects, suggesting that in addition to water table depth and plant available water, other factors have an influence on soil organic carbon. Soil carbon stocks were markedly greater in the older, forested transects (BC5 and BC6) (Fig. 4-12). Organic horizons were described in many of the very poorly, poorly, and somewhat poorly drained soils (low and mid positions), and often comprised a significant portion of the total carbon stocks in the soil. In the forested transects, organic horizons were described across all topographic positions, and made up a substantial portion of the total stocks in the low and mid positions.

Soil carbon stocks at Assateague Island were initially calculated to 0.5 m, since some of the soils were shallow (less than 0.5 m to a buried surface). While this was more suitable for comparisons among the Assateague sites, most studies evaluate carbon stocks to 1.0 m. In order to make comparisons with other studies, average bulk density values were used to calculate carbon stocks in horizons from 0.5 to 1.0 m. Soil carbon stocks (0-1.0 m) ranged from 0.49 to 12.3 kg C m^{-2}. Using a global soil pedon database, Kern (1994) estimated soil carbon stocks (0-1.0 m) for different

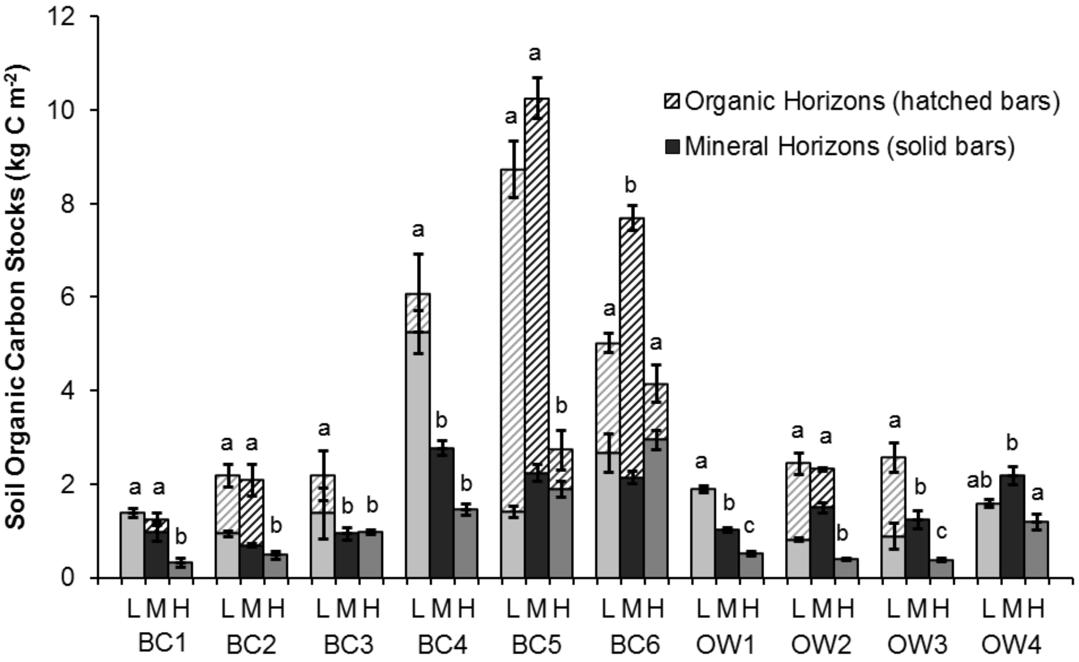


Fig. 4-12. Soil organic carbon stocks (0-0.5 m) of soils along ten topographic transects on Assateague Island National Seashore, MD, USA. Stocks are the average of three sample cores collected at each of the transect positions. Transect positions, low (L), mid (M), and high (H) are indicated by shading. Carbon stocks are divided between the mineral horizons (solid bars) and, when present, organic horizons (hatched bars). Within a transect, total soil carbon stocks followed by the same letter are not significantly different (Tukey HSD, α=0.05). Error bars represent the standard error of the mean.

ecosystems, including forests (10.9 to 15.9 kg C m^{-2}), grasslands (8.4 to 12.4 kg C m^{-2}), and marshes, swamps, and littoral regions (5.3 to 124.0 kg C m^{-2}). Higher carbon stocks (0-1.0 m), of 29.3 kg C m^{-2} were documented by Nielsen et al (2010) on a beach ridge chronosequence in Denmark in soils ranging from 1500 to 3000 years old. The soil carbon stocks at Assateague Island tend to be low compared to world-wide averages; this may in part be related to the relatively young age of the soils (less time for organic carbon to have accumulated) and limited nutrient availability (quartz-rich sand mineralogy) in these soils (lower plant productivity). Syers et al. (1970) measured soil organic carbon on a sand dune chronosequence in New Zealand where stocks (0-1.0 m) increased from 0.59 to 21.0 kg C m^{-2} over the first 10,000 years of soil development. The carbon stocks in soils at Assateague were on the low end of this range, but the Assateague soils were also young compared to many of the soils included in the New Zealand chronosequence. Some of the sites at Assateague Island National Seashore had carbon stocks exceeding soils on the 50 and 500 year old dunes (1.96 and 4.69 kg C m^{-2}, respectively) in the study by Syers et al. (1970). Climatic factors may also help account for the differences between these studies. The oldest, forested soils in this study, BC5 (190 years) and BC6 (228 years) had carbon stocks approaching the range given for forest soils by Kern (1994), and averages given for U.S. soils (0-1.0 m), 13.6 kg C m^{-2}, and Entisols in the U.S., 10.2 kg C m^{-2}, by Wills et al. (2013). In comparison, the younger sites and those with sparse vegetation on Assateague Island had relatively low carbon stocks.

Soil organic carbon accumulation is dependent upon organic inputs (plant biomass) and losses (decomposition) from the soil. When decomposition rates are low relative to the amount of organic matter added to the soil (through plant biomass production), soil organic carbon increases. Over time, total soil carbon stocks increase as inputs exceed losses through decomposition. Comparison of accumulation rates, rather than soil carbon stocks, constrains time as an influence on the quantity of soil carbon in the soil. Long term average accumulation rates for each site were calculated by dividing total carbon stocks by the age of the soil. Although carbon input, decomposition, and accumulation rates have likely fluctuated over the course of soil development, this still provides a relative measure for comparison of sites. In general, higher carbon accumulation rates were observed at sites with greater inputs (Fig. 4-13a). The positive relationship between inputs and accumulation rates was observed across all the sites, but within plant community types the response was less straightforward. Among herbaceous plant communities ($n = 6$), there was a positive relationship between carbon accumulation rates and inputs (Fig. 4-13a). However, there was no significant response in the dwarf-shrubland ($p = 0.3918$, $n = 3$), shrubland ($p = 0.1035$, $n = 4$), and forest ($p = 0.2751$, $n = 6$) communities. There was only one woodland site in this study, so the relationship between inputs and carbon accumulation rates could not be evaluated. The lack of a response in these communities may partly be an artifact of the lower number of sites in the sample set, particularly in the dwarf-shrubland ($n = 3$) and shrubland ($n = 4$) sites. The lack of a response was particularly noticeable in the plant communities dominated by trees and shrubs, where litterfall was the dominant carbon input (i.e., forests), suggesting that in these settings, carbon inputs are less of a controlling factor on carbon accumulation rates. In addition to inputs, carbon accumulation is also driven by decomposition

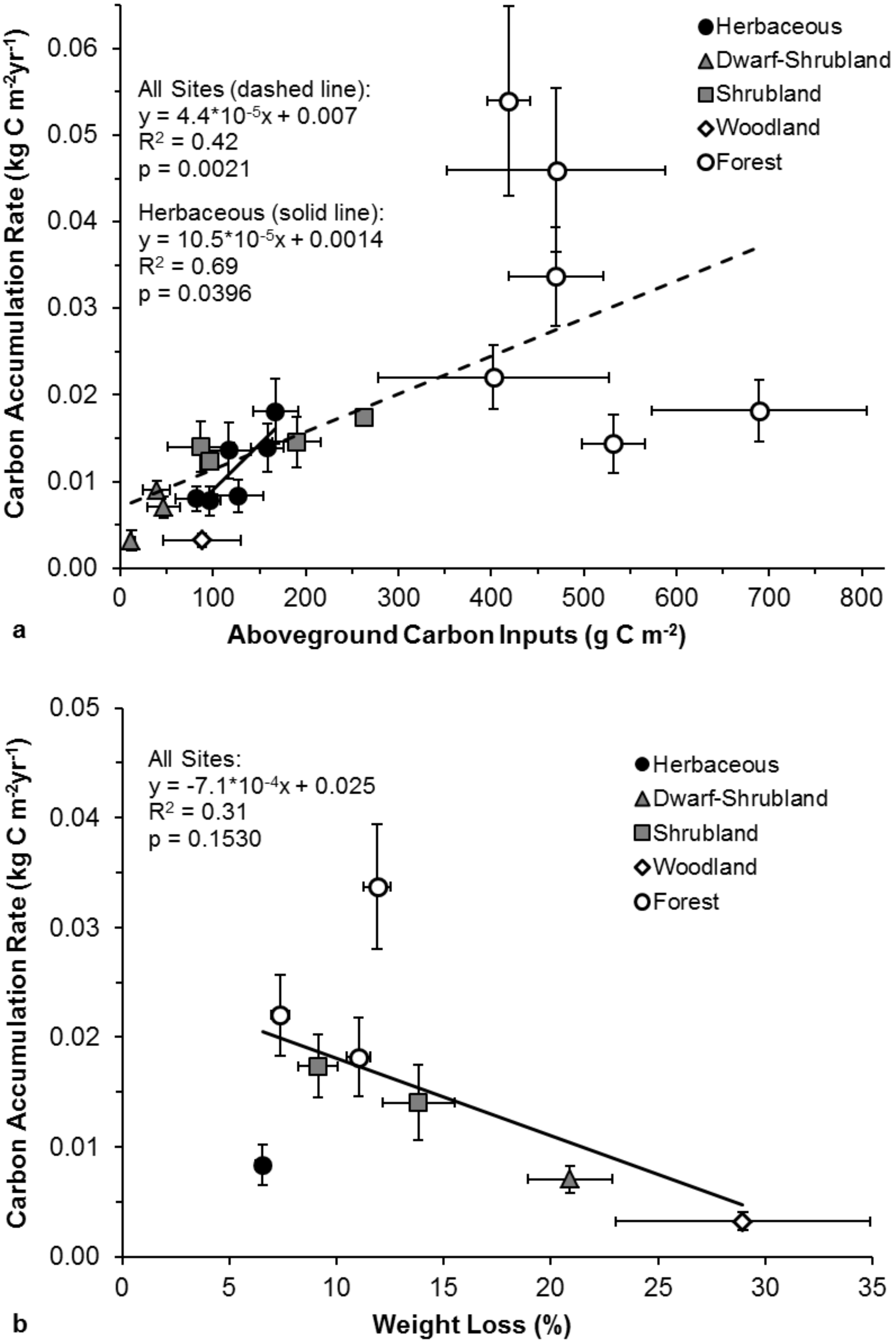


Fig. 4-13. Influence of (a) carbon inputs and (b) relative decomposition rates (measured as wooden stick weight loss) on carbon accumulation rates in soils at Assateague Island National Seashore, MD, USA. Sites are grouped according to plant community type (indicated by symbols).

rates. Carbon accumulation rates tended to be lower in sites where organic matter decomposition was high (measured using the wooden stake assay), although this relationship was not statistically significant (p=0.1530) (Fig. 4-13b). The response in individual plant communities could not be evaluated because of the low number of sites within each community type (relative decomposition rates were studied in only nine of the soils). Higher decomposition rates were observed in the drier soils where aerobic conditions allow for more rapid decomposition of organic carbon (Fig. 4-11), resulting in decreased accumulation of carbon.

In sites where vegetation was predominantly herbaceous, biomass and estimated carbon inputs tended to be greater at wetter sites where soil moisture was less apt to be limiting (Fig. 4-4a) and as a result, these sites also had higher carbon stocks than the better drained soils. At the very poorly and poorly drained sites, decomposition rates were slowed under saturated and reducing conditions as microbes utilized anaerobic respiration pathways. The higher carbon stocks seen at these sites were attributed to both higher carbon inputs and slower decomposition rates relative to their drier counterparts. For example, aboveground biomass production was greater at OW3L (very poorly drained) than at OW3H (moderately well drained) (Fig. 4-3). Relative decomposition rates (based on stake weight loss) were decreased at the low position relative to the high (Fig. 4-10c). As a result of high inputs and low loss rates, organic carbon stocks were higher at the low position than at the high (where inputs were lower and decomposition rates were higher) (Fig. 4-12).

Over time, organic carbon will accumulate in the soil as long as losses through decomposition are offset by inputs. Accordingly, soil carbon stocks will increase with soil age. At Assateague Island, plant species composition tended to shift towards shrub and tree dominated plant communities with increased soil age (Fig. 4-2). The shift towards more mature plant communities coincided with increases in total carbon inputs. This transition establishes a feedback loop, with increased nutrient availability in the soil (due to increased organic matter) allowing for the establishment of less stress-tolerant plant communities with higher biomass production, which can result in even greater carbon inputs.

In the older forested sites (transects BC5 and BC6), carbon inputs were not influenced by water table depth (Figs. 4-7 and 4-8) because the tree and shrub species at these sites were able to access water at greater depths, and water availability was not limiting to growth. However, water table depth did influence decomposition rates. Lower decomposition rates were seen at the low position of the BC6 transect than at the mid or high positions (Fig. 4-10b). Higher decomposition rates under aerobic conditions at the drier positions resulted in lower carbon stocks relative to the low positions within these transects (Fig. 4-12), while plant production (litterfall) had less of an impact.

Relative decomposition rates indicated by the stakes were likely more representative of decomposition of belowground carbon inputs than of aboveground inputs. Higher decomposition rates have been measured in buried litter relative to surface litter (McLachlan and van Der Merwe, 1991). While not directly measured in this study, belowground carbon inputs are often a large proportion of total carbon inputs, particularly in herbaceous plant communities (Schlesinger, 1997). The relative proportions of aboveground and belowground carbon inputs and their respective decomposition rates may affect carbon stocks and accumulation rates among different vegetation communities. Lower carbon accumulation rates may be observed in plant communities where belowground inputs are the bulk of total carbon inputs because decomposition rates are higher relative to that of aboveground carbon inputs. However, the potential differences between plant community types and the magnitude of these effects could not be determined from this study.

Although there was no statistically significant difference in the C:N ratios among the organic matter inputs at the sites, differences in litter quality not considered in this study (e.g., lignin, total nitrogen, phosphorus, or nutrient ratios) may have also contributed to differences observed in plant production, decomposition rates, and resulting carbon stocks seen among the sites. Environmental factors, such as salinity and soil pH may also affect decomposition rates.

Organic horizons were present at many of the very poorly to somewhat poorly drained sites, and in some cases made up a substantial proportion of the total carbon stocks. Organic horizons are layers that are dominated by organic materials, and are divided into three groups, Oa (sapric), Oe (hemic), and Oi (fibric) based on the degree of organic matter decomposition (Soil Survey Staff, 2010). At the wetter sites (very poorly to somewhat poorly drained soils) organic soil horizons were highly to moderately decomposed, having muck (Oa horizons) or mucky peat (Oe horizons) textures.

Despite being similar in drainage conditions (to other low positions), the low positions at the youngest transects, OW1L and OW4L (both poorly drained), did not have Oa or Oe horizons. The OW1 and OW4 transects were both located on relatively active washover fans and the soil ages were estimated to be 13 years. Carbon inputs (predominantly herbaceous biomass) (Fig. 4-7) at these sites were equal to or greater than measured at many of the older, wet soils where organic horizons were present (e.g., BC1M, BC2L, BC2M, BC3L, OW2L, and OW2M). This suggests that at OW1L and OW4L there simply had not been enough time for sufficient organic matter to accumulate and form organic horizons.

Among the better drained soils, Oi horizons (comprised of slightly decomposed plant material) were described only at the two oldest sites, BC5H (soil age, 190 years) and BC6 H (soil age, 228 years). Plant material in Oi horizons was predominantly pine needles, leaves, and pine cones. BC5H was excessively drained and rarely saturated above 1.0 m. BC6 H was somewhat poorly drained, and while not as dry as BC5H, saturated and reducing conditions did not occur within the upper 30 cm (non-hydric). Organic carbon accumulation in these soils cannot be attributed to slow decomposition rates associated with saturated and reducing conditions as observed at the lower, poorer drained soils. Instead, carbon input rates, which were relatively high compared to the other transects (regardless of drainage) exceeded the rate of organic carbon decomposition, resulting in the formation of organic horizons at the surface.

In an attempt to estimate an average soil carbon stock value (0-1.0 m) for barrier island soils, a hydrogeomorphic map created by Krantz (2010) was used to determine the spatial extent of various landforms at Assateague Island National Seashore. Using the hydrogeomorphic map and characterization of map units detailed by Krantz (2010), transects from this study were assigned to map units of the interior portions of the island (excludes tidal marshes). An average carbon stock value for each map unit was calculated from the representative transects (Table 4-4). Based on the spatial extent of each of the map units, a weighted average for soils across the island was calculated to be 3.34 kg C m^{-2}. There were a number of assumptions that went into this calculation. Overwash areas, which were distinguished in Krantz's mapping based on the frequency of overwash, were grouped since we did not measure carbon stocks on the beach and more frequently flooded overwash areas (OW1 and OW4 had been mapped by Krantz as intermittent overwash areas). Additionally, our sampling methods (and focus on the freshwater and brackish wetlands of the island) likely resulted in oversampling of wetter soils, which have higher carbon stocks. These assumptions may have resulted in a slight overestimation of average soil carbon stocks on the island. On the other hand, our estimation of average carbon stocks was based solely on interior portions of the island and excluded the tidal marshes. According to Krantz's hydrogeomorphic map, tidal marshes (and associated landforms) make up approximately 34% of Assateague Island National Seashore (the bulk of the area unaccounted for in our calculations). Chmura et al. (2003) estimated average carbon stocks in salt marshes globally to be 39.0 kg C m^{-2}. Along the Atlantic and Gulf coasts, measures of soil carbon stocks (0-1.0 m) in tidal marshes range from 6.9 to 85.3 kg C m^{-2} (Rabenhorst, 1995). Inclusion of the tidal marshes in estimations

Table 4-4. Estimations of the range and spatial extent of soil carbon stocks across the interior portions (marshes excluded) of Assateague Island National Seashore, MD, USA. Hydrogeomorphic map units were assigned, described, and mapped by Krantz (2010), based on landforms and hydrology of Assateague Island. Representative transects from this study were used to estimate average carbon stocks for soils in each landform.

Map Unit[†]	General Characteristics	Area	Proportion of Total Area	Representative Transects	Average Carbon Stocks (0-1.0 m)[‡]	Estimated Carbon Stocks in Map Unit
		ha	%		kg C m^{-2}	Mg C
IC2	• Back-barrier overwash platforms • Protected from saltwater intrusion except during intense and moderate storms • Herbaceous/shrubland communities with salt-resistant plants	158.2	4.3	BC3, BC4	2.95	4,660
IC3/IC4	• Higher elevation sections of island • Protected from overwash • Older growth and maritime forest communities	433.7	11.8	BC5, BC6	9.39	40,702
IC5	• Highest elevation ridges • Vegetation is less dense and comprised of freshwater obligate plants	219.4	6.0	BC1, BC2	1.50	3,291
IN/WA	• Low elevation former inlets and slightly higher elevation features within the inlet (washarounds) • Saline to brackish groundwater • Zoned vegetation (along moisture and salinity gradients)	796.4	21.7	OW3, OW2	2.04	16,268

Map Unit[†]	General Characteristics	Area	Proportion of Total Area	Representative Transects	Average Carbon Stocks (0-1.0 m)[‡]	Estimated Carbon Stocks in Map Unit
		ha	%		kg C m^{-2}	Mg C
OW	- Ocean side of island - Subjected to frequent (during spring high tides and minor storms) to intermittent (stronger minor and moderate storms, 1-2 times per year) seawater overwash	760.9	20.7	OW1, OW4	1.87	14,223
Total		2,369	64.5		3.34	79,144

[†] Map units of Krantz (2010), IC = Island Core (barrier core), IN = (former) Inlet, WA = Washaround, and OW = Overwash.

[‡] Soil carbon stocks are the average across representative transects within each map unit. Carbon stocks are from 0-1.0 m and include buried soils where present.

of average carbon stocks for soils on Assateague Island would likely result in higher values than presented here.

4.4.7 Subsoil Carbon Stocks

In most of the soils included in this study, the soil profile and evidence of pedogenic processes extended below the 50 cm depth of the sampled soil cores. The majority of organic carbon accumulation was in surface horizons, with organic carbon contents ranging from 151 to 489 g C kg^{-1} and 1.1 to 142 g C kg^{-1} in O and A horizons, respectively. Due to the relatively young age of these soils, horizons with substantial organic accumulation did not extend beyond the upper 50 cm of the soil profile. In comparison, carbon contents in the Bw, C, Cg, and Cse horizons were relatively low, ranging from 0.1 to 3.6 g C kg^{-1}. While carbon concentrations tend to decrease in deeper horizons, the proportion of total carbon stock in lower parts of the profile can still be substantial because of the total volume of soil (Harrison et al., 2011; Jobbagy and Jackson, 2000; Rumpel et al., 2002).

Geomorphic processes common to barrier islands can result in relatively frequent depositional (or erosional) events (e.g., overwash deposition associated with storm surges, movement of dunes due to aeolian forces). In some cases, the deposition buries a previously stable soil surface and associated organic matter accumulations. When soil carbon stocks associated only with the current soil surface are calculated (i.e., from the soil surface to the depth of a buried surface horizon up to 2.0 m) average stocks were 2.99 kg C m^{-2} and ranged from 0.57 to 12.3 kg C m^{-2} (Fig. 4-14). Among the soils in this study, the depth to a buried surface ranged from 0.23 to over 2.0 m in depth. In most soils, the bulk (average 79.9%) of the total carbon stock was within the upper 0.5 m of the soil profile, and nearly all (average 92.5%) was within the upper 1.0 m. Using global soil databases (total of 2721 pedons), Jobbagy and Jackson (2000) estimated lower proportions of the total carbon stock in the upper 1.0 m (relative to stocks from 0 to 3.0 m), 56%, 64%, and 70% for soils in shrublands, forests, and grasslands, respectively. Comparison of these values with soils at Assateague Island was somewhat complicated by the shallow nature of some of the soils at Assateague. In some cases overwash deposits were not very deep (often less than 1 m). In these instances, measures of subsoil carbon stocks would include buried surfaces (and therefore, multiple soils), rather than a soil that has formed continuously in a uniform parent material, as in other studies that document subsoil carbon stocks. If we consider only Assateague Island soil profiles that extend 2.0 m or deeper without encountering a buried soil surface (nine soils in this study), 62.9% of carbon stocks are within the upper 0.5 m of the soil surface, and 82.6% are within the top meter. These values, while more similar to those presented by Jobbagy and Jackson (2000), still suggest that relative to other soil profiles, subsoil horizons in these soils include a lower proportion of the total carbon stocks. Given the young age of the soils, there has been less time for addition or translocation of organic matter to deeper portions of the soil profile.

Distinct, buried surface horizons were described in soil profiles (0 to 2.0 m) at all but two of the transects (BC1 and BC3), and organic carbon contents in these buried horizons were generally similar to those in surface horizons. As a result,

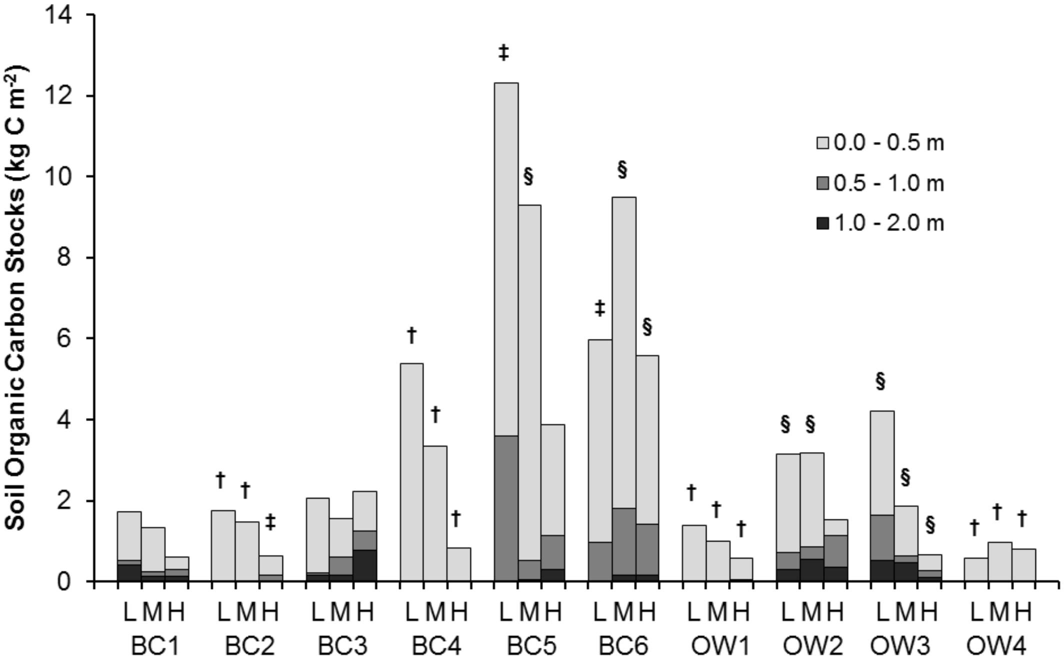


Fig. 4-14. Soil organic carbon stocks associated with the current soil surface (soil surface to the depth of a buried surface horizon up to 2.0 m) of soils along ten topographic transects on Assateague Island National Seashore, MD, USA. Soils were sampled at three topographic positions within each transect, low (L), mid (M), and high (H). Depth increments within the soil profile are indicated by shading. Symbols indicate profile depth when less than 2.0 m, † = 0.0 – 0.5 m, ‡ = 0.0 – 1.0 m, and § = 1.0 – 2.0 m.

organic carbon stocks calculated to a depth of 2.0 m (with buried soils included in calculations) were often substantially higher than those measured including only the upper 0.5 m of the soil profile (Fig. 4-15). Carbon stocks to a depth of 2.0 m ranged from 0.62 kg C m^{-2} in a soil without a distinct buried surface horizon, to 37.6 kg C m^{-2} in a soil with a thick buried marsh surface occurring 0.93 m below the soil surface. On average, only 46% of the total carbon stocks were contained within the upper 0.5 m of the soil profile, emphasizing the scale and importance of consideration of subsoil carbon stocks when estimating soil organic carbon storage in these landscapes.

Burial of a soil can result in the long term sequestration of potentially large amounts of soil carbon. Processes that slow decomposition in near-surface horizons, such as changes in soil organic matter chemical properties, soil aggregation, and sorption, precipitation, or complexation by minerals, cations, or metals, can also play a role in regulating decomposition in buried soils (Chaopricha and Marín-Spiotta, 2014; Sollins et al., 1996), but may be less important in quartz-rich sands. Environmental factors associated with subsoil environments (low oxygen diffusivity, moisture and temperature conditions, and low nutrient availability) can further limit microbial activity in subsoil horizons (Chaopricha and Marín-Spiotta, 2014), and these factors are likely present on Assateague Island. An incubation study by Fontaine et al (2007) showed that organic carbon stored in subsoil horizons (0.6-0.8 m) did not provide sufficient energy to sustain microbial activity and additions of fresh carbon sources were needed to facilitate decomposition of the carbon present, even under otherwise favorable conditions. Relatively shallow water tables in many

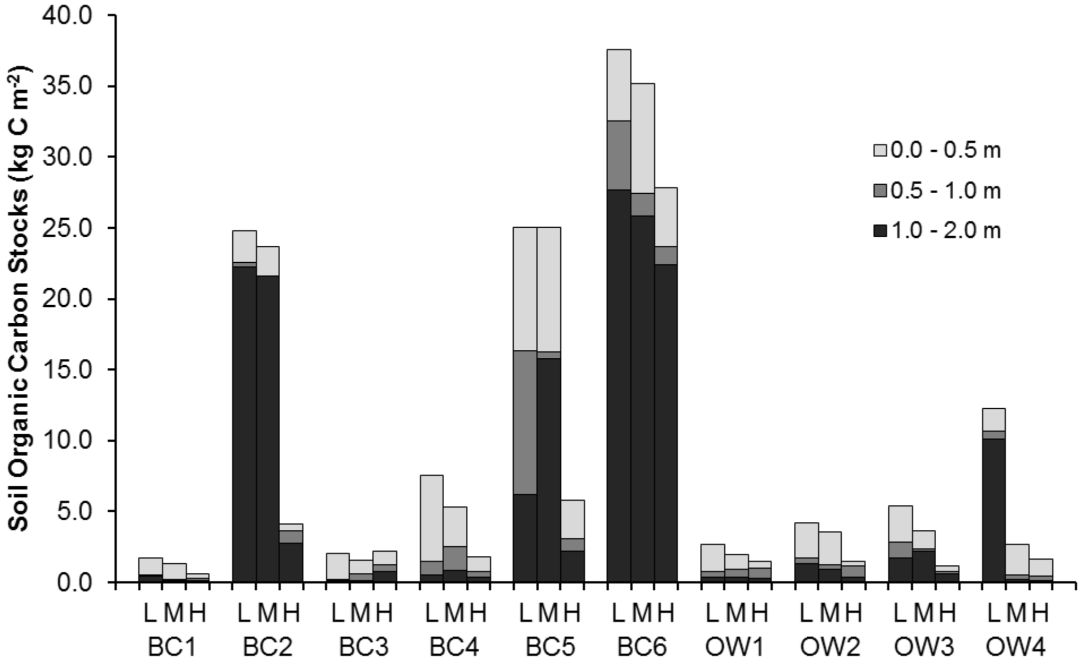


Fig. 4-15. Soil organic carbon stocks (0-2.0 m) of soils along ten topographic transects on Assateague Island National Seashore, MD, USA. Carbon stock calculations included buried soils (when present) occurring within the upper 2.0 m of the profile. Soils were sampled at three topographic positions within each transect, low (L), mid (M), and high (H). Depth increments within the soil profile are indicated by shading.

of the Assateague Island soils (and resulting low oxygen availability) further limit microbial activity with depth. Depending on the magnitude (thickness and spatial extent) of sedimentary deposits, organic matter that had accumulated on a previously stable surface could be buried deep enough that it is essentially isolated and protected from further decomposition. However, the establishment of preferential flow paths and/or root zones within the soil can connect this subsoil carbon with fresh carbon, oxygen, and/or nutrient supplies allowing for reactivation or continuation of decomposition processes (Chabbi et al., 2009; Fontaine et al., 2007). Reworking of overlying deposits by water or wind can expose previously buried deposits. A potentially large source of organic carbon, buried marsh surfaces, can be exhumed during rapid island transgression driven by sea level rise (Oertel and Kraft, 1994). Additionally, human activities which interrupt natural geomorphic processes can restrict natural burial and/or erosional processes or alter the rate at which they occur.

In this study, soil descriptions were generally made to depths of 2.0 to 2.5 m, however, stratigraphic studies on other barrier islands and coastal environments suggest that within a stratigraphic column, multiple buried soils may be present below the zone included in this study. The buried soils may represent previous marsh and lagoon deposits covered during island migration and by overwash processes (Kraft, 1971; Oertel and Kraft, 1994) or during alternating periods of stabilization and destabilization of sand dunes (Clemmensen et al., 2009; Havholm et al., 2004; Wilson et al., 2004). While barrier islands are somewhat limited in aerial extent, they do make up approximately 15% of the world’s coastlines, and 27% of the North American coastline (Glaeser, 1978; Ritter et al., 2002). Recognizing the potential recurrence and magnitude of buried soils, barrier island landscapes are a potentially significant reserve of sequestered carbon, despite having seemingly limited soil development. The frequency and magnitude of depositional events controls the amount of carbon that is potentially buried, and how protected it is from further decomposition. On the other hand, this sequestered carbon can be lost upon exposure caused by natural or human-induced landscape changes. The overall balance of these processes is an important question when considering long term organic carbon dynamics on barrier islands and in coastal environments, and their role in global carbon cycling.

4.4.8 Soil Organic Carbon Accumulation Rates

Rates of carbon accumulation were calculated for carbon stocks in the upper 0.5 m of the soil profile that was associated with the current soil surface (excludes buried soils), since the buried surfaces were older than the overlying soil. The age determined for the current soil surface was not representative of the time over which carbon accumulated in the buried soil. Soils where a buried surface was described within 0.5 m of the current soil surface (10 soils, BC2L and all three sites along transects BC4, OW1, and OW4) were excluded from the analysis to avoid potential complications caused by mixing of carbon associated with the buried soil and carbon accumulating on the current soil surface. Exclusion of soil carbon stocks below 0.5 m may underestimate accumulation rates, but since the portion of carbon stocks occurring below 0.5 m was determined to be relatively low (0 to 35%) it is assumed that their omission had little effect on these calculations.

Total organic carbon stocks were dependent on drainage (proximity of the water table to soil surface and frequency and duration of saturation) in addition to soil age, so accumulation rates were calculated separately for the relatively dry soils (moderately well drained and drier) and wet (somewhat poorly drained and wetter). Rates of carbon accumulation were greater in the wetter soils, 0.047 kg C $m^{-2}yr^{-1}$, than in the drier soils, 0.013 kg C $m^{-2}yr^{-1}$ (Fig. 4-16). These rates are greater than the range of presented by Schlesinger (1990) (0.0002 to greater than 0.010 kg C $m^{-2}yr^{-1}$) for upland soils from a range of pedogenic environments. The average long term accumulation rate of 0.002 kg C $m^{-2}yr^{-1}$ given by Schlesinger (1990), was for soils that are 3000 to 10,000 years old, and suggest that the higher rates in this study may be related to the young age of the soils on Assateague Island. On the other hand, much higher accumulation rates have been measured in young (less than 60 years) soils in urban environments, 0.082 kg C m^{-2} yr^{-1} in a soil chronosequence study in Baltimore, MD (Raciti et al., 2011). The much higher accumulation rates in that study are attributed to greater inputs due to increased nutrient and water availability in urban environments (relative to sand dunes of a barrier island).

The average rates reported by Jones et al. (2008) on a 145 year dune system in North Wales, UK were more similar to values we observed. They measured accumulation rates of 0.073 kg C $m^{-2}yr^{-1}$ in wet dune slacks and 0.058 kg C $m^{-2}yr^{-1}$ on dry dune crests. Higher accumulation rates in wetter soils have been attributed to both greater carbon inputs resulting from increased plant biomass production, and to lower decomposition rates under anaerobic conditions (Craft, 2001; Grootjans et al., 1998; Jones et al., 2008). Nielsen et al. (2010) calculated carbon accumulation rates on a

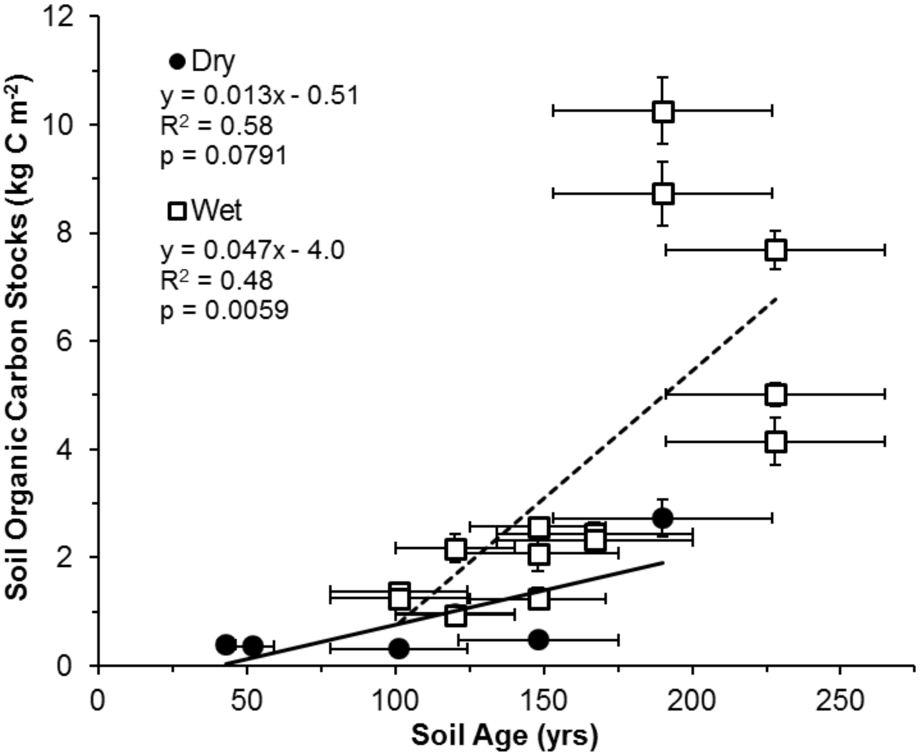


Fig. 4-16. Soil organic carbon accumulation in relatively dry (moderately well drained and drier) and wet (somewhat poorly drained and wetter) soils at Assateague Island National Seashore, MD, USA. Carbon stocks were measured to a depth of 50 cm. Error bars show the standard error of the mean. Soil ages were estimated using comparisons of historical aerial photography (soils less than 60 years) and Optically Stimulated Luminescence (OSL) dating (soils over 60 years). Error associated with age estimates are shown, but are in some cases too small to be visible in the figure.

beach ridge chronosequence in Denmark that were similar to those in the wet soils at Assateague Island, 0.0485 kg C $m^{-2}yr^{-1}$. In that study, carbon accumulation rates decreased to 0.0065 kg C $m^{-2}yr^{-1}$ in older soils (greater than 200 years) suggesting that soil carbon had approached or reached a steady state condition within the first two centuries. Higher carbon accumulation rates, ranging from 0.063 to 0.101 kg C $m^{-2}yr^{-1}$ have been measured in *Morella cerifera* (wax myrtle) shrub thickets that were 12 to 50 years old on Hog Island, VA, however nearby grassland sites (10 to 140 years) had lower average rates, 0.005 kg C $m^{-2}yr^{-1}$ (Brantley and Young, 2010). Higher accumulation rates in *M. cerifera* thickets are attributed to the nitrogen fixing capabilities of *M. cerifera* and resulting greater nitrogen availability in the soil, increasing biomass production and carbon inputs. Accumulation rates measured by Lichter (1998) on Lake Michigan sand dunes ranging from 25 to 440 years old, 0.009 kg C $m^{-2}yr^{-1}$, are similar to those of the drier soils at Assateague Island. Some of the differences reported among sites may be attributable to regional climatic differences.

In both the wet and dry soils, carbon stocks appeared to increase at a linear rate (Fig. 4-16), however previous work suggests that carbon accumulation in dune soils follows a sigmoid ("S"-shaped curve) (Jones et al., 2008; Lichter, 1998) or have an early phase of rapid accumulation followed by lower rates as carbon stocks reach a steady state condition (Nielsen et al., 2010; Syers et al., 1970) (Fig. 4-17). Initially, carbon accumulation is minimal as vegetation becomes established. Following the establishment of vegetation, organic carbon typically increases rapidly (at a nearly linear rate) before reaching a steady state condition when organic inputs are balanced by losses through decomposition (Birkeland, 1999; Schlesinger, 1990).

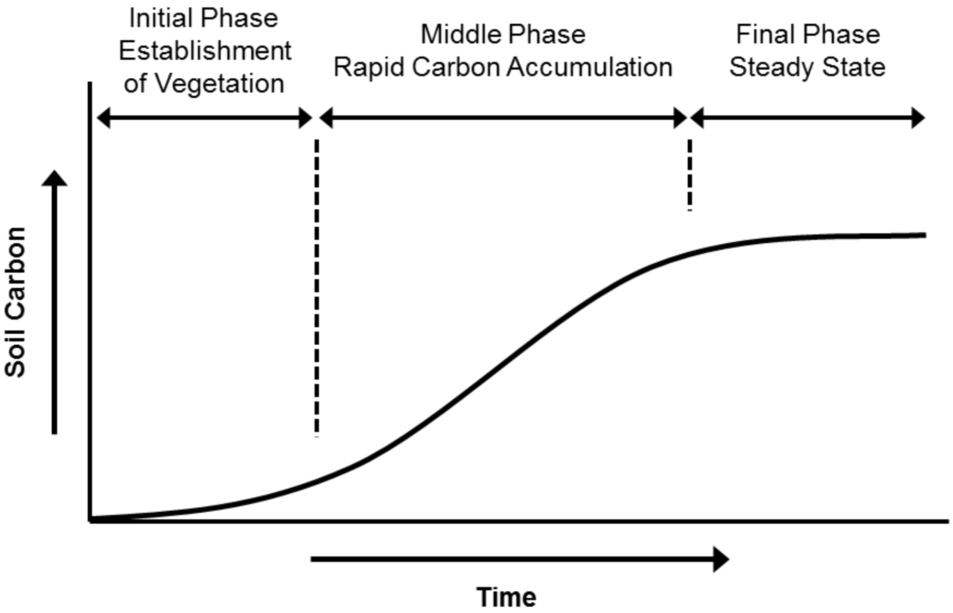


Fig. 4-17. Schematic diagram of soil organic carbon accumulation over time. Initially accumulation rates are low as vegetation becomes established. Following the establishment of vegetation, soil carbon stocks increase rapidly before reaching a steady state condition when organic inputs are balanced by decomposition.

The ages of the wet soils used in calculating accumulation rates ranged from 101 to 228 years. All of the sites were well vegetated with complete surface cover, suggesting that the sites were in the rapid accumulation (nearly linear) portion of the sigmoid curve. Accumulation rates tended to increase with soil age among the wet sites (Fig. 4-18) which served as further evidence that the steady state stage had not been reached. Based on our data, we cannot be certain the time needed to develop sufficient vegetation coverage (and increased carbon inputs) for the rapid phase of carbon accumulation to begin, since dense herbaceous vegetation was present at the youngest of these sites (101 years). Establishment of herbaceous vegetation likely occurred much earlier than this, as tree and shrub species (which would become established after herbaceous vegetation) were present in soils over 100 years old, and closed canopy forests were observed on sites older than 150 years, (Fig. 4-2a). Relatively rapid plant establishment (within 11 years), has been documented in wet dune slacks of North Wales, UK (Jones et al., 2008). Historical aerial photography of Assateague Island National Seashore was compared to look at vegetation patterns among the sites. Transect BC1 (OSL age 101 years) appeared relatively unvegetated in pictures from 1952, 1966, 1982, and 1983. Similarly, the BC2 transect (OSL age 148 years) appeared unvegetated in the 1952 and 1966 photographs. This might suggest that the initial lag phase was much longer in the Assateague soils; however the aerial photographs provide limited information. Some herbaceous vegetation may not have been apparent in the black and white aerial photographs or in pictures taken during fall and winter months. Other site conditions, such as water availability or

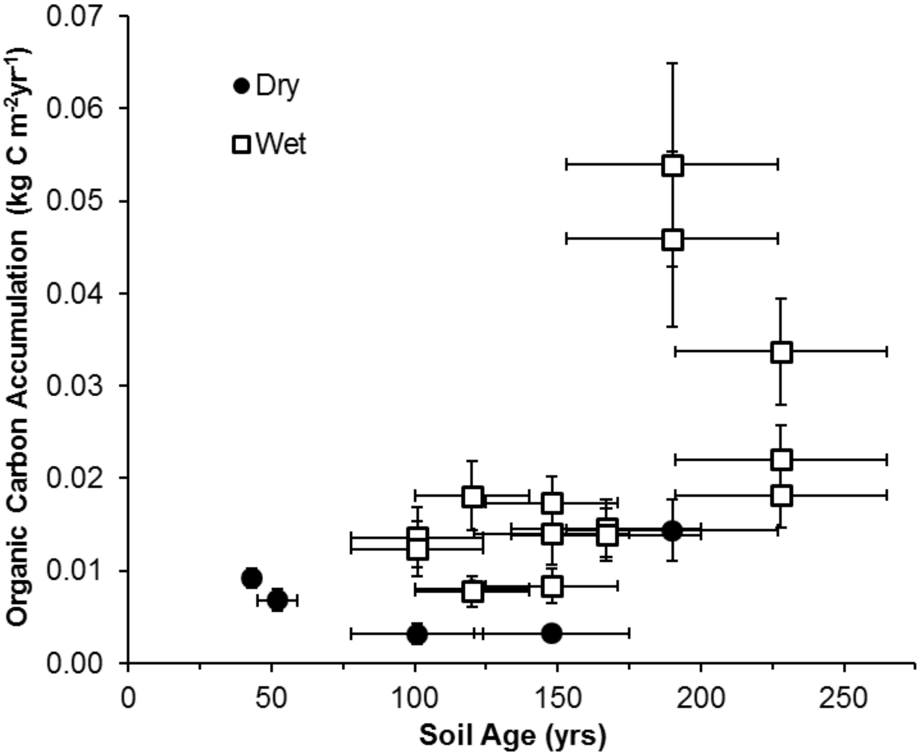


Fig. 4-18. Long term average soil organic carbon accumulation rates as a function of soil age in relatively dry (moderately well drained and drier) and wet (somewhat poorly drained and wetter) soils at Assateague Island National Seashore, MD, USA. Carbon stocks were measured to a depth of 0.5 m. Error bars show the standard error of the mean. Soil ages were estimated using comparisons of historical aerial photography (soils less than 60 years) and Optically Stimulated Luminescence (OSL) dating (soils over 60 years). Error associated with age estimates are shown, but are in some cases too small to be visible in the figure.

surface stability, may have changed over the period that appeared unvegetated, allowing for plant establishment that was previously inhibited. Based on the aerial photographs alone, we cannot determine when that change may have occurred, and the actual length of time it took for vegetation to establish under the current site conditions. During Hurricane Sandy (October 2012), 6 to 34 cm of sediment was deposited on the OW1 and OW4 transects. Dune colonizing plant species were observed on these deposits the following spring, and although vegetation coverage was sparse, it does suggest that plant establishment can occur rapidly in these environments.

The dry group of soils ranged in age from 43 to 190 years, and dense vegetation coverage was only present at the oldest site. Given the difference in vegetation and the low carbon accumulation rate (relative to the wetter sites), we believe that carbon accumulation at the drier sites was still in the initial lag period of the sigmoid curve. The carbon accumulation rates in the drier soils showed very little change across the chronosequence (Fig. 4-18). More rapid establishment of vegetation in the soils with higher water tables was likely due to higher soil moisture availability, which would favor plant growth (Jones et al., 2008). Additionally, moister conditions may also help to diminish reworking (winnowing and transport) of the soil surface by wind (Kochel and Wampfler, 1989), which otherwise might limit the establishment of many plant species. Jones et al. (2008) documented establishment of vegetation on young dry dunes within 22 years, however a number of environmental factors (e.g., salinity, climate, nutrient availability, and plant physiology) could explain these differences between that study and stabilized dunes at Assateague Island.

It does not appear that soil carbon stocks have reached a steady state condition in either the wet or dry soils. While the time at which this happens varies among soils, reviews of soil chronosequence studies across a range of environments have suggested this process occurs on average at approximately 3000 years, although up to 20,000 years has been documented in some soils (Birkeland, 1999; Schlesinger, 1990). Chronosequence studies on sandy beach and dune soils have suggested that this steady state condition could be reached even earlier, ranging from 60 to 3000 years (Jones et al., 2008; Lichter, 1998; Nielsen et al., 2010; Protz et al., 1984; VandenBygaart and Protz, 1995). However, in contrast, work by Syers et al. (1970) on a sand dune chronosequence in New Zealand suggested that soil carbon stocks had not yet reached a steady state after 10,000 years of soil development. Minor reworking of these soils by aeolian action may have allowed these soils to sustain rapid accumulation rates for a longer period of time. Total carbon stocks of the Assateague Island soils were far less than those measured for 1500 to 3500 year old soils (0-1.0 m) on beach ridges in Denmark, where carbon stocks had reached a steady state condition at 29.3±3.4 kg C m^{-2}. Accumulation rates at Assateague Island are also greater than the 0.0065 kg C m^{-2} reported for the older soils approaching the steady state condition in that study (Nielsen et al., 2010). Variations in the time to reach a steady state condition and the magnitude of soil carbon stocks at steady state conditions can be caused by a variety of environmental factors (e.g., climate, nutrient availability, plant communities, and soil parent material), but given the relatively young ages of the soils studied on Assateague Island and the trend of increasing accumulation rates with soil age, it is likely that the organic carbon levels have not yet reached a steady state condition.

Organic horizons were present in almost all of the somewhat poorly, poorly, and very poorly drained soils. Among the older sites in particular, carbon in organic horizons made up a large proportion of the total carbon stocks (Fig. 4-12). In both wet and dry soils, carbon stocks in the mineral horizons increased with soil age, 0.012 kg C $m^{-2}yr^{-1}$ (Fig. 4-19), and there was no significant difference in accumulation rates between the wet and dry soils ($p = 0.4579$). The mineral horizon carbon accumulation rate is similar to rates measured on mineral horizons of a Denmark beach ridge chronosequence, 0.013 kg C $m^{-2}yr^{-1}$ over 3000 years (Nielsen et al., 2010). While carbon stocks in the organic horizons tended to increase with soil age, this relationship was not statistically significant ($p = 0.1537$) (Fig. 4-19). Only one of the drier soils (BC5H, excessively drained, 190 years) had an organic horizon, so differences in the rate of carbon accumulation in organic horizons due to soil drainage class could not be determined. Based on the soils included in this study, it appears that in better drained soils, organic horizons do not form unless there are high litter inputs under relatively dense forest cover. Accumulation rates in mineral horizons did not differ between wet and dry soils, despite there being differences in total carbon accumulation rates. Higher total carbon stocks in the wetter soils were due to increased carbon accumulation rates in organic horizons, and did not reflect differences in accumulation rates in the mineral horizons.

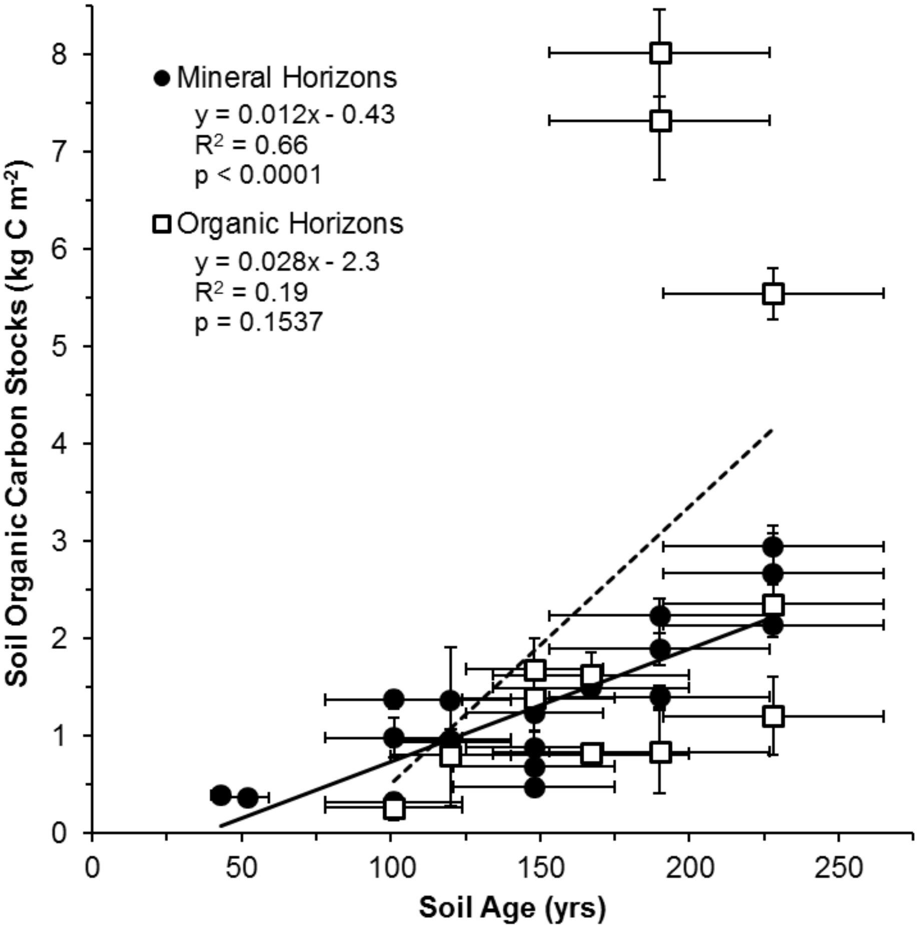


Fig. 4-19. Soil organic carbon accumulation in organic and mineral horizons of soils at Assateague Island National Seashore, MD, USA. Carbon stocks were measured to a depth of 0.5 m. Error bars show the standard error of the mean. Soil ages were estimated using comparisons of historical aerial photography (soils less than 60 years) and Optically Stimulated Luminescence (OSL) dating (soils over 60 years). Error associated with age estimates are shown, but are in some cases too small to be visible in the figure.

4.5 CONCLUSIONS

Organic carbon accumulates in soils as inputs (plant biomass) exceed losses through decomposition (microbial respiration) and represents the predominant soil development process in young soils. The manifestation of soil carbon accumulation as soil carbon stocks appears to be the result of a set of fairly complicated interactions. Carbon stocks seem to be driven primarily by carbon inputs, which are a function of plant community. In younger landscapes dominated by shallow rooted herbaceous vegetation, biomass production is enhanced by proximity of the water table and plant available soil moisture. The proximity of the water table becomes less important in older landscapes dominated by more deeply rooted forest communities. On Assateague Island, plant communities appear to change over time from those dominated by herbaceous species to shrub type species, and eventually to tree-dominated maritime forest communities. This transition could be seen across the soils included in this study, ranging from 12 to 228 years. In the young herbaceous communities, plant carbon inputs to the soil are much greater in the wet soils (located in interdunal swales and depressions), whereas in the older forested communities, carbon inputs to the soil are more uniform across the landscape, and less affected by soil moisture. Interposed on this relationship, is the effect of soil saturation on the development of anaerobic (reducing) conditions. Carbon decomposition under anaerobic conditions is a less efficient process than aerobic respiration (as occurs in upland, oxidized soils), inhibiting or slowing carbon decomposition by microbial respiration. The effect of saturation and anaerobiosis on decomposition rates would be important both in the younger herbaceous communities as well as older forest communities.

Numerous studies have demonstrated that carbon accumulation tends to follow a sigmoidal function, with initially rapid increases following the establishment of vegetation that are followed by a gradual decrease in rates as the system approaches a steady state. In most soils this process occurs over a couple thousand years. The young age of these soils (less than 228 years) would suggest that these soils are on the front edge of the sigmoidal curve. At many of the drier sites, vegetation was not yet fully established. These sites also had low carbon accumulation rates, suggesting that the phase of rapid carbon accumulation has not yet begun in these soils. On the other hand, where vegetation was denser in the wetter soils with greater plant available water, higher accumulation rates were observed. Among these wet soils, carbon accumulation rates increased with soil age and these soils appear to be in the rapid phase of carbon accumulation. The duration of this rapid accumulation phase, or at what point in time soil organic carbon will reach a steady state condition, is uncertain. Given the sometimes rapid and/or frequent changes in landforms on barrier islands, it is possible that the soils do not remain stable long enough to reach a steady state condition. Burial of soil surfaces (and accumulated organic carbon) due to overwash and aeolian forces, may restart carbon accumulation processes, maintaining the initial rapid phase of carbon accumulation over a longer period of time. Evidence of multiple burial events within the soil profile suggest that despite their young age, barrier island soils could potentially store large amounts of soil organic carbon by repeatedly burying carbon-rich surface horizons and sequestering these materials at greater depths.

CHAPTER 5: HYDRIC SOIL FIELD INDICATORS FOR USE IN BARRIER ISLAND LANDSCAPES

5.1 ABSTRACT

Hydric soils in Holocene-aged barrier island landscapes lack morphologies typically associated with saturated and reducing conditions. Furthermore, many better drained soils (non-hydric) have low chroma colors due to parent material effects, making identification and delineation of wetlands problematic. Our objective was to develop field indicators that could be used to effectively recognize hydric soils in these environments. Ten topographic transects were established at Assateague Island National Seashore, MD, USA. Transects spanned a gradient of topographic positions from dune crests to interdunal swales. Water tables and reducing conditions were monitored to determine hydric status. Soil descriptions along each transect were used to identify morphological features indicative of soil wetness. Of 16 documented hydric soils, only 5 met recognized field indicators. Hydric soils were best identified by the presence of matrix colors with chromas less than 2 in mineral soils, or the presence of at least 1 cm of muck (Oa horizon). Based on these characteristics, we propose a revision to a current indicator and a new indicator restricted for use in Holocene-aged barrier island landscapes in the Mid-Atlantic region. These indicators will allow for identification of hydric soils, improving the accuracy and ease of delineation of wetlands.

5.2 INTRODUCTION

Barrier islands are found on approximately 15% of the world’s coasts, and are particularly extensive along the eastern United States, spanning from New England, down the Atlantic Coast and Gulf of Mexico to Texas (Glaeser, 1978; Ritter et al., 2002). Barrier islands are elongate, generally up to several kilometers long and less than a few kilometers wide, and composed of unconsolidated marine sediments (Davis, 1994). Running parallel to the mainland coast, barrier islands protect the adjacent mainland, coastal bays, and marshes from storm surges and direct wave action of the ocean (Stone and McBride, 1998). As the interface between terrestrial and marine ecosystems, the islands themselves provide a key habitat for marine and terrestrial species that are dependent upon both ecosystems for portions of their life cycle (e.g., nesting, reproduction, and/or food sources). Freshwater ponds and wetlands found throughout the islands support salt-intolerant plant species and provide habitat for a number of mammalian, amphibian, reptilian, and fish species (Hall, 2005). Barrier islands have also become valuable to humans for residential, commercial, industrial, and recreational development. These developmental pressures and their potential detrimental effects on habitat have led to the preservation and protection of some barrier islands by public and private organizations. However, a number of others are still subject to private development. Recognition, delineation, and protection of freshwater wetlands on barrier islands can be difficult because of the relatively limited pedological development of the hydric soils in these young landscapes.

The Corp of Engineers has defined wetlands as “areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions” (U.S. Army Corps of Engineers Environmental Laboratory, 1987), and that definition requires the recognition of hydric soils (as well as hydrophytic vegetation and hydrology). Hydric soils are identified or delineated in the field using a set of field indicators approved by the National Technical Committee for Hydric Soils (NTCHS) and the Natural Resources Conservation Service (NRCS). The indicators are regionally specific and based on characteristic morphologies that develop in soils subjected to repeated periods of saturation and reduction (USDA-Natural Resources Conservation Service, 2010).

Prolonged periods of saturation combined with microbial activity (decomposition of organic matter) deplete oxygen and promote anaerobic respiration within the soil. Under anaerobic conditions, microbes utilize alternative electron acceptors, such as nitrate (NO_3^-), manganese (Mn(IV)) oxides, iron (Fe(III)) (hydro)oxides, sulfate (SO_4^{2-}), or carbon dioxide (CO_2). Reducing conditions, or alternating periods of reduction and oxidation of Fe and Mn compounds in the soil, lead to the formation of soil redoximorphic features. Redoximorphic features (concentrations, depletions, and reduced matrices), along with the accumulation of organic carbon or production of hydrogen sulfide (H_2S) gas, can be useful for identifying hydric soils in the field, and are the basis for the Hydric Soil Field Indicators adopted by the NTCHS and NRCS (USDA-Natural Resources Conservation Service, 2010). In the absence of morphological field indicators, or to develop or test new indicators, soil saturation can be monitored and reduction can be documented using a variety of methods (such as α,α'-dipyridyl dye, Eh measurements using Pt electrodes, or IRIS tubes) according to the Technical Standard of the NTCHS (Childs, 1981; National Technical Committee for Hydric Soils, 2007).

Identification of hydric soils on barrier islands, and in other young, sandy deposits, presents particular difficulties because these soils often do not express hydromorphic indicators as observed in other soil environments. The relatively young age of the barrier islands, the dynamic nature of the landforms on the island, and the weathering resistant mineralogy (quartz-rich sands) combine to limit soil development in these systems, and thus also limit the use of currently recognized hydric soil field indicators (Kuehl et al., 1997; Lindbo, 1997). Low amounts of Fe in the parent material results in soils with a low chroma color even under non-hydric conditions. Non-hydric soils could be erroneously recognized as hydric because of the low chroma colors, sometimes referred to as "dry hydric morphologies" (Robinette et al., 2004). On the other hand, due to low amounts of Fe-rich weatherable minerals, hydric soils may not develop redoximorphic features, such as Fe concentrations and depletions, or show positive reactions with α,α'-dipyridyl dye. A better understanding of the relationship between soil morphology and hydrology in these systems is needed in order to more accurately delineate freshwater wetlands for habitat protection.

The objective of our study was to further our understanding of the processes leading to the development and expression of morphological features associated with hydric soils on Mid-Atlantic barrier island landscapes. This would include islands located in Major Land Resource Area (MLRA) 153D (Northern Tidewater Area) and

153B (Tidewater Area) of Land Resource Region (LRR) T, the Atlantic and Gulf Coast Lowland Forest and Crop Region (USDA - Natural Resources Conservation Service, 2006). Our aim was to develop new indicators (or revise currently approved indicators) that would be suitable for identifying and delineating hydric soils in Holocene-aged dune and overwash landscapes of the Mid-Atlantic.

5.3 MATERIALS AND METHODS

5.3.1 Study Site

This study was conducted at Assateague Island National Seashore (Fig. 5-1). Assateague Island is typical of Mid-Atlantic barrier islands and is approximately 60 km long and located along the eastern coast of Maryland and Virginia. It is jointly managed by the National Park Service, U.S. Fish and Wildlife Service, and the State of Maryland. As protected federal and state owned land, human manipulation of the island is somewhat limited, allowing for the study of processes that are more reflective of the natural conditions and factors influencing soil development. Ten sites were identified, at each of which topographic transects were established, that extended from relatively well drained areas at dune crests and summits to poorly or very poorly drained positions in swales and depressions (Table 5-1). Freshwater to brackish wetlands are predominately located in the barrier core and overwash areas of barrier islands, so transects were located in these two geomorphic areas. Soil development on the beach portions of the island is inhibited by constant wave action, so these areas were excluded from the study. Also omitted from this study were soils in the marshes, since marsh soils have been studied more extensively and are better understood (Darmody and Foss, 1979; Griffin and Rabenhorst, 1989; Redfield, 1972).

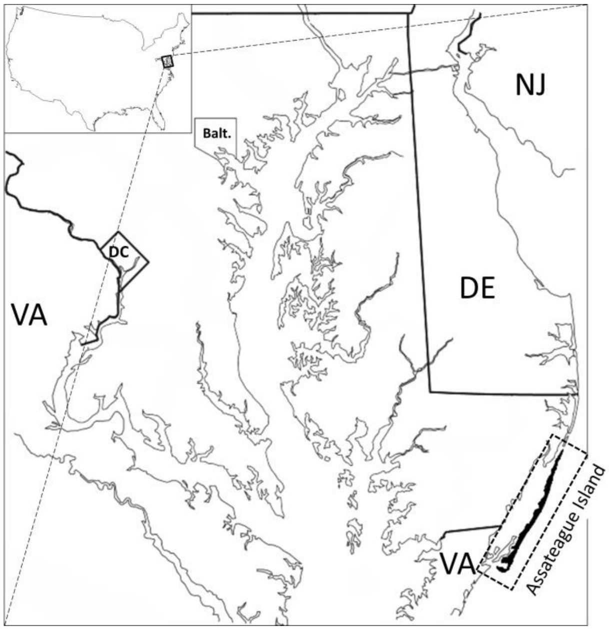


Fig. 5-1. Regional map of Maryland and surrounding states showing location of Assateague Island.

Table 5-1. Location, elevation, median water table depths, and frequency of saturation at study sites at Assateague Island National Seashore, MD, USA. Water tables were monitored February 2011 through January 2013.

Transect	Location	Transect Length[†]	Topographic Position	Elevation	Median Water Table Depth	Freq. of Saturation above 25 cm
		m		------------ m	------------	%
BC1	38° 7.60’N	20	Low	0.80	-0.02	93
	75° 10.93’W		Mid	0.93	-0.14	81
			High	1.42	-0.64	<1
BC2	38° 8.43’N	16	Low	0.90	0.03	97
	75° 10.69’W		Mid	1.00	-0.09	81
			High	1.37	-0.46	14
BC3	38° 7.74’N	19	Low	0.63	-0.05	86
	75° 10.95’W		Mid	0.99	-0.33	32
			High	1.23	-0.66	4
BC4	38° 10.05’N	83	Low	0.75	-0.16	84
	75° 10.16’W		Mid	1.02	-0.37	4
			High	1.41	-0.69	<1
BC5	38° 7.67’N	26	Low	0.21	-0.07	90
	75° 11.17’W		Mid	0.46	-0.40	4
			High	1.20	-1.20	0
BC6	38° 7.67’N	13	Low	-0.02	0.07	97
	75° 10.85’W		Mid	0.15	-0.07	87
			High	0.40	-0.37	3
OW1	38° 9.31’N	23	Low	0.73	-0.16	75
	75° 10.35’W		Mid	0.93	-0.37	4
			High	1.08	-0.55	<1
OW2	38° 9.14’N	42	Low	0.39	0.00	93
	75° 10.52’W		Mid	0.58	-0.13	79
			High	0.97	-0.53	<1
OW3	38° 9.29’N	36	Low	0.29	0.01	93
	75° 10.46’W		Mid	0.33	-0.15	83
			High	0.90	-0.65	<1
OW4	38° 9.10’N	23	Low	0.72	-0.23	56
	75° 10.41’W		Mid	0.84	-0.35	<1
			High	1.02	-0.44	2

[†] Transect length is the distance from the high to low topographic position of a transect.

Marsh soils typically have thick organic accumulations and hydric soils can be easily identified (Rabenhorst, 2001b).

5.3.2 Field Methods

Instrumentation and Data Collection

To assess the presence and extent of hydric soils within the landform units, topographic transects were instrumented to measure water table depth and reducing soil conditions. Two meter deep wells were installed at high (moderately well, well, or excessively drained), mid (poorly or somewhat poorly drained), and low (poorly or very poorly drained) positions along each transect. Automatic recording data loggers were programmed to measure water level twice daily (6 am and 6 pm). Water level in the well is a measure of the total hydraulic head over the entire depth of the well. However, the soils studied are sandy and have relatively constant hydraulic conductivities with depth. Comparisons of well readings and free standing water depths showed that hydrostatic conditions occurred at the sites, and total hydraulic head was roughly equal to the water table depth. Therefore, well readings were used as a measure of water table depth.

Since weather conditions can be highly variable along coastlines, precipitation and air temperature was measured on the island. Four tipping-bucket rain gauges with recording data loggers were installed in proximity to the study sites. Gauges were installed in the overwash zone where vegetation coverage is low and would not interfere with precipitation collection. Precipitation was recorded in 0.25 mm increments. Additional precipitation data was obtained from a National Weather

Service Remote Automatic Weather Station (RAWS) located on Assateague Island approximately 9.5 km south southeast of the study sites (Western Regional Climate Center, 2013).

Indicator of Reduction in Soils (IRIS) tubes were installed at each of the transect positions for multiple four week intervals from February to May in 2011 and 2012. IRIS tubes assess reducing conditions by estimation of Fe oxide paint removal and the presence of reduced sulfur (S^{2-}) (Castenson and Rabenhorst, 2006; Rabenhorst and Burch, 2006; Rabenhorst et al., 2010). At each position five IRIS tubes were installed to a depth of 50 cm. At the end of each four week period tubes were removed and replaced with a new set. Immediately upon removal, tubes were gently rinsed with water to remove adhering soil and organics and photographed to document the presence of iron monosulfides (FeS) (Rabenhorst et al., 2010). The FeS minerals are not stable under aerobic conditions and can rapidly oxidize, disappearing from the IRIS tube (Rabenhorst et al., 2010). After FeS had oxidized (approximately two days), IRIS tubes were rinsed and photographed again for semi-quantitative analysis.

Changes in elevation along topographic transects were measured using a level and rod. Relative elevation was measured at 1.0 m intervals and at high, mid, and low transect positions. Topographic profiles were joined to available LIDAR data to determine actual elevations at each of the transect points.

Soil Description and Sampling

Soil morphology was described at high, mid, and low positions along each transect according to the procedures of Schoeneberger et al. (2012). Soils were described in small hand-dug pits to the depth of the water table. An auger was used to describe the soil below the water table to at least 2 m. Pedons in very poorly and poorly drained positions were described in the summer of 2011 when water tables were lowest, so a greater portion of the soil profile could be exposed and described in a small pit. Soils in better drained positions were described in the fall of 2011 and winter of 2011–2012 when moister conditions made excavation of a small pit more feasible. Better drained, non-hydric soils were included in the study in order to distinguish between morphological features associated with hydric and non-hydric soils.

Morphological descriptions focused on features in the upper 30 cm of the soil profile that might be indicative of soil wetness (e.g., organic accumulation, presence of redoximorphic features, and depleted or reduced matrices) and the presence of any currently recognized hydric soil field indicators. Soil reaction to H_2O_2 and observations of H_2S gas odors were used to identify the presence of sulfides in saturated soil horizons (Fanning et al., 2002). The presence of Fe^{2+} was determined using α,α’-dipyridyl in saturated soils (Childs, 1981). Soil reaction with α,α’-dipyridyl was evaluated biweekly at three selected transects (BC2, BC6, and OW3) at soil depths of 12.5, 25, and 40 cm during the monitoring period of February to May, and monthly for the remainder of the year. Reaction was assessed visually and classified as very weak, weak, moderate, or strong based on a set of standards created in the laboratory. Since color variation between horizons in sandy, quartz-rich soils is often subtle, measurements of soil value and chroma were made to the half unit, by interpolating between chips using the Munsell Color Book (Munsell Colors, Grand Rapids, MI) as a guide (Rabenhorst et al., 2014).

Within each pedon, soils were sampled by horizon. Sampled soils were stored in sealed plastic sampling bags to ensure they remained at field moist condition prior to laboratory analyses.

5.3.3 Laboratory Methods

Sampled mineral soil horizons were air dried, crushed, and sieved to pass through a 2 mm sieve. Organic horizons were air dried and crushed to homogenize the sample. Organic carbon content was measured on soil samples to confirm the presence of organic horizons. Approximately 2.0 g of the fine earth fraction of mineral soils was ground with a mortar and pestle to pass through a #60 mesh (0.25 mm) sieve. Organic samples were initially ground with a coffee grinder, and then with a mortar and pestle to pass through a #60 mesh sieve (0.25 mm). Air-dried, ground mineral and organic samples were dried at 105°C. Total carbon was measured by dry combustion at 950°C using a LECO CHN-2000 analyzer (LECO corporation, St. Joseph, MI) (Nelson and Sommers, 1996). Potentially calcareous soils were identified by the presence of shells, reaction (effervescence) following treatment with 10% HCl, or an above neutral pH. All calcareous soil horizons were pre-treated with 5% sulfurous acid to remove calcium carbonate prior to organic carbon determination (Balduff, 2007; Nelson and Sommers, 1996).

5.3.4 Data Analysis

Water table measurements and IRIS tube data were used to determine if soils were saturated and reducing for a sufficient duration and frequently enough to be considered hydric according to the Technical Standard for Hydric Soils developed by the NTCHS (2007). To meet the Technical Standard, anaerobic and saturated conditions must occur for at least 14 consecutive days with a frequency of at least 50% (more than one in two years) under normal rainfall conditions. For a soil to meet the saturated conditions part of the standard, the soil must have free water within 25 cm of the soil surface. Hydrographs for each site were developed spanning February 2011 through January 2013. The number of consecutive days during the spring season (February through May) when the water table was above 25 cm was calculated from the hydrographs. To meet the anaerobic conditions of the Technical Standard, at least three out of five IRIS tubes must have greater than 30% paint removal from a 15 cm zone occurring within 30 cm of the soil surface (National Technical Committee for Hydric Soils, 2007). Using IRIS tube photographs, paint removal was estimated to determine if anaerobic conditions were met for each of the four week periods when IRIS tubes had been installed. The presence of FeS on IRIS tubes was also used as an indicator of paint removal and anaerobic conditions (Fe^{3+} in paint is reduced to Fe^{2+} and precipitated as FeS on the tube).

5.4 RESULTS AND DISCUSSION

5.4.1 Climate

Precipitation was monitored over the two year study period in order to determine if observations were made during normal weather conditions. The range of normal precipitation is defined as being between the 30th and 70th percentile as reported by National Weather Service weather station data over a 30 year monitoring period (Sprecher and Warne, 2000). Precipitation measured by our on-site rain gauges and the RAWS located on Assateague Island (Western Regional Climate Center, 2013) was compared to the WETS Table data from Assateague Island (Natural Resources Conservation Service - Water and Climate Center, 2013) (Fig. 5-2). Actual precipitation and antecedent precipitation were evaluated using the methods of Sprecher and Warne (2000) and the NRCS Engineering Field Handbook (Natural Resources Conservation Service, 1997). Three month antecedent precipitation is a weighted average of the precipitation during the month of interest and the two previous months. Greatest weight is given to the month of interest with progressively less weight given to the preceding months. While large storms, including Hurricanes Irene (August 28, 2011) and Sandy (October 29, 2012), produced above average precipitation during the fall months, monthly precipitation and antecedent precipitation during the monitoring period (February through May) was normal to dry (Fig. 5-2). While this does reduce the possibility of typically non-hydric soils meeting the Technical Standard due to excessively wet conditions, there is the potential that some hydric soils may not have met the Technical Standard during our study due to the drier than normal conditions.

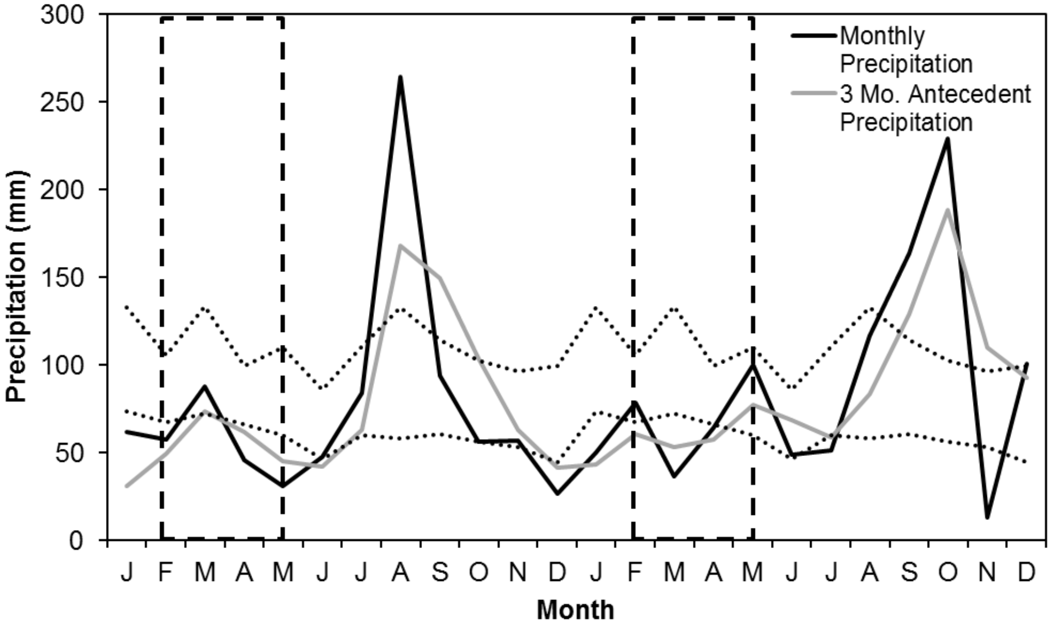


Fig. 5-2. Monthly precipitation and antecedent precipitation measured from January 2011 through December 2012 at Assateague Island National Seashore, MD, USA. Total monthly precipitation was measured by on-site rain gauges and a National Weather Service Remote Automatic Weather Station (RAWS) located on Assateague Island. Dotted lines show the range of normal precipitation (30th and 70th percentile) as reported by National Weather Service weather station data over a 30 year monitoring period. The monitoring period (February through May) for reducing conditions is highlighted by the dashed boxes.

5.4.2 Technical Standard

In order to meet the conditions of saturation, free water must exist within 25 cm of the soil surface (National Technical Committee for Hydric Soils, 2007). At all transects, water tables were closest to the surface at low sites and deepest at the high sites (Table 5-1). Median water table depth for all of the soils in the low positions was within 30 cm of the soil surface. Soils at the low sites were saturated within 25 cm of the surface for most of 2011 and 2012 (Table 5-1). Median water table depths at the high sites showed greater variation between transects, ranging from 39 to 120 cm below the surface. At the mid sites, median water table depths were within the upper 40 cm of the soil profile. Accordingly, the mid sites are less frequently saturated within the upper 25 cm then the low sites. At the high sites, saturation above 25 cm occurs rarely, if ever.

Reducing conditions can be confirmed by measuring redox potential, IRIS tubes, or a positive reaction to α,α’-dipyridyl. Digital photos of IRIS tubes were analyzed to estimate maximum paint loss in a 15 cm zone in the upper 30 cm of the soil surface. As expected, paint loss (and when present, FeS) was greatest in the lower topographic positions within each transect (Table 5-2). Paint loss at low sites was fairly uniform between installation periods, likely due to the consistent and nearly constant saturation within 30 cm observed at these sites (Table 5-1). Greater temporal variation was observed at the mid sites; this was attributed to seasonal variations in temperature and water table. The water tables at the mid sites are deeper than their respective low sites and the water table more commonly dropped below 30 cm (Table 5-1). Reducing conditions did not occur as frequently or as consistently in these

Table 5-2. Maximum paint loss from Indicator of Reduction In Soils (IRIS) tubes installed at study sites at Assateague Island National Seashore, MD, USA. Maximum paint loss from a 15 cm zone within the upper 30 cm of the soil surface was visually estimated on five tubes from each site. Values reported are the averages for the five tubes. Tubes were installed for three consecutive four week periods in 2011 and 2012. For a soil to meet the conditions for reduction in the Technical Standard for Hydric Soils, at least three out of five tubes must have greater than 30% paint removal from a 15 cm zone occurring within the upper 30 cm of the soil surface (National Technical Committee for Hydric Soils, 2007). Number of IRIS tubes meeting the Technical Standard is given in parentheses.

		Maximum Percent Paint Loss (average of 5 IRIS tubes)[†]					
Transect	Topographic Position	2/26/11-3/24/11	3/24/11-4/21/11	4/21/11-5/21/11	2/16/12-3/15/12	3/15/12-4/12/12	4/12/12-5/12/12
BC1	Low	93 (5)	100 (5)	100 (5)	100 (5)	100 (5)	100 (5)
	Mid	2 (0)	9 (0)	27 (2)	66 (5)	100 (5)	95 (5)
	High	0 (0)	0 (0)	nd	0 (0)	0 (0)	0 (0)
BC2	Low	100 (5)	100 (5)	100 (5)	100 (5)	100 (5)	100 (5)
	Mid	100 (5)	100 (5)	98 (5)	0.4 (0)	100 (5)	100 (5)
	High	0 (0)	0 (0)	nd	0 (0)	0 (0)	0 (0)
BC3	Low	100 (5)	100 (5)	100 (5)	100 (5)	100 (5)	100 (5)
	Mid	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
	High	0 (0)	0 (0)	nd	0 (0)	0 (0)	0 (0)
BC4	Low	100 (5)	100 (5)	100 (5)	97 (5)	97 (5)	97 (5)
	Mid	0 (0)	0 (0)	0 (0)	36 (4)	0 (0)	3 (0)
	High	0 (0)	0 (0)	nd	0 (0)	0 (0)	0 (0)
BC5	Low	54 (5)	69 (5)	69 (5)	0.4 (0)	90 (5)	48 (4)
	Mid	0 (0)	0 (0)	0 (0)	19 (2)	0 (0)	0 (0)
	High	0 (0)	0 (0)	nd	0 (0)	0 (0)	0 (0)
BC6	Low	100 (5)	100 (5)	100 (5)	100 (5)	100 (5)	100 (5)
	Mid	28 (2)	99 (5)	79 (5)	91 (5)	100 (5)	92 (5)
	High	0 (0)	0 (0)	0 (0)	3 (0)	0 (0)	0 (0)
OW1	Low	100 (5)	94 (5)	80 (5)	99 (5)	91 (5)	94 (5)
	Mid	0 (0)	0 (0)	5 (0)	0 (0)	0 (0)	0 (0)
	High	0 (0)	0 (0)	nd	0 (0)	0 (0)	0 (0)
OW2	Low	94 (5)	100 (5)	100 (5)	100 (5)	100 (5)	100 (5)
	Mid	nd	5 (0)	34 (4)	100 (5)	74 (5)	55 (5)
	High	0 (0)	0 (0)	nd	0 (0)	0 (0)	0 (0)
OW3	Low	100 (5)	100 (5)	100 (5)	79 (5)	100 (5)	97 (5)
	Mid	57 (4)	86 (5)	94 (5)	85 (5)	100 (5)	97 (5)
	High	0 (0)	0 (0)	nd	0 (0)	0 (0)	0 (0)
OW4	Low	65 (5)	98 (5)	61 (5)	100 (5)	58 (5)	67 (5)
	Mid	6 (0)	34 (4)	21 (2)	0 (0)	0 (0)	17 (1)
	High	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)

[†] nd = not determined, tubes were not installed during this time period

slightly drier positions. Despite this, six of the mid sites were sufficiently reducing to meet the anaerobic conditions of the Technical Standard. With the exception of one set of tubes from BC6, none of the tubes installed at high sites had any paint removal within the top 30 cm, indicating that reducing conditions did not occur in this zone. Accumulations of FeS were observed on all of the tubes installed at the low sites and on many of the tubes at mid sites. The concentration and depth of FeS varied between sites and over the course of the season.

Soils meeting the Technical Standard for Hydric Soils must be saturated and reducing for at least 14 consecutive days with a frequency of greater than 50% (more than one out of two years) under normal precipitation (National Technical Committee for Hydric Soils, 2007). While water table measurements were made year round, reducing conditions were only assessed from mid-February through mid-May. The Technical Standard was met at 16 sites for at least one 4 week period during 2011 and 2012 (Fig. 5-3 and Table 5-3). For 14 of the sites, saturated and reducing conditions were met in both years and for longer than four weeks.

The mid position at transect BC1 met the conditions of saturation during both 2011 and 2012, however paint removal on the IRIS tubes installed during 2011 was not sufficient to meet anaerobic conditions. While still not meeting the IRIS tube criteria of the Technical Standard, the tubes installed later in the 2011 spring season showed greater paint loss than early spring, suggesting that cooler temperatures earlier in the spring may have been inhibitory to reduction. Median water table depths were not substantially different between the 2011 and 2012 spring seasons. Since the median water table at this site during 2011 and 2012 was 14.4 cm below the surface,

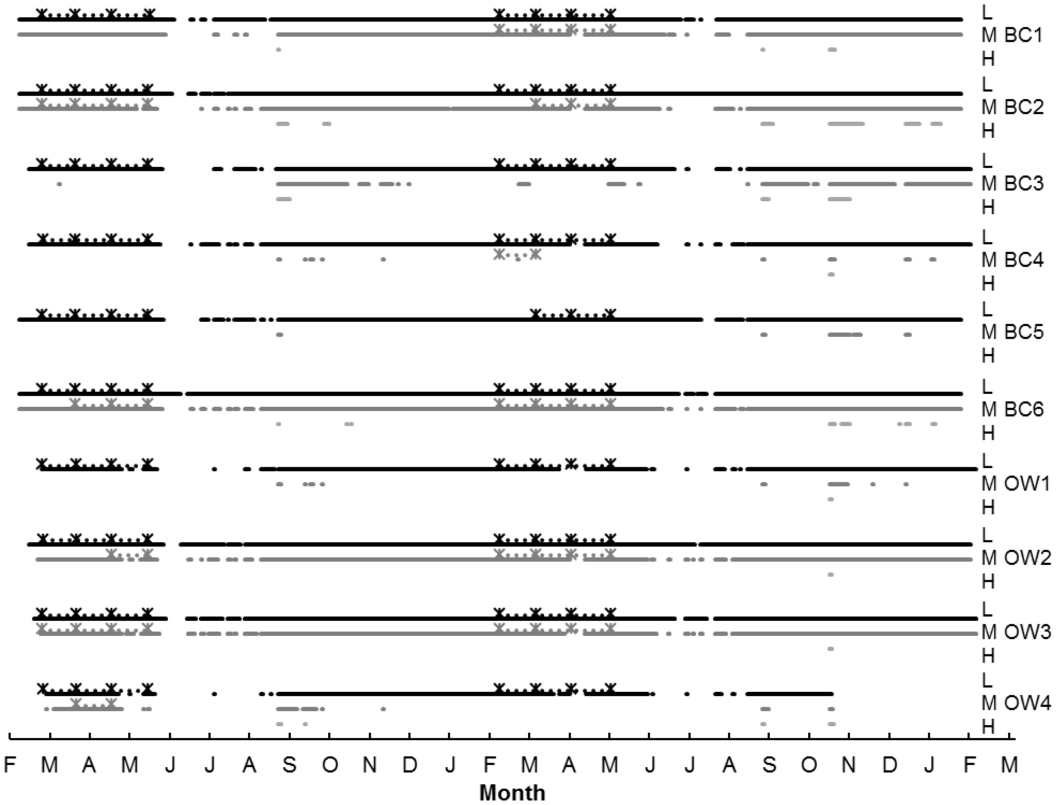


Fig. 5-3. Documentation of saturated and reducing conditions at landscape positions (low, mid, high) in each of the ten study transects at Assateague Island National Seashore, MD, USA meeting the saturation and reduction requirements of the Technical Standard of the NTCHS. Duration of reducing conditions is indicated by dashed lines with star symbol, and duration of saturated conditions is shown with solid lines from February 2011 through January 2013. Within each transect (labeled on the right side of the figure) lines for low (L), mid (M), and high (H) positions are arranged in descending order. At some transects neither saturated nor reducing conditions occur at the high site, so no lines are present. Reducing conditions were only monitored from mid-February to mid-May (both years). Outside of those intervals, reducing conditions may have occurred but were not assessed, and therefore not shown on the graph. The Technical Standard for Hydric Soils is met when both saturated and reducing conditions exist for at least 14 consecutive days in a year with normal rainfall (National Technical Committee for Hydric Soils, 2007).

Table 5-3. List of Assateague Island study sites and hydric/non-hydric soil status as determined by the Technical Standard for Hydric Soils (TSHS) (National Technical Committee for Hydric Soils, 2007), currently recognized Hydric Soil Field Indicators (HSFI) (USDA-Natural Resources Conservation Service, 2010), and Hydric Soil Field Indicators proposed in this study. Soils determined to be non-hydric are indicated by an "X".

		Consecutive Days of Saturation and Reduction[†]				Proposed Hydric Soil Field Indicators	
Transect	Topographic Position	2011	2012	TSHS	HSFI	Revised A9	Low Chroma Matrix
BC1	Low	82	86	Hydric	A4	X	Hydric
	Mid	0	54	Hydric	X	X	X
	High	0	0	X	X	X	X
BC2	Low	82	86	Hydric	X	Hydric	Hydric
	Mid	74	24	Hydric	A9	Hydric	X
	High	0	0	X	X	X	X
BC3	Low	82	86	Hydric	X	X	Hydric
	Mid	0	0	X	X	X	X
	High	0	0	X	X	X	X
BC4	Low	81	53	Hydric	A9	Hydric	X
	Mid	0	1	X	X	X	X
	High	0	0	X	X	X	X
BC5	Low	82	58	Hydric	A4	X	X
	Mid	0	0	X	X	X	X
	High	0	0	X	X	X	X
BC6	Low	82	86	Hydric	X	Hydric	X
	Mid	56	86	Hydric	X	X	X
	High	0	0	X	X	X	X
OW1	Low	62	45	Hydric	X	X	X
	Mid	0	0	X	X	X	X
	High	0	0	X	X	X	X
OW2	Low	81	85	Hydric	X	Hydric	Hydric
	Mid	7	51	Hydric	A9	Hydric	Hydric
	High	0	0	X	X	X	X
OW3	Low	82	86	Hydric	X	Hydric	Hydric
	Mid	62	48	Hydric	X	X	X
	High	0	0	X	X	X	X
OW4	Low	56	40	Hydric	X	X	Hydric
	Mid	27	0	Hydric	X	X	X
	High	0	0	X	X	X	X

[†] Longest duration of saturated and reducing conditions occurring during the monitoring period (February through May). Saturated and reducing conditions may have occurred outside of, or continued for a longer duration beyond the monitoring period.

the frequency of saturation above 25 cm was 80%, and reducing conditions were observed during 2012 and at slightly deeper depths in 2011, we believe that this soil meets the conditions of saturation and reduction frequently enough to be considered hydric.

The mid position at the OW4 transect met the Technical Standard in 2011, but didn’t satisfy the criteria for reduced or saturated conditions during 2012. The OW4 transect was partially buried under a deposit of fresh sediment during storm surges occurring during Hurricane Irene (August 28, 2011). The new deposit thins across the transect, ranging from 17 to 6 cm of sand at the high and mid sites, respectively. No new sediment was deposited at the low position. The new deposit raised the soil surface relative to the water table, so while the Technical Standard was met in 2011, saturated and reducing conditions may no longer occur close enough to the surface for this soil to be considered hydric. More recent sedimentation during Hurricane Sandy (October 29, 2012) has again raised the soil surface with respect to the water table. However, given that both observation periods during 2011 and 2012 were slightly drier than normal, it is possible that under wetter conditions the criteria of the Technical Standard could be satisfied and the soil would be considered hydric despite alterations in the soil surface relative to the water table. Since the soil description was made in 2011, it is reflective of the hydrologic conditions when the soil met the Technical Standard. For the purposes of this study this soil was considered to be hydric even though it may now no longer be a hydric soil.

With one exception, reducing conditions occurred only when the soil was saturated within the upper 25 cm of the soil. At the mid site of the BC4 transect the water table was briefly (1 day) within the upper 25 cm, however there was sufficient paint removal from the IRIS tubes to meet the Technical Standard's conditions for reduction. The median water table at this site during this period was 37.0 cm, which means there may have been sufficient moisture in the upper 30 cm for long enough during this period for reducing conditions to develop. This may have been aided by slightly above average temperatures during February and March 2012. Since at no other point were reducing conditions observed, and the conditions for saturation were never met, we considered this soil to be non-hydric.

Reaction with α,α'-dipyridyl did not appear to be a reliable indicator of anaerobic conditions in these soils, based on preliminary observations and regular monitoring at three transects. Despite saturated and reducing conditions, there were no or only very weak reactions with α,α'-dipyridyl at many of the sites. In some cases, positive reactions occurred at deeper depths, but these deeper observations would not be permitted to identify hydric soils. Reactions with α,α'-dipyridyl seemed to be, at least to some extent, seasonally and spatially variable within a profile. Stronger reactions were often observed along root channels, while there would be little to no reaction in the matrix. A negative reaction to α,α'-dipyridyl indicates that Fe^{2+} is not present in the soil. This could be attributed to aerobic conditions (all Fe occurs as Fe^{3+}), the soil is anaerobic, but Fe^{3+} has not been reduced to Fe^{2+}, or the soil is anaerobic, but there is no Fe^{2+} present. Iron contents in these sandy soils might be too low to generate a reaction with the dye, Fe^{2+} may have been precipitated with S^{2-}, or sustained anaerobic conditions may have resulted in leaching of any available Fe from the profile (Childs, 1981; Griffin, 2013).

5.4.3 Hydric Soil Morphology

Of the 30 sites monitored in this study, 16 were determined to be hydric based on the Technical Standard for Hydric Soils. At each transect the low position was hydric, while the high positions were non-hydric. Six of the transects had mid points that met the Technical Standard. Of the 16 soils meeting the Technical Standard for Hydric Soils, only 5 met a currently recognized Hydric Soil Field Indicator (Table 5-3). Indicators met were A9, 1 cm Muck (3 soils) and A4, Hydrogen Sulfide (2 soils).

Soils at all sites showed minimal pedological development (e.g., Table 5-4). Within a transect, organic matter accumulations were greater and O and A horizons were thicker and darker in color in the wetter positions (low and mid). Better drained sites (high positions) typically had little, if any, accumulation of organic matter. The A horizons were thin, light in color, and had low organic carbon levels. Due to the limited accumulation of organic matter, many of these surface horizons were described as AC or CA horizons. Organic matter accumulation occurs when input rates exceed decomposition rates. Under poorly drained, anaerobic environments, decomposition rates are slow relative to aerobic environments that favor the more efficient aerobic decomposition reactions. Differences in the type of organic matter accumulating (e.g., muck, mucky peat) and the color is thought to reflect differences in the nature of the organic matter and the conditions under which it is decomposing (aerobic vs. anaerobic) (Rabenhorst, 2011).

Organic matter accumulation varied between transects, indicating that in addition to soil moisture, other factors such as vegetation, landform stability, and soil

Table 5-4. Soil profile descriptions of selected soils at Assateague Island National Seashore, MD. Detailed soil descriptions were made to a depth of 2 m, however these descriptions are focused on horizons occurring within 30 cm of the soil surface (of primary concern in hydric soil delineation).

Site	Technical Standard and HSFI(s)[†]	Horizon	Depth	Texture	Matrix Color (moist)	Redox Features[‡]	Organic Carbon	Other[§]
			cm				$g\ kg^{-1}$	
BC2 Mid	Hydric, meets A9, revised A9, and proposed SLCM	Oa	0-1.5	MUCK	10YR 2/1		201.2	Surface cover: 0-0.5 cm leaves, dead grass
		A	1.5-8	S	10YR 4.5/2		5.3	OSF, 10YR 3/2, SC
		Cg1	8-22	S	10YR 4.5/1.5		0.6	OSF, 10YR 3/2, SC
		Cg2	22-28	S	10YR 4.5/1.5		0.4	
		Cg3	28-60	S	2.5Y 4.5/2		0.5	
BC2 Low	Hydric, meets revised A9 and proposed SLCM	Oa	0-2.5	MUCK	10YR 2/2		156.4	
		AC	2.5-5	FS	10YR 4/2		2.8	
		Cg1	5-18	S	2.5Y 5.5/1.5		1.0	
		Cg2	18-25	S	2.5Y 4.5/2		0.4	
		Cg3	25-39	S	2.5Y 4/2		0.6	
BC3 Low	Hydric, meets proposed SLCM	A	0-1.5	MK S	10YR 3/2		95.4	
		AC	1.5-7	S	10YR 4/2		6.4	
		Cg1	7-22	S	2.5Y 5.5/1.5		0.6	1-2 cm bands of fine sand, 2.5Y 3/1 OSF, 10YR 3.5/4
		Cg2	22-33	S	2.5Y 4/1		0.3	

Site	Technical Standard and HSFI(s)[†]	Horizon	Depth	Texture	Matrix Color (moist)	Redox Features[‡]	Organic Carbon	Other[§]
			cm				g kg^{-1}	
BC3	Not Hydric, no	AC	0-6	S	10YR 3/1		5.5	
High	HSFI	CA	6-14	S	10YR 3.5/2	<1%, 2 mm, D, F3M, 7.5YR 4/6, RPO	2.1	
		C1	14-26	S	10YR 5/2	1%, 2 mm, D, F3M, 7.5YR 4/6, RPO	0.7	
		C2	26-50	S	2.5Y 5.5/2	5%, 10-50 mm, P, F3M 10YR 5/6, 7.5YR 5/6, 5 YR 5/6, MAT	0.5	

[†] HSFI = Hydric Soil Field Indicators, A9 = 1 cm Muck, revised A9 = proposed revision to the A9 HSFI, proposed SLCM = proposed Sandy Low Chroma Matrix HSFI

[‡] Contrast classes: F = faint, D = distinct, P = prominent; F3M = iron (Fe^{3+}) masses; MAT = in the matrix, RPO = on surfaces along root channels

[§] OSF = organic stains, SC = on surfaces along root channels age also play a role in soil development. The thickest organic horizons were described in forested transects, while transects with herbaceous vegetation had thinner organic horizons. In transects with herbaceous vegetation, organic horizons (Oa and Oe horizons) were limited to the wettest topographic positions (hydric soils). In forested transects, comparatively thick organic horizons were described in all topographic positions. In general, Oa and Oe horizons were described in wetter (hydric) positions while Oe and Oi horizons were described in the drier (non-hydric) positions. Rapid decomposition of soil organic matter in oxidized, better drained positions limited the formation of Oa horizons. Leaf litter accumulating at these sites was rapidly broken down and incorporated into the A horizon. In wetter positions, decomposition rates and incorporation of organic matter into A horizons is slower and highly or partially decomposed organic matter (muck or mucky peat) accumulates at the soil surface forming Oa or Oe horizons.

While Oa (muck) horizons were described in seven of the hydric soils, only three of these soils actually met the conditions of the Hydric Soil Field Indicator A9, 1 cm Muck. The criteria for this indicator state that the chroma of the muck layer must be 1 or less. The muck layer at these sites had chromas ranging from 1 to 2 (e.g., Table 5-4, BC2 Mid and BC2 Low). Oa horizons were not observed at any non-hydric sites.

Reduced, depleted, or gleyed matrices are commonly used to identify hydric soils where organic accumulation is less substantial (i.e., no organic horizons). A soil horizon with a depleted matrix has low chroma and high value colors caused by the reduction and translocation of Fe. To be considered a depleted matrix the soil color must meet the following criteria: value of 6 or greater and chroma 2 or less or value of 5 or greater and chroma 1 or less, with or without redoximorphic concentrations occurring as soft masses or pore linings; value of 4 or 5 and chroma of 2 or value 4 and chroma 1, with at least 2% distinct or prominent redox concentrations occurring as soft masses and/or pore linings (Galbraith and Vasilas, 2011; USDA-Natural Resources Conservation Service, 2010). A reduced matrix is low chroma in situ, but changes color upon exposure as reduced Fe in solution is oxidized. Soils with a gleyed matrix are low chroma with grey, bluish, and/or greenish hues due to prolonged saturation and reduction of Fe.

Of the soils studied at Assateague Island, high value (≥4) and low chroma colors (≤2) were prevalent in both hydric and non-hydric soils (Table 5-4). These observations are consistent with soils described and mapped on barrier islands throughout the Mid-Atlantic region (Soil Survey Staff, 2014b). The soils had low mafic mineral contents, which limited the formation of Fe oxide minerals that give the soil yellow, brown, and/or red hues and brighter chromas (Schwertmann, 1993; Soileau and McCracken, 1967). Iron oxide formation was further limited by the relatively short duration of surface stability and time for soil development. Additionally, organic matter, which acts as a black or brown pigmenting agent in soils, is typically low in barrier island landscapes when compared to older, more developed soils. Weak subsoil development was observed at some of the high (non-hydric) positions, but not in their hydric counterparts. These oxidized subsoil horizons had slightly brighter chromas (2-3) than the unweathered parent material (chroma 1.5-2) or overlying A horizons, reflecting slight accumulations of iron (hydro)oxides and organic matter (e.g., Table 5-4, BC3 High). These iron accumulations did not occur in saturated and reducing soil horizons (Cg). Accordingly, the matrix colors in saturated soils were lower in chroma (<2) and had yellower hues (e.g., Table 5-4, BC2 Low, BC2 Mid, BC3 Low).

Redoximorphic features (concentrations and/or depletions) were only observed in a few soils, typically deeper in the profile at high positions. The lack of redox concentrations restricted use of the S5 Sandy Redox indicator. Additionally, the masking of sand particles by organic material in the surface horizons was not sufficient to meet the criteria of the S7 Dark Surface or S9 Thin Dark Surface indicators.

Due to the dominantly siliceous mineralogy of the parent material and limited pedogenesis, color changes between horizons were often subtle. In order to recognize these subtle differences, colors were described using the Munsell Soil Color Book and estimating to half units of chroma and value (Rabenhorst et al., 2014). In hydric soils with limited organic matter accumulation, these subtle changes in matrix hue and chroma appeared to be the most reliable morphologic indicator of soil wetness. Soil horizons with values of 4 or greater and chroma of 2 (or greater) were not consistently saturated (Fig. 5-4). Horizons with matrix chromas of less than 2 (i.e., 1.5, 1.0, <1.0) had a higher occurrence of saturation. Additionally, regularly saturated horizons typically had hues yellower than 10YR.

Despite being dominantly freshwater wetlands (Hall, 2005), there was substantial evidence of some, at least episodic, marine water influence at most of the

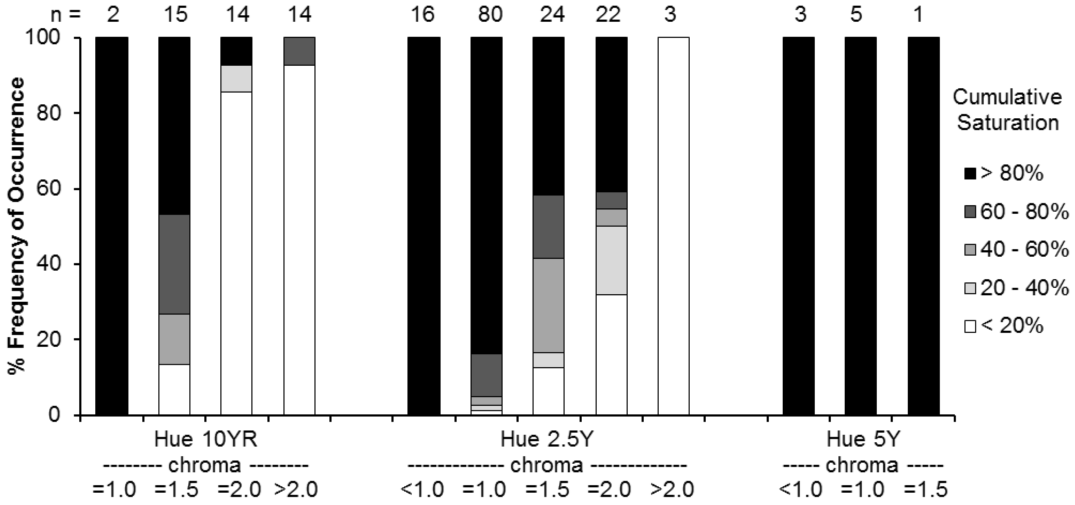


Fig. 5-4. Cumulative saturation of mineral horizons sampled at Assateague Island National Seashore, MD, USA grouped by matrix color (hue and chroma). Shading indicates frequency of saturation. Values were generally 4 or greater. Dark colored horizons with significant accumulations of organic matter (O and A horizons) were excluded. Number of samples (n) within each color grouping is indicated above the bar.

sites. Iron monosulfide (FeS) accumulations were present on many of the IRIS tubes and H_2S odors were observed at some of the sites. The presence of H_2S (determined by a rotten egg odor) within the upper 30 cm of the soil profile is a hydric soil indicator (A4, Hydrogen Sulfide), however its use is somewhat limited. It is only observed in sites containing sulfur that are saturated and reducing for long periods of time and can generally only be used for identifying a hydric soil, rather than delineating the hydric soil boundary (Hurt and Carlisle, 2001). Furthermore, H_2S is only present when the soil is saturated and reduced, limiting its use to times when the soil is most saturated. The presence of H_2S was noticed at a number of sites in this study, but often deeper than 30 cm. This was likely because soil descriptions were made during drier months when water tables had dropped below 30 cm. Fluctuations in the water chemistry (particularly sulfur concentrations) temporally and spatially may further limit the use of the A4 indicator at these sites.

5.4.4 Proposed Indicators

Given the properties of soils on Mid-Atlantic barrier islands and the limitations of currently recognized hydric soil field indicators in these landscapes, we propose a revision to the A9 indicator and consideration of a new indicator for hydric soil identification. The use of these indicators would be restricted to Holocene-aged barrier islands of the Mid-Atlantic region (MLRA 153D and 153B). Older deposits will likely show more soil development and the use of these indicators may not be needed. Outside of the Mid-Atlantic region, the mineralogy of the soils may be more favorable to weathering. Greater proportions of mafic minerals, and therefore greater iron availability, will increase the likelihood of the development of redoximorphic features in hydric soils. Furthermore, climatic differences can influence weathering rates and therefore, iron availability and redoximorphic feature development. Nevertheless, these proposed indicators should be tested for suitability and potential use in other MLRAs or LRRs.

Revision to Hydric Soil Field Indicator A9, 1 cm Muck: A layer of muck 1 cm or more thick with value of 3 or less and **chroma of 2 or less** and starting within 15 cm of the soil surface.

Organic matter accumulation was greatest at the wettest sites, and in more stable areas this has resulted in the formation of organic horizons, namely Oa (muck) horizons. More rapid decomposition in aerobic environments limits organic matter accumulation and muck horizons were not observed in non-hydric soils. The hydric soils with Oa horizons would have met the A9 1 cm Muck indicator except for the color requirement. We propose expanding the criteria of the A9 indicator to include muck layers with chromas of 2 or less (rather than 1 or less as currently written) (e.g., Table 5-4, BC2 Mid and BC2 Low).

New Indicator – Sandy Low Chroma Matrix Indicator: A layer 10 cm or more thick with a low chroma matrix that has a hue of 2.5Y or yellower, a value of 4 or more and a chroma **less than 2**, starting within 15 cm of the soil surface. An **overlying surface layer at least 1 cm thick** must have an accumulation of organic matter **with a value of 4 or less and a chroma of 2 or less.** The requirement of an O or A horizon above the low chroma layer excludes sediments from recent depositional events (especially common in overwash areas) which are not hydric. Low chroma colors in recent deposits are likely due to the nature of the parent material and not related to soil moisture.

Despite there being only subtle color variations between hydric and non-hydric soils, the 2 chroma appears to be a boundary between hydric and non-hydric soils. Soil horizons saturated for a significant portion of the year have chromas less than 2 and yellower hues (i.e., 2.5 Y or yellower). Horizons less frequently saturated have chromas of 2 (or greater) and redder hues (10 YR or redder). Chromas brighter than 2 were not as common, and are limited to the drier sites on more stable landforms. This slight color change is attributed to weak accumulations of iron oxide and organic matter. Organic matter accumulations (5 to 30 g kg^{-1} organic carbon) resulted in lower chromas in both hydric and non-hydric soils (data not shown), however, horizons with organic accumulations also had redder hues (10 YR or redder) and values less than 4.

While low chroma colors (<2) are restricted to subsoil horizons in hydric soils, these colors were also described at the soil surface in some recent overwash deposits. These overwash deposits were not necessarily hydric, but the recently deposited sediments lack the iron oxide and/or organic accumulations observed in more stable (older) positions with similar drainage characteristics. To avoid an erroneous delineation of hydric soils in these landforms, the requirement of an overlying layer with organic accumulation has been added to the proposed indicator. Non-hydric soils in these relatively young deposits do not support sufficient vegetation for accumulation of organic matter, however hydric soils do. These two requirements sufficiently distinguish between hydric soils, non-hydric soils, and fresh sedimentary deposits (e.g., Table 5-4, BC2 Mid, BC2 Low, BC3 Low).

Of the 16 hydric soils described in this study, only 5 met currently recognized field indicators. Using the proposed indicators, 10 of the hydric soils would meet an indicator (Table 5-3). Of these 10 soils, 5 already meet a currently recognized indicator. Seven hydric soils meet the sandy low chroma matrix indicator. Seven of the hydric soils would meet the revised A9 indicator; only three of these soils meet the current A9 indicator. Four of the hydric soils meeting the revised A9 indicator also met the sandy low chroma matrix indicator. The Oa horizons are more common to the older soils (on more stable landforms) and not seen in the youngest soils, where low chroma matrix colors are present. The revised A9 indicator is slightly more limited in use across the island, since there hasn’t been sufficient time for organic horizon development in the younger hydric soils.

There were six hydric soils that did not meet a current indicator or either of the proposed indicators. In two of these instances (BC1 Mid and BC5 Low), colors meeting the low chroma matrix requirement started within 16 to 18 cm of the soil surface (top of a mineral or muck horizon), just outside of the 15 cm depth requirement. In the remaining four hydric soils not meeting a proposed or recognized field indicator, low chroma matrix colors occurred too deep and an Oa horizon was not present. In some cases, for example BC6 Mid a forested site, organic carbon accumulations were relatively high and extended deeper in the profile. As a result of the increased organic carbon (13.8 g C kg^{-1} averaged over 15 cm starting below the Oe horizon), the soil matrix colors have redder hues (10 YR) extending to 46 cm below the muck or mineral soil surface.

According to the Technical Standard for Hydric Soils, saturated and reducing conditions must exist within the upper part of the soil, which for sandy soils (such as Mid-Atlantic barrier island soils) is from the top of the muck or mineral soil surface to a depth of 15 cm (National Technical Committee for Hydric Soils, 2007). Consequently, Hydric Soil Field Indicators for sandy soils are based on morphological features occurring within 15 cm of the soil surface that are indicative of wetness. While extending the depth requirements would capture many of these hydric soils (that do not meet the proposed sandy low chroma matrix indicator), there would be less certainty of the frequency and duration of saturated and reducing conditions in the upper part of the soil. None of the non-hydric soils met a current field indicator or either of the proposed field indicators. Hydric Soil Field Indicators are intended to be “proof-positive”, meaning that while some hydric soils may not meet an indicator, no non-hydric soil will ever meet an indicator.

5.5 CONCLUSIONS

Soils developed on Holocene-age barrier islands of the Mid-Atlantic region have limited development due to their young age and weathering resistant mineralogy. As a result, hydric soils associated with freshwater and brackish wetlands in these landscapes do not express morphologic features typically associated with hydric soils. Most hydric soils on these barrier islands do not meet the criteria of the currently recognized Hydric Soil Field Indicators developed by NRCS (2010) for hydric soil identification and wetland delineation. However, soils in these landscapes do show morphologic features indicative of wetness. Thin accumulations of muck (Oa horizons) and low chroma matrices in the upper 15 cm of the soil profile can be used to identify hydric soils. Based on our observations of soil morphology and documentation of saturated and reducing conditions we propose a revision to a current field indicator and consideration of a new indicator for hydric soil identification in Mid-Atlantic Holocene-aged barrier island landscapes (LRR T, MLRA 153D and 153B). Of the 16 described hydric soils in this study, only 5 met a currently recognized indicator. Using the proposed indicators, 10 of the soils would be identified as hydric. None of the non-hydric soils met a currently recognized or proposed indicator. This improved set of indicators will assist land use managers and regulators in the identification of hydric soils and delineation and protection of wetlands in these sensitive environments.

These indicators were developed based on properties of hydric and non-hydric soils on Holocene age barrier islands in the Mid-Atlantic region (within LRR T, MLRA 153D and 153B) and use of these indicators should, at this time, be limited to these areas. Barrier islands are extensive along the eastern seaboard of the United States. Given some of the similarities among soils on these islands (sandy, relatively young age, weathering resistant mineralogy) there may be similar needs for more suitable Hydric Soil Field Indicators in other regions. This could potentially include barrier islands along the coast of the southeastern US (southern portion of MLRA 153B), New England (coastal regions of LRR S, MLRA 149B, and LRR R, MLRA

144A and 144B), and the Gulf of Mexico (coastal regions of LRR T, MLRA 150B, 151, and 152A, and LRR U, MLRA 155). While not located on barrier islands, soils formed in sand dunes along the coast of Lake Michigan (LRR L, MLRA 97 and 96) also have similar properties to soils described on barrier islands. Further study in these areas would be required to assess the need for new indicators and the suitability of the proposed indicators in this work; however observations from this study may be useful in the development of indicators for other regions.

CHAPTER 6: CONCLUSIONS

Although barrier islands are relatively small in area, they make up a significant portion of coastlines globally and in particular, along the Atlantic coast of North America. As part of a dynamic coastal zone, barrier islands provide a number of ecosystem services and are also valued for recreational, residential, and commercial interests. The environmental and anthropogenic pressures faced by these ecosystems emphasize the need for a solid understanding of their formation and evolution. The pedosphere, or soils, exist at the interface of the lithosphere, atmosphere, and hydrosphere, and as such are an important component of all ecosystem studies. A study of soil development processes and influencing factors was conducted at Assateague Island National Seashore with the aim of improving our understanding of pedogenic processes and characteristics of soils on Mid-Atlantic barrier islands.

While Mid-Atlantic barrier islands are estimated to be between 5000 to 7000 years in age, the soils and landforms on the islands are much younger, due to geomorphic processes common to barrier islands and coastal environments (Oertel and Kraft, 1994). Using Optically Stimulated Luminescence (OSL) techniques and comparisons of historical aerial photography, we concluded that soils studied on the barrier core and overwash zones of Assateague Island ranged in age from less than 1 to 228 years. Older soils occurred on the more stable landforms of the barrier core, that are more protected from overwash, storm surges, and high winds. Soils observed on active washover fans are very young (< 12 years), due to intermittent overwash events that deposit new sediment and bury older soils. Comparison of soils on landforms of various age permitted assessment of soil development as a function of time.

On landforms subjected to frequent disturbance (e.g., washover fans, transects OW1 and OW4) vegetation was sparse and dominated by early-colonizing, herbaceous plants that are tolerant of frequent disturbance (by wind or water), low nutrient availability, low water availability, and varying levels of salt water inputs. While biomass production in these plant communities is low, they do contribute organic matter to the soil, which can accumulate over time if the surface remains stable. Accumulation of organic matter in the soil increases nutrient availability and water holding capacity (Jones et al., 2008; Lichter, 1998; Tackett and Craft, 2010). Soils on stable landforms protected from overwash, high winds, and sea spray (e.g., dune fields and flats of the barrier core) provide a more hospitable environment that is able to support less-stress tolerant plant species leading to increased plant biomass production (Ehrenfeld, 1990). Therefore, as soils increased in age (reflecting greater landform stability) there was a shift towards more mature plant communities, dominated by tree and shrub species. Shrub and tree dominated communities tended to have higher levels of aboveground biomass production, and therefore greater soil carbon inputs.

While there was evidence of soil development across the chronosequence, pedogenesis on Assateague Island was minimal relative to soils on older landforms. The young age of these landscapes limits soil development because there simply has not been enough time for pedogenic processes such as clay formation and translocation to occur. Additionally, the soil parent materials are sands dominated by siliceous minerals (90-94%) which are highly resistant to physical and chemical weathering, further slowing pedogenesis. The lack of iron-containing mafic minerals in the parent material (siliceous sands) also limits the release of Fe oxides that can form redoximorphic features indicative of soil wetness.

Soil development proceeded in parallel with plant community succession as organic matter accumulated in the soil, forming A horizons at the surface. Organic matter accumulates as organic matter inputs to the soil (in the form of plant biomass) exceed losses due to decomposition (oxidation of carbon compounds by microbial respiration). Aboveground plant biomass production increased in conjunction with increases in plant density and succession to higher order plant communities in more stable landforms and older soils. In the youngest soils, surface horizons were described as CA or AC horizons, with low organic carbon contents (generally less than 1 to 2 g kg^{-1}) and slight evidence of melanization, hues of 2.5 Y to 10 YR, values of 4 to 5, and chromas of 1.5 to 2. In older soils, surface horizons were darker (10 YR hue, values 2 to 3, chromas 1 to 2) and had substantially higher organic carbon contents, reflecting the accumulation of organic matter over time and increases in carbon inputs.

Growth of herbaceous plants in these systems can be limited by water availability. In poorly and very poorly drained soils, water availability is high, owing to water tables frequently at or near the soil surface. As a result, herbaceous plant communities in the wetter soils support higher levels of biomass production than on the drier (droughty) portions of the landscape. Surface horizons tended to be darker, thicker, and contain more organic carbon in the wetter soils where herbaceous biomass was higher and decomposition rates were slowed due to anaerobic conditions. In many of the very poorly and poorly drained soils, organic horizons (Oa or Oe) were observed at the surface. As landscape and soil surfaces increased in age and plant communities transitioned towards forests, soil moisture was less of a limiting factor for plant growth. Trees are able to access deeper water reserves, and high levels of litterfall (and therefore carbon inputs) were seen across a range of drainage conditions.

While carbon inputs were the main driver of carbon accumulation, soil carbon stocks were also affected by decomposition rates, which were higher in drier, oxidizing soil environments. Microbial respiration (organic carbon oxidation) is more efficient under aerobic conditions than under saturated and reducing conditions where microbes utilize anaerobic respiratory pathways and alternate electron acceptors. The effect of decomposition rates on carbon accumulation was best demonstrated in the older (forested) soils where carbon inputs were similar despite differences in water table depths between sites. Decomposition rates were higher in the drier soils, so total carbon accumulation was less, and O and A horizons, while present, were not as well developed as in the wetter soils.

Total soil carbon stocks (0-1.0 m) ranged from 0.49 to 18.8 kg C m^{-2}. The relatively low carbon stocks seen in many of the soils on Assateague Island are likely due to the young age of the soils and low carbon inputs associated with environmental limitations on plant growth on barrier islands (e.g., water and nutrient availability, salinity, frequent disturbance). Carbon stocks were greatest in forest soils, where high carbon inputs and longer periods of surface stability have allowed for greater accumulation of organic carbon. In the forested portions of the island, carbon stocks, ranging from 3.56 to 18.8 kg C m^{-2} (0-1.0 m) were similar or greater than average soil carbon stocks reported for U.S. soils (13.6 kg C m^{-2}) by Kern (1994). Among soils of similar ages, total carbon stocks were higher in the wetter soils where carbon inputs were relatively high and decomposition rates were slowed. Based on the spatial extent of landforms and plant communities and their associated average soil carbon stocks, it is estimated that carbon stocks (0-1.0 m) across the interior portions of Assateague Island average 3.34 kg C m^{-2}. This estimation did not include the tidal marsh soils (approximately 34% of Assateague Island), which would be expected to have higher carbon stocks.

Buried soils were observed in many of the soils at Assateague Island, representing previous marsh, washover fan, and dune surfaces. The magnitude of organic carbon stored in deeper portions of the profile (as buried soils) suggests the total stored carbon in these soils may be much greater than indicated by studies focused only on the upper portion of the profile (0-1.0 m). Considering the carbon stored in the upper 2.0 m of the profile, on average 46%, 17%, and 38% of total soil carbon stocks were stored in the 0-0.5 m, 0.5-1.0 m, and 1.0-2.0 m depth intervals, respectively. If only soils lacking buried surfaces are included in the calculated stocks, the proportions of total carbon stocks in the 0-0.5 m, 0.5-1.0 m, and 1.0-2.0 m intervals are 70%, 13%, and 8% respectively. Other studies of Mid-Atlantic barrier island stratigraphy suggest that buried surfaces are common to these landforms and multiple organic-rich buried surfaces could occur even deeper than 2 m (e.g., Havholm et al., 2004; Kraft, 1971; Oertel and Kraft, 1994).

Given the young age of these soils (even at the forest sites) they are thought to be still rapidly accumulating carbon, especially in the wetter topographic positions, and soil carbon stocks have not yet reached a steady state condition. It is uncertain when, or if, these soils would reach a steady state condition due to instability of the landforms. Semi-frequent burial events could sustain high sequestration rates especially in hydric soils. The role of burial in long term sequestration rates may be an important factor in consideration of carbon dynamics in these systems. While sequestered organic carbon is viewed as protected from oxidation, if released it could become a source of greenhouse gas. Buried surfaces (and sequestered organic carbon) can be exposed by erosion caused by natural geomorphic processes common to coastal environments, as well as by human influenced landform changes. The magnitude of these processes on a global scale is uncertain, however, the potential role of these soils and landscapes in global carbon cycles warrants consideration.

In addition to affecting plant community characteristics and organic matter accumulation, depth to the water table and the frequency and duration of saturation also had significant effects on the development of subsoil features. In the moderately well drained and drier soils, the accumulation of small amounts of Fe(III) (hydro)oxides and organic matter in the subsoil led to the formation of weak Bw horizons with slightly redder hues and brighter chromas. Bw horizons typically had 10YR hues and chromas of 2 to 3, which represents a relatively subtle difference from the 2.5Y hue and chromas of 1.5 to 2 seen in the parent material. Clay eluviation and illuviation and more intense rubification (the development of red color in the subsoil) are not evident in these soils, likely due to the limited time for soil development and the weathering-resistant nature of the parent material. Low quantities of iron-bearing mafic minerals limit the formation of secondary clay and iron oxide minerals (generally red, yellow, or brown in color). In the more poorly drained soils, Bw horizons are absent because any iron oxides present become reduced to the soluble and colorless Fe^{2+} form and subsequently leached from the soil. The unmasked sand grains give the soil a matrix color with chromas less than 2. The leaching and depletion of reduced Fe^{2+} from the soil could occur relatively quickly because of the low iron oxide content in the siliceous parent materials and the high hydraulic conductivity of the sandy soils.

Large disturbances, such as burial during storm surges (overwash), will restart pedogenic processes, burying previously formed soils and vegetation. Pedogenic development and plant establishment can occur repeatedly. The occurrence of these processes was observed over the course of this study, during overwash events associated with Hurricane Irene in August 2011 (at transect OW4) and Hurricane Sandy in October 2012 (at transects OW1 and OW4). In the absence of such disturbance, it is conceivable that the pedogenic processes observed in this study would continue (ongoing organic matter accumulation and thickening or deepening of O, A, and/or Bw horizons). However, carbon accumulation has been shown to follow a sigmoidal function, with a phase of rapid increase followed by a slower phase with minimal increases as carbon stocks approach a steady state condition in the soil.

Further development of subsoil horizons, such as argillic or spodic horizons, has been documented in older (late Pleistocene) soils formed in sandy parent materials. However, such features and horizons were not observed in soils at Assateague Island National Seashore. Their absence reflects the young age of the soils as there simply has not been sufficient time for them to form. It is uncertain whether under current conditions landforms on a barrier island would remain stable long enough for the formation of diagnostic subsurface horizons.

Mapping and soil characterization efforts on Mid-Atlantic barrier islands, to this point, have been limited. We found that the current soil series established for use on Assateague Island and other Mid-Atlantic barrier islands do not encompass the range in morphologies observed in this study. The degree of organic carbon accumulation (in organic surface horizons and organic-rich mineral A horizons) and development of Bw horizons as observed at Assateague Island is not currently documented in official soil series descriptions (Soil Survey Staff, 2014a). Additionally, the influence of saline water and presence of sulfidic horizons in the non-tidal portions of the island could have significant effects on vegetation, warranting inclusion in soil descriptions and maps. Observations from this study also raised a number of questions regarding current taxonomic classifications of these soils, particularly in regard to sulfidic horizons, mineralogy, and soil temperature regimes. It is hoped that the larger data set produced by this study will aid mapping efforts by providing more detailed information regarding the range of characteristics seen across barrier island soil landscapes. It is anticipated that modifications to current soil series and the addition of new series will be required to accomplish this.

Despite having relatively shallow water tables, many of the hydric soils studied at Assateague Island did not show the typical morphological features associated with soil wetness and did not meet recognized Hydric Soil Field Indicators (HSFI) as set forth by the National Technical Committee for Hydric Soils and the Natural Resources Conservation Service (USDA-Natural Resources Conservation Service, 2010). Low iron oxide content limited the formation of redox concentrations (required to meet HSFI S5, Sandy Redox). Additionally, A and O horizons at the surface often did not meet the criteria for field indicators associated with organic matter accumulation (e.g., HSFI A9, 1 cm Muck, S7, Dark Surface, or S9, Thin Dark Surface). However, soils at Assateague Island did show morphologic features that were indicative of wetness, primarily in the form of thin organic (Oa) horizons at the soil surface and low chroma (value ≥ 4, chroma <2) matrix colors in the upper 30 cm of the soil profile. These features were determined to be reliable indicators of hydric soils on these landscapes and formed the basis of a proposed revision to current field indicator A9 and the proposal for a new indicator for hydric soil identification based on low chroma matrix colors. The proposed indicators would be restricted for use in Mid-Atlantic Holocene-aged barrier island landscapes (LRR T, MLRA 153D and 153B), however they may have application on other barrier islands or coastal environments where hydric soils are formed in Holocene age, sandy soils. Testing of the proposed indicators would be needed before they were approved for use outside of the Mid-Atlantic region.

This study has added to our knowledge and understanding of pedogenic processes on Mid-Atlantic barrier islands, however there are a number of questions remaining. Suggestions for modification of current soil series have been made based on observations of soils at Assateague Island National Seashore, MD. It is expected that these soil series and the range of characteristics would carry over to barrier islands throughout the Mid-Atlantic region, however their extent beyond that is uncertain. Taxonomic questions regarding mineralogy, soil temperature regimes, and sulfidic materials in sandy soils are still somewhat unresolved and may need investigation in other regions as well. Organic carbon accumulation is an important process in barrier island soils. While carbon stocks tend to be low, particularly on the less stable landforms of the island, the magnitude of deep (> 2.0 m) carbon stocks in buried soils has not been fully addressed. The role of burial in sustaining high sequestration rates (and losses of large amounts of sequestered carbon through erosion) deserves additional study to understand their importance in these systems and on a global scale.

APPENDIX

APPENDIX A: SOIL PROFILE DESCRIPTIONS, ORGANIC CARBON, AND SITE PHOTOGRAPHS

(abbreviations given at end)

Site: BC1 Low
Lat/Long: 38°07’36.0006”N, 75°10’56.2794”W
Landscape/Landform/Microfeature: barrier island, dune field, dune slack
Classification: Sandy, siliceous, thermic Haplic Sulfaquents
Diagnostic Features: Ochric epipedon: 0-5 cm
Sulfidic materials: 13-73 cm
Aquic conditions: starting at 5 cm
Drainage Class: Very poorly
Hydric Soil Status: Hydric, A4
Vegetation (% cover by species): *Schoenoplectus americanus* (70%), *Setaria parviflora* (40%), *Pluchea odorata* (20%), *Mikania scandens* (10%), *Polygonum puncatum* (10%), *Lythrum lineare* (3%), *Phragmites australis* (3%), *Solidago sempervirens* (3%), *Eupatorium capillifolium* (<1%), *Panicum amarum* (<1%)

Described: 7/19/2011, Annie Rossi, Judith Turk
Observation Method: small pit to 26 cm, auger boring to 212 cm
Elevation: 0.80 m

Horizon	Depth	Texture	Matrix Color	Roots	Redox Features	Rxn w/ ααd	Rxn w/ 30% H_2O_2	pH (field)	Organic Carbon	Other
	cm								g kg^{-1}	
A	2	FS	7.5YR 2.5/2	--	--	--	--	4.21	23.89	
A/C	5	FS	10YR 3/3	2f	--	--	--	3.50	9.10	C part: 1-2 cm, discontinuous, wavy boundary, 2.5Y 4/2
Cg	13	S	2.5Y 5.5/1.5	2f	<1%, 10 mm, P, 10YR 5/6, F3M, RPO	--	--	4.18	1.00	1-2% OSF, 1cm, 10YR 3/3, SC
Cse	73	S	2.5Y 4.5/1	2f	--	none	--	5.76	0.19	H_2S odor
C’g1	104	S	2.5Y 5/1	--	--	none	--	7.15	0.09	
C’g2	184	S	2.5Y 4.5/1	--	--	none	--	7.00	0.30	1 cm bands of FS, 2.5Y 3/0.5
C’g3	212	S	2.5Y 4/1	--	--	none	--	7.50	0.20	H_2S odor

BC1 Low

Site: BC1 Mid
Lat/Long: 38^{o}07’35.8212”N, 75^{o}10’56.4594”W
Landscape/Landform/Microfeature: barrier island, dune field, dune slack
Classification: Siliceous, thermic Typic Psammaquents
Diagnostic Features: Ochric epipedon: 0-2 cm
Sulfidic materials: 85-250 cm
Aquic conditions: starting at 16 cm
Drainage Class: Very poorly
Hydric Soil Status: Hydric, no FI

Described: 8/17/2011, Annie Rossi, Mark Matovich
Observation Method: small pit to 41 cm, auger boring to 250 cm
Elevation: 0.93 m

Vegetation (% cover by species): *Morella cerifera* (60%), *Hydrocotyle umbellate* (50%), *Vaccinium corymbosum* (20%), *Dichanthelium acuminatum* (10%), *Lythrum lineare* (10%), *M. pensylvanica* (10%), *Pinus taeda* (10%), *Andropogon virginicus* (3%), *Baccharis halimifolia* (3%), *Eragrostis spectabilis* (3%), *Erechtites hieraciifolia* (3%), *Eupatorium capillifolium* (3%), *Juncus scirpoides* (3%), *Mikania scandens* (3%), *Panicum amarum* (3%), *Solidago sempervirens* (3%), *Toxicodendron radicans* (3%), *Diodia teres* (<1%), *Euthamia caroliniana* (<1%), *Juncus dichotomus* (<1%), *Pluchea foetida* (<1%), *Polygonum puncatum* (<1%), *Schoenoplectus americanus* (<1%), *Solidago fistulosa* (<1%), *Fimbristylis castanea* (trace), *Hypericum gentianoides* (trace), *Scleria verticillata* (trace)

Horizon	Depth	Texture	Matrix Color	Roots	Redox Features	Rxn w/ ααd	Rxn w/ 30% H_2O_2	pH (field)	Organic Carbon	Other
	cm								g kg^{-1}	
A	2	FS	10YR 2/2	2vf	--	--	--	4.76	34.14	60% OSF on sand grains
C	16	S	10YR 4.5/2	1vf, 1f	--	--	--	4.71	0.96	1% OSF, 10YR 3/2, SC
Cg	85	S	2.5Y 5.5/1.5	--	--	weak	--	6.97	0.17	1% OSF, 10YR 3/3, SC
Cse1	138	FS	2.5Y 5.5/1	--	--	weak	2.5Y 6.5/1	7.20	0.06	0.5-1.0 cm bands of FS, 10YR 2/1
Cse2	234	S	2.5Y 4/1	--	--	weak	2.5Y 5.5/1	7.12	0.10	
Aseb	250	FS	2.5Y 3/0.5	--	--	weak	--	7.91	2.12	H_2S odor

BC1 Mid

Site: BC1 High
Lat/Long: 38^{o}07’36.0006”N, 75^{o}10’56.2794”W
Landscape/Landform/Microfeature: barrier island, dune field, dune
Classification: Thermic, uncoated Aquic Udipsamments
Diagnostic Features: Ochric epipedon: 0-16 cm
Aquic conditions: starting at 78 cm
Drainage Class: Moderately well
Hydric Soil Status: Not hydric, no FI
Vegetation (% cover by species): *Morella pensylvanica* (10%), *Hudsonia tomentosa* (3%), *Pinus taeda* (3%), *Schizachyrium scoparium* (3%), *Hypericum gentianoides* (<1%), *Panicum amarum* (<1%), *Salicornia depressa* (<1%), *Aristida tuberculosa* (trace), *Cyperus grayi* (trace), *Dichanthelium acuminatum* (trace), *Diodia teres* (trace), *Solidago sempervirens* (trace)

Described: 1/5/2012, Annie Rossi, Mark Matovich
Observation Method: small pit to 78 cm, auger boring to 213 cm
Elevation: 1.42 m

Horizon	Depth	Texture	Matrix Color	Roots	Redox Features	Rxn w/ ααd	Rxn w/ 30% H_2O_2	pH (field)	Organic Carbon	Other
	cm								g kg^{-1}	
CA	16	FS	10YR 5/2	1f	--	--	--	5.70	0.99	1% OSF, 1-2 cm, 10YR 2/2, SC
C1	41	S	10YR 5.5/2.5	--	--	--	--	5.63	0.34	
C2	60	S	10YR 5.5/2	1m	<1%, 1-2 mm, P, 10YR 3/4, F3M	--	--	5.58	0.19	
C3	78	FS	2.5Y 5/2	--	1%, 1-5 mm, P, 10YR 4/6, F3M 10%, F, 2.5Y 4.5/1.5, FED	--	--	5.25	0.07	
Cg1	131	S	2.5Y 4/1.5	--	--	none	--	6.50	0.06	
Cg2	161	S	2.5Y 4/1.5	--	--	v.weak	--	7.09	0.10	
Cg3	187	S	5Y 5/1	--	--	v.weak	--	6.96	0.10	bands of FS, N 2.5
Cg4	213	FS	5Y 3.5/1	--	--	v.weak	5Y 5/1	7.20	0.06	

BC1 High

BC1 Transect

BC1 Low

BC1 Mid

BC1 High

Site: BC2 Low
Lat/Long: 38^{o}08’24.9612”N, 75^{o}10’41.7”W
Landform/Landscape/Microfeature: barrier island, dune field, dune slack
Classification: Siliceous, thermic Typic Psammaquents
Diagnostic Features: Ochric epipedon: 0-4.5 cm
Sulfidic materials: 92-147 cm; 171-198 cm
Aquic conditions: starting at 5 cm
Drainage Class: Very poorly
Hydric Soil Status: Hydric, no FI
Vegetation (% cover by species): *Schoenoplectus americanus* (60%), *Polygonum puncatum* (50%), *Mikania scandens* (10%), *Ptilimnium capillaceum* (10%), *Andropogon virginicus* (3%), *Echinolchloa walteri* (3%), *Pluchea odorata* (3%), *Dichanthelium scabriusculum* (<1%), *Dichanthelium dichotomum* (trace), *Pluchea foetida* (trace)

Described: 6/15/2011, Annie Rossi, Mark Matovich
Observation Method: small pit to 36 cm, auger boring to 198 cm
Elevation: 0.90 m

Horizon	Depth	Texture	Matrix Color	Roots	Redox Features	Rxn w/ ααd	Rxn w/ 30% H_2O_2	pH (field)	Organic Carbon	Other
	cm								g kg^{-1}	
Oa	2.5	MUCK	10YR 2/2	--	--	--	--	4.95	156.35	
AC	5	FS	10YR 4/2	2vf	--	--	--	4.38	2.75	
Cg1	18	S	2.5Y 5.5/1.5	2f, 2m, 2c	--	--	--	5.83	0.98	
Cg2	25	S	2.5Y 4.5/2	2m	--	--	--	6.42	0.40	
Cg3	39	S	2.5Y 4/2	1m	--	none	--	6.41	0.61	
2CAb	56	FS	10YR 3/1.5	1f	--	none	--	5.85	2.26	bands of FS, 2.5Y 3/1
2Cg	92	S	2.5Y 4.5/1	--	--	none	--	4.21	0.34	
2Cse1	127	COS	2.5Y 4.5/1	--	--	none	--	4.83	0.10	1% gravels
2Cse2	147	COS	2.5Y 4/1	--	--	none	--	4.59	0.16	1% gravels
3Ab1	164	L	5Y 3/1	--	--	none	--	6.11	63.12	Organic fragments, 10YR 3/3; OSF, 10YR 2/1
3Ab2	171	L	2.5Y 2.5/1	--	--	none	--	6.38	52.46	Organic fragments, 10YR 3/3 and 10YR 3/4
3Aseb1	183	L	2.5Y 3/1	--	--	none	--	5.66	42.40	Organic fragments, 10YR 3/3 and 10YR 3/4
3Aseb2	198	FSL	10YR 2.5/1.5	--	--	none	--	5.08	22.77	

BC2 Low

Site: BC2 Mid **Described:** 8/3/2011, Annie Rossi, Dan Fenstermacher
Lat/Long: 38^{o}08’25.3206”, 75^{o}10’41.8794” **Observation Method:** small pit to 28 cm, auger boring to 212 cm
Landscape/Landform/Microfeature: barrier island, dune field, dune slack **Elevation:** 1.00 m
Classification: Siliceous, thermic Typic Psammaquents
Diagnostic Features: Ochric epipedon: 0-8 cm
Sulfidic materials: 70-212 cm
Aquic conditions: starting at 8 cm
Drainage Class: Very poorly
Hydric Soil Status: Hydric, no FI

Vegetation (% cover by species): *Ptilimnium capillaceum* (60%), *Schoenoplectus americanus* (40%), *Polygonum puncatum* (30%), *Baccharis halimifolia* (10%), *Dichanthelium scabrusculum* (10%), *Andropogon virginicus* (3%), *Juncus scirpoides* (3%), *Mikania scandens* (3%), *Panicum amarum* (3%), *Panicum virgatum* (3%), *Spartina patens* (3%), *Dichanthelium acuminatum* (<1%), *Cenchrus tribuloides* (trace), *Echinochloa walteri* (trace), *Eragrostis spectabilis* (trace), *Eupatorium capillifolium* (trace), *Fimbristylis caroliniana* (<1%), *Hydrocotyle verticillata* (trace), *Morella cerifera* (trace), *Pluchea odorata* (trace), *Setaria parviflora* (trace), *Solidago sempervirens* (trace)

Horizon	Depth	Texture	Matrix Color	Roots	Redox Features	Rxn w/ αα d	Rxn w/ 30% H_2O_2	pH (field)	Organic Carbon	Other
	cm								g kg^{-1}	
Oa	1.5	MUCK	10YR 2/1	--	--	--	--	5.88	201.20	Surface cover: 0-0.5 cm leaves, dead grass
A	8	S	10YR 4.5/2	1vf, 2f	--	--	--	5.03	5.25	OSF, 0.5 cm., 10YR 3/2, SC
Cg1	22	S	10YR 4.5/1.5	1f	--	--	--	4.30	0.62	OSF, 10YR 3/2, SC
Cg2	28	S	10YR 4.5/1.5	--	--	mod.	2.5Y 5.5/1.5	4.73	0.42	
Cg3	60	FS	2.5Y 4.5/2	--	--	mod.	2.5Y 5/1	5.95	0.48	
Ab	70	FS	2.5Y 3/1	--	--	weak	2.5Y 5/1.5	5.75	3.03	Organic matter fragments, 10YR 2/2
Cse1	94	S	10YR 4.5/1	--	--	weak	2.5Y 6/1	5.93	0.48	
2Cse2	106	S	2.5Y 4.5/1	--	--	none	2.5Y 5.5/1	6.96	0.19	bands of FS, 10YR 2/1
2Cse3	153	S	2.5Y 4/1	--	--	v.weak	2.5Y 6/1	6.94	0.09	<1% gravels
2ACseb	165	S	10YR 4/1	--	--	none	--	6.98	1.77	10% organic fragments
3Aseb1	174	L	2.5Y 3.5/1	--	--	none	--	6.88	43.36	Organic fragments, 10YR 3/3
3Aseb2	186	MK CL	10YR 2/2	--	--	none	--	7.03	102.20	Organic fragments, 10YR 3/2
3Aseb3	197	CL	2.5Y 3/1	--	--	none	--	6.89	72.09	Organic fragments, 10YR 3/3
3Aseb4	212	FSL	2.5Y 3/1.5	--	--	none	--	5.88	22.47	Organic fragments, 10YR 3/3

BC2 Mid

Site: BC2 High
Lat/Long: 38°08’25.5006”N, 75°10’41.6388”W
Landscape/Landform/Microfeature: barrier island, dune field, dune
Classification: Thermic, uncoated Aquic Quartzipsamments
Diagnostic Features: Ochric epipedon: 0-19 cm
Sulfidic materials: 123-220 cm
Aquic conditions: starting at 63 cm
Drainage Class: Moderately well
Hydric Soil Status: Not hydric, no FI
Vegetation (% cover by species): *Pinus taeda* (10%), *Andropogon virginicus* (3%), *Juncus dichotomus* (3%), *Juncus scirpoides* (3%), *Panicum virgatum* (3%), *Schizachyrium scoparium* (3%), *Cyperus grayi* (<1%), *Dichanthelium acuminatum* (<1%), *Salicornia depressa* (<1%), *Juncus gerardii* (trace)

Described: 8/3/2011, Annie Rossi, Dan Fenstermacher
Observation Method: small pit to 67 cm, auger boring to 220 cm
Elevation: 1.37 m

Horizon	Depth cm	Texture	Matrix Color	Roots	Redox Features	Rxn w/ ααd	Rxn w/ 30% H_2O_2	pH (field)	Organic Carbon g kg^{-1}	Other
CA	19	S	10YR 4.5/2	1f, 1m	--	--	--	5.27	1.63	Surface cover: <0.5 cm, pine needles and leaves, variable in thickness and presence
Bw1	29	S	2.5Y 6/3	--	1%, <2 mm, D, 10YR 5/6, F3M	--	--	4.94	0.26	
Bw2	63	S	10YR 5.5/2.5	--	3%, 5-20 mm, D, 10YR 3/4 and 10YR 3/6, F3M, RPO and MAT	--	--	5.88	0.16	0.2 cm bands of FS, 10YR 2/1
Cg	77	S	2.5Y 4.5/1.5	--	3%, 5-20 mm, D, 10YR 3/4, F3M	weak-mod	--	5.52	0.15	
2Cg/Ab	123	FS	10YR 4/1.5	--	--	weak	--	6.72	2.04	A part: 2 mm, 2.5Y 3/1, MK S, organic fragments
2Cse1	159	S	2.5Y 4/1	--	--	weak	2.5Y 6.5/1	6.96	0.63	OSF, 10YR 3.5/1.5
2Cse2	185	COS	2.5Y 4.5/1	--	--	v.weak	2.5Y 6/1	7.60	0.19	<1% gravels
2ACseb	198	S	2.5Y 3/1	--	--	none	2.5Y 5/1	7.00	2.20	Few organic fragments, 10YR 2/2
3Aseb	214	L	2.5Y 3/0.5	--	--	none	--	7.08	39.21	30% organic fragments, 10YR 2/2 and 7.5YR 2.5/3
3Oa	220	MUCK	10YR 2/2	--	--	none	--	6.90	189.50	

BC2 High

BC2 Transect

BC2 Low

BC2 Mid

BC2 High

Site: BC3 Low
Lat/Long: 38°07’43.7406”N, 75°10’56.2794”W
Landscape/Landform/Microfeature: barrier island, barrier flat, swale
Classification: Siliceous, thermic Typic Psammaquents
Diagnostic Features: Ochric epipedon: 0-6.5 cm
Sulfidic materials: 101-238 cm
Aquic conditions: starting at 7 cm
Drainage Class: Very poorly
Hydric Soil Status: Hydric, no FI
Vegetation (% cover by species): *Spartina patens* (60%), *Echinochloa walteri* (40%), *Schoenoplectus americanus* (3%), *Setaria parviflora* (3%), *Mikania scandens* (<1%), *Pluchea odorata* (<1%), *Cyperus esculentus* (<1%)

Described: 6/16/2011, Annie Rossi, Mark Matovich
Observation Method: small pit to 43 cm, auger boring to 238 cm
Elevation: 0.63 m

Horizon	Depth	Texture	Matrix Color	Roots	Redox Features	Rxn w/ αα d	Rxn w/ 30% H_2O_2	pH (air dry)	Organic Carbon	Other
	cm								g kg^{-1}	
A	1.5	MK S	10YR 3/2	--	--	--	--	5.88	95.39	
AC	7	S	10YR 4/2	1vf	--	--	--	5.10	6.37	
Cg1	22	S	2.5Y 5.5/1.5	--	--	--	--	4.35	0.56	1-2 cm bands of FS, 2.5Y 3/1 OSF, 0.5 cm, 10YR 3.5/4
Cg2	33	S	2.5Y 4/1	--	--	--	--	6.55	0.25	
Cg3	101	S	2.5Y 4.5/1	--	--	none	--	6.72	0.10	
Cse1	115	S	2.5Y 3/1	--	--	none	--	5.97	0.10	
Cse2	182	S	2.5Y 4.5/1	--	--	none	--	6.18	0.09	
Cse3	224	S	2.5Y 2.5/1	--	--	none	--	4.26	0.10	
2Aseb	238	LFS	N 3	--	--	none	--	4.50	2.81	

BC3 Low

Site: BC3 Mid
Lat/Long: 38°07’44.04”N, 75°10’56.3982”W
Landscape/Landform/Microfeature: barrier island, barrier flat
Classification: Siliceous, thermic Typic Psammaquents
Diagnostic Features: Ochric epipedon: 0-8 cm
Sulfidic materials: 87-240 cm
Aquic conditions: starting at 31 cm
Drainage Class: Somewhat poorly
Hydric Soil Status: Not hydric, no FI
Vegetation (% cover by species): *Spartina patens* (60%), *Juncus dichotomus* (3%), *Euthamia caroliniana* (<1%), *Hypericum gentianoides* (<1%), *Schizachyrium scoparium* (<1%), *Dichanthelium acuminatum* (trace), *Eupatorium capillifolium* (trace), *Lactuca canadensis* (trace), *Opuntia humifusa* (trace)

Described: 8/17/2011, Annie Rossi, Mark Matovich
Observation Method: small pit to 64 cm, auger boring to 240 cm
Elevation: 0.99 m

Horizon	Depth	Texture	Matrix Color	Roots	Redox Features	Rxn w/ ααd	Rxn w/ 30% H_2O_2	pH (field)	Organic Carbon	Other
	cm								g kg^{-1}	
AC	8	S	10YR 3.5/1.5	3vf, 3f	--	--	--	6.42	5.36	Mildly hydrophobic
C1	31	S	10YR 5/1.5	1f	--	--	--	6.12	0.85	
C2	48	S	2.5Y 4.5/1.5	1f	--	--	--	5.56	0.31	
Cg1	64	S	2.5Y 4.5/1	--	--	--	--	4.65	0.21	bands of FS, 0.1-0.2 cm, 10YR 2/1
Cg2	76	S	10YR 4/1.5	--	--	none	--	7.08	0.36	OSF, 10YR 3/2
Ab/Cg	87	FS	2.5Y 3/1	--	--	none	--	7.00	1.34	Cg part: 2.5Y 4.5/1
Cse1	105	FS	10YR 5/1	--	--	none	2.5Y 6.5/1	6.96	0.16	
Cse2	235	S	2.5Y 4.5/1	--	--	none	2.5Y 6.5/1.5	7.22	0.10	
2Aseb	240	S	2.5Y 2.5/1	--	--	none	--	7.55	1.39	

BC3 Mid

Site: BC3 High
Lat/Long: 38^{o}07’44.22”N, 75^{o}10’56.7588”W
Landscape/Landform/Microfeature: barrier island, barrier flat
Classification: Aquic Udipsamments
Diagnostic Features: Ochric epipedon: 0-6 cm
Sulfidic materials: 59-250 cm
Aquic conditions: starting at 50 cm
Drainage Class: Moderately well
Hydric Soil Status: Not hydric, no FI
Vegetation (% cover by species): *Spartina patens* (70%), *Morella pensylvanica* (10%), *Diospyros virginiana* (3%), *Euthamia caroliniana* (3%), *Schizachyrium scoparium* (3%), *Vaccinium corymbosum* (3%), *Vitis rotundifolia* (3%), *Dichanthelium acuminatum* (<1%), *Eragrostis spectabilis* (<1%), *Eupatorium hyssopifolium* (<1%), *Juncus dichotomus* (<1%), *Rumex acetosella* (<1%), *Opuntia humifusa* (trace)

Described: 1/5/2012, Annie Rossi, Mark Matovich
Observation Method: small pit to 73 cm, auger boring to 250 cm
Elevation: 1.23 m

Horizon	Depth	Texture	Matrix Color	Roots	Redox Features	Rxn w/ ααd	Rxn w/ 30% H_2O_2	pH (field)	Organic Carbon	Other
	cm								g kg^{-1}	
AC	6	S	10YR 3/1	1vf	--	--	--	5.56	5.45	
CA	14	S	10YR 3.5/2	1vf, 1f	<1%, 2 mm, D, 7.5YR 4/6, F3M, RPO	--	--	5.60	2.11	
C1	26	S	10YR 5/2	1m	1%, 2 mm, D, 7.5YR 4/6, F3M, RPO	--	--	5.69	0.71	
C2	50	S	2.5Y 5.5/2	--	5%, 10-50 mm, P, 10YR 5/6, 7.5YR 5/6, 5YR 5/6, F3M, MAT	--	--	6.21	0.49	
Cg	59	S	2.5Y 5.5/1	--	--	none	--	6.14	0.26	
Cse1	73	S	2.5Y 4.5/1	--	--	weak-mod	2.5Y 5.5/1	7.52	0.16	1%, 0.5-2 cm, P, N 2.5, FeS masses, reaction with 30% H_2O_2 color change to 7.5YR 4/6 H_2S odor
Cse2	112	S	2.5Y 5/1.5	--	--	none	2.5Y 5.5/1.5	7.69	0.81	OSF, possible buried surface at 90 cm, 2.5Y 3/2
Cse3	135	FS	2.5Y 4.5/1.5	--	--	none	2.5Y 5.5/1.5	7.58	0.58	
Cse4	238	S	2.5Y 4.5/1	--	--	none	2.5Y 5/1	7.63	0.44	
2Aseb	250	FS	5Y 3.5/1	--	--	none	5Y 4/1	7.81	1.13	

BC3 High

BC3 Transect

BC3 Low

BC3 Mid

BC3 High

Site: BC4 Low
Lat/Long: 38°10’2.2182”N, 75°10’12.4212”W
Landscape/Landform/Microfeature: barrier island, back-barrier flat
Classification: Sandy, siliceous, thermic Haplic Sulfaquents
Diagnostic Features: Ochric epipedon: 0-17 cm
Sulfidic materials: 46-130 cm
Aquic conditions: starting at 9.5 cm
Drainage Class: Very poorly
Hydric Soil Status: Hydric, A9

Described: 8/16/2011, Annie Rossi, Mark Matovich
Observation Method: small pit to 32 cm, auger boring to 180 cm
Elevation: 0.75 m

Vegetation (% cover by species): *Andropogon virginicus* (60%), *Dichanthelium acuminatum* (40%), *Dichanthelium scabriusculum* (30%), *Morella cerifera* (20%), *Chasmanthium laxum* (10%), *Baccharis halimifolia* (3%), *Juncus dichotomus* (3%), *Juncus scirpoides* (3%), *Leersia virginica* (3%), *Mikania scandens* (3%), *Panicum virgatum* (3%), *Phytolacca Americana* (3%), *Erechtites hieraciifolia* (<1%), *Solidago fistulosa* (<1%), *Carex hormathodes* (trace), *Pluchea odorata* (trace), *Schoenoplectus americanus* (trace)

Horizon	Depth	Texture	Matrix Color	Roots	Redox Features	Rxn w/ ααd	Rxn w/ 30% H_2O_2	pH (field)	Organic Carbon	Other
	cm								g kg^{-1}	
Oa	5	MUCK	7.5YR 2.5/1	2f, 1m, 2c	--	--	--	4.06	180.55	
A	9.5	S	10YR 2/2	1vf, 1f	--	--	--	4.84	6.68	
CA	17	S	10YR 3/1.5	1f	--	--	--	5.88	4.06	<1% gravel
Cg	25	FS	2.5Y 4.5/2	1f	--	--	--	6.38	1.26	
Ab	26	FS	2.5Y 2.5/1	--	--	--	--	6.44	9.39	
C’g	28	FS	2.5Y 4.5/1	--	--	--	--	6.44	0.99	
A’b	30	S	2.5Y 2.5/1	--	--	--	--	6.45	22.45	
C’’g	46	S	2.5Y 5/2	--	1%, 2-4 mm, P, 10YR 3/4, F3M, RPO	weak-mod.	--	6.77	2.52	
Cse1	67	S	10YR 4/1.5	--	--	weak	10YR 5.5/1	6.59	0.93	
Cse2	89	FS	2.5Y 4.5/1	--	--	weak	2.5Y 5/1	6.60	0.30	
Cse3	130	FS	2.5Y 3.5/1	--	--	weak	2.5Y 5.5/1	7.38	0.30	
C’’’g	180	FS	2.5Y 3.5/0.5	--	--	weak	2.5Y 5/1	7.60	0.39	<1% shell fragments

BC4 Low

Site: BC4 Mid
Lat/Long: 38^{o}10’4.26”N, 75^{o}11’10.0782”W
Landscape/Landform/Microfeature: barrier island, back-barrier flat
Classification: Siliceous, thermic Typic Psammaquents
Diagnostic Features: Ochric epipedon: 0-10 cm
Sulfidic materials: 71-120 cm
Aquic conditions: starting at 43 cm
Drainage Class: Somewhat poorly
Hydric Soil Status: Not hydric, no FI
Vegetation (% cover by species): *Andropogon virginicus* (70%), *Dichanthelium scabriusculum* (60%), *Dichanthelium acuminatum* (40%), *Pinus taeda* (20%), *Baccharis halimifolia* (10%), *Chasmanthium laxum* (10%), *Morella cerifera* (10%), *Smilax rotundafolia* (10%), *Juncus dichotomus* (3%), *Panicum virgatum* (3%), *Rubus* sp. (3%), *Vitus rotundifolia* (3%), *Eupatorium hyssopifolium* (trace), *Lonicera japonica* (trace), *Parthenocissus quinquefolia* (trace), *Vaccinium corymbosum* (trace)

Described: 8/24/2011, Annie Rossi, Mark Matovich
Observation Method: small pit to 45 cm, auger boring to 212 cm
Elevation: 1.02 m

Horizon	Depth	Texture	Matrix Color	Roots	Redox Features	Rxn w/ ααd	Rxn w/ 30% H_2O_2	pH (field)	Organic Carbon	Other
	cm								g kg^{-1}	
A	10	FS	10YR 2/2	1c, 1m, 2f	--	--	--	4.89	33.20	50% OSF on sand grains
CA	22	FS	10YR 4/2	1vf, 1f	--	--	--	5.19	2.11	1% OSF, 10YR 3/2, SC
C	43	FS	10YR 4/1.5	1vf	--	--	--	5.23	0.49	
Cg	45	S	2.5Y 3/1	--	--	--	--	5.61	0.55	
ACb	71	FS	10YR 4/1.5	--	--	mod.	--	5.97	2.24	OSF, 10YR 3/2
Cse	120	S	2.5Y 4/1.5	--	--	mod.	--	6.45	0.43	
C’g1	177	FS	2.5Y 4.5/1	--	--	mod.	--	7.86	0.49	
C’g2	212	FS	2.5Y 4/1	--	--	mod.	--	7.88	0.72	1-2% shell fragments <1% gravels

BC4 Mid

Site: BC4 High
Lat/Long: 38°10’3.8994”N, 75°10’9.4182”W
Landscape/Landform/Microfeature: barrier island, back-barrier flat
Classification: Thermic, uncoated Aquic Quartzipsamments
Diagnostic Features: Ochric epipedon: 0-10 cm
Aquic conditions: starting at 52 cm
Drainage Class: Moderately well
Hydric Soil Status: Not hydric, no FI
Vegetation (% cover by species): *Triplasis purpurea* (60%), *Andropogon virginicus* (3%), *Dichanthelium acuminatum* (3%), *Eupatorium hyssopifolium* (3%), *Opuntia humisfusa* (3%), *Panicum amarum* (3%), *Panicum virgatum* (3%), *Rubus* sp. (3%), *Rumex acetosella* (3%), *Schizachyrium scoparium* (3%), *Dichanthelium scabriusculum* (<1%), *Spartina patens* (<1%), *Baccharis halimifolia* (trace), *Bulbostylis capillaris* (trace), *Hypochaeris radicata* (trace), *Smilax glauca* (trace), *Solidago sempervirens* (trace), *Vitus rotundifolia* (trace)

Described: 5/3/2012, Annie Rossi, Mark Matovich
Observation Method: small pit to 74 cm, auger boring to 198 cm
Elevation: 1.41 m

Horizon	Depth	Texture	Matrix Color	Roots	Redox Features	Rxn w/ ααd	Rxn w/ 30% H_2O_2	pH (field)	Organic Carbon	Other
	cm								g kg^{-1}	
A	2.5	S	10YR 2/2	2vf, 2f, 1m	--	--	--	4.77	11.53	10% OSF on sand grains
CA	10	S	10YR 4/2	1vf, 1f	--	--	--	5.67	1.60	
C1	21	S	10YR 4/2	1vf	--	--	--	5.89	0.45	1% OSF, 1 cm, 7.5YR 2.5/2
C2	32	S	10YR 4.5/2.5	--	--	--	--	5.86	0.38	
Ab	38	FS	7.5YR 3/2	1vc, 1c, 1m, 1f	--	--	--	5.37	1.06	
ACb	43	FS	10YR 3/2	--	--	--	--	5.27	0.52	
C’	52	S	10YR 5.5/2	--	1%, 5-10 mm, P, 10YR 4/6, F3M	--	--	5.35	0.43	
Cg1	70	FS	10YR 5/2	--	--	none	--	5.32	0.48	
Cg2	76	FS	2.5Y 4/1	--	--	none	--	5.96	1.52	
Cg3	113	S	10YR 4/1.5	--	--	none	--	6.43	0.44	<1% gravel
Cg4	136	S	10YR 4.5/1.5	--	--	none	--	6.35	0.20	bands of FS, 10YR 2/1 <1% gravel
AC’b	156	S	2.5Y 3/2	--	--	weak	2.5Y 4/2	6.23	0.15	1-2% gravel
C’g1	182	S	2.5Y 4/1	--	--	v.weak	2.5Y 5/1	6.75	0.15	
C’g2	198	COS	2.5Y 3/1	--	--	strong	2.5Y 4.5/1	8.29	0.25	<1% shell fragments

BC4 High

BC4 Transect

BC4 Low

BC4 Mid

BC4 High

Site: BC5 Low
Lat/Long: 38°07’39.9606”N, 75°11’10.4388”W
Landscape/Landform/Microfeature: barrier island, dune field, dune slack

Described: 7/27/2011, Annie Rossi, Martin Rabenhorst
Observation Method: small pit to 32 cm, auger boring to 198 cm
Elevation: 0.21

Classification: Siliceous, thermic Typic Psammaquents
Diagnostic Features: Ochric epipedon: 0-20 cm
Sulfidic materials: 157-198 cm
Aquic conditions: starting at 20 cm
Drainage Class: Very poorly
Hydric Soil Status: Hydric, A4
Vegetation (% cover by species): *Acer rubrum* (30%), *Morella cerifera* (20%), *Pinus taeda* (10%), *Vaccinium corymbosum* (10%), *Amelanchier canadensis* (3%), *Ilex opaca* (3%), *Smilax rotundafolia* (<1%), *Toxicodendron radicans* (trace)

Horizon	Depth	Texture	Matrix Color	Roots	Redox Features	Rxn w/ ααd	Rxn w/ 30% H_2O_2	pH (field)	Organic Carbon	Other
	cm								g kg^{-1}	
Oe	13	MPT	5YR 2.5/2	--	--	--	--	3.14	457.55	Surface cover: 0.5 cm pine needles and leaves
A	20	FS	10YR 2.5/1.5	--	--	--	--	4.10	9.96	
Cg1	30	FS	2.5Y 4.5/2	--	--	v.weak (near org.)	--	5.02	0.89	3-4% OSF, 0.2-1 cm, 7.5YR 2.5/3 and 10YR 3/1.5 H_2S odor
Cg2	56	FS	2.5Y 4.5/1.5	--	--	v.weak	--	6.00	0.59	H_2S odor
Cg3	82	FS	2.5Y 4.5/1	--	--	v.weak	--	6.35	0.26	H_2S odor
2Ab1	99	MK SICL	7.5YR 2.5/2	--	--	none	--	6.62	141.70	
2Ab2	109	FSL	7.5YR 2.5/1	--	--	none	--	6.48	44.57	
3Cg	157	FS	10YR 4.5/1.5	--	--	none	--	6.84	1.10	
3Cse1	177	FS	2.5Y 3.5/1	--	--	none	2.5Y 5/2	6.87	1.24	
3Cse2	198	S	2.5Y 3.5/1	--	--	none	2.5Y 5/2	6.84	0.24	<1% gravels

BC5 Low

Site: BC5 Mid
Lat/Long: 38°07’40.26”N, 75°11’10.0782”W
Landscape/Landform/Microfeature: barrier island, dune field
Classification: Siliceous, thermic Typic Psammaquents
Diagnostic Features: Ochric epipedon: 0-24 cm
Sulfidic materials: 92-119 cm
Aquic conditions: starting at 51 cm
Drainage Class: Somewhat poorly
Hydric Soil Status: Not hydric, no FI
Vegetation (% cover by species): *Pinus taeda* (50%), *Acer rubrum* (40%), *Smilax rotundafolia* (20%), *Diospyros virginiana* (10%), *Vaccinium corymbosum* (10%), *Amelanchier canadensis* (3%), *Smilax glauca* (trace)

Described: 7/27/2011, Annie Rossi, Martin Rabenhorst
Observation Method: small pit to 65 cm, auger boring to 196 cm
Elevation: 0.46 m

Horizon	Depth	Texture	Matrix Color	Roots	Redox Features	Rxn w/ ααd	Rxn w/ 30% H_2O_2	pH (field)	Organic Carbon	Other
	cm								g kg^{-1}	
Oe	13	MPT	5YR 2.5/2	--	--	--	--	3.78	457.56	Surface cover: ~1 cm pine needles, leaves
A	24	FS	10YR 4.5/1.5	1f, 2m	--	--	--	4.08	17.05	5-10% OSF, 10YR 3/2
C1	51	FS	10YR 5.5/2	1f, 1m	--	--	--	4.22	1.91	5% OSF, 7.5YR 4/4 and 10YR 4/3
C2	65	S	2.5Y 5.5/2	1f, 1m	--	--	--	4.59	0.39	3% OSF, 7.5YR 3/3
C3	92	S	10YR 5/2	--	--	v.weak	--	5.74	0.82	
Cse	119	FS	2.5Y 5/1	--	--	none	v. slight	6.12	0.19	H_2S odor
2Ab1	131	MK L	10YR 2/2	--	--	none	--	6.59	115.15	
2Ab2	136	LFS	10YR 2/1	--	--	none	--	6.54	39.86	
3Ab3	152	FS	10YR 3/1	--	--	none	--	6.64	9.17	
3ACb	170	FS	2.5Y 3.5/1.5	--	--	none	--	6.80	1.77	
3Cg	196	S	2.5Y 4.5/1.5	--	--	none	--	6.54	0.79	

BC5 Mid

Site: BC5 High
Lat/Long: 38^{o}07’40.3212”N, 75^{o}11’10.4388”W
Landscape/Landform/Microfeature: barrier island, dune field, dune
Classification: Thermic, uncoated Typic Quartzipsamments
Diagnostic Features: Ochric epipedon: 0-30 cm
Sulfidic materials: 171-198 cm
Aquic conditions: starting at 171 cm
Drainage Class: Somewhat excessively
Hydric Soil Status: Not hydric, no FI
Vegetation (% cover by species): *Pinus taeda* (50%), *Diospyros virginiana* (40%), *Vitus rotundifolia* (10%), *Chasmanthium laxum* (3%), *Smilax rotundafolia* (3%), *Amelanchier canadensis* (trace), *Carex hormathodes* (trace), *Smilax glauca* (trace)

Described: 1/6/2012, Annie Rossi, Mark Matovich
Observation Method: small pit to 145 cm, auger boring to 268 cm
Elevation: 1.20 m

Horizon	Depth	Texture	Matrix Color	Roots	Redox Features	Rxn w/ ααd	Rxn w/ 30% H_2O_2	pH (field)	Organic Carbon	Other
	cm								g kg^{-1}	
Oi	2.5	SPM	7.5YR 2.5/2	--	--	--	--	4.27	485.75	Surface cover: ~2 cm, pine needles and cones, and leaves
Oe	6	MPM	60% 5YR 2.5/1 40% 2.5YR 2.5/2	--	--	--	--	3.77	245.80	
AE	19	FS	10YR 4/2	2m, 2f	--	--	--	3.87	3.10	
A	30	FS	7.5YR 3/1.5	2c, 2m, 2f, 1vf	--	--	--	3.88	2.11	
Bw1	77	S	10YR 5.5/3	1c, 1f	--	--	--	4.18	0.21	
Bw2	98	S	10YR 6/2.5	1c	--	--	--	4.28	0.07	
Bw3	145	FS	10YR 4/2.5	--	--	none	--	4.31	0.29	
C	171	S	2.5Y 5/2	--	--	v.weak	--	4.03	0.10	
Cse	198	FS	2.5Y 4/0.5	--	--	mod.	--	5.41	0.16	
2Ab1	216	FSL	5Y 3/1	--	--	none	--	6.38	45.66	35% org. fragments, 10YR 3/2
2Ab2	232	MK LFS	10YR 2/1	3vf	--	none	--	6.35	67.12	40% org. fragments
3Cg	268	FS	10YR 4/1.5	3vf	--	none	--	6.83	1.34	

BC5 High

BC5 Transect

BC5 Low

BC5 Mid

BC5 High

Site: BC6 Low
Lat/Long: 38°08’23.1606”N, 75°10’50.4006”W
Landscape/Landform/Microfeature: barrier island, dune field, dune slack
Classification: Siliceous, thermic Typic Psammaquents
Diagnostic Features: Ochric epipedon: 0-9.5 cm
Sulfidic materials: 142-210 cm
Aquic conditions: starting at 0 cm
Drainage Class: Very poorly
Hydric Soil Status: Hydric, no FI
Vegetation (% cover by species): *Acer rubrum* (60%), *Morella cerifera* (60%), *Vaccinium corymbosum* (20%), *Amelanchier canadensis* (10%), *Echinochloa walteri* (3%), *Pinus taeda* (3%), *Cyperus esculentus* (trace), *Pluchea odorata* (trace)

Described: 6/14/2011, Annie Rossi, Mark Matovich
Observation Method: small pit to 40 cm, auger boring to 210 cm
Elevation: -0.02 m

Horizon	Depth	Texture	Matrix Color	Roots	Redox Features	Rxn w/ ααd	Rxn w/ 30% H_2O_2	pH (field)	Organic Carbon	Other
	cm								g kg^{-1}	
Oe	2	MPT	7.5 YR 2.5/2	--	--	--	--	5.42	297.95	
Oa	5	MUCK	5YR 2.5/1.5	--	--	--	--	5.51	201.40	
A1	7	MK VFSL	2.5Y 4/1	--	--	--	--	5.77	63.00	
A2	9.5	LS	2.5Y 3/1	--	--	--	--	5.69	23.60	
2Cg1	20	S	2.5Y 5.5/2	--	--	weak	--	5.80	2.60	5% OSF, 10YR 3/1, SC
2Cg2	33	FS	2.5Y 5/1.5	--	--	v.weak	--	5.93	1.03	<2% OSF, 10YR 3/1, SC
2Cg3	78	FS	2.5Y 4.5/1	--	--	v.weak	--	4.39	0.35	1-2 cm bands of FS, 2.5Y 5.5/1
2Cg4	93	S	2.5Y 5/1	--	--	none	--	6.46	0.41	<1% organic fragments
3Ab	110	L	2.5Y 3.5/1	--	--	none	--	6.50	45.66	35-40% organic fragments, 7.5YR 3/3
3Oa	117	MUCK	7.5YR 2.5/1.5	--	--	none	--	5.76	228.65	
3A’b1	128	FSL	2.5Y 3.5/1	--	--	none	--	5.76	37.95	15% organic fragments, 10YR 3/3
3A’b2	142	MK SCL	2.5Y 3.5/1	--	--	none	--	5.51	83.15	45% organic fragments, 10YR 3/3
3Aseb	168	LFS	5Y 4/1	--	--	none	--	4.69	11.55	5-10% organic fragments, 10YR 3/3
4Cse	210	FS	2.5Y 4.5/0.5	--	--	none	--	4.17	0.40	

BC6 Low

Site: BC6 Mid
Lat/Long: 38°08’22.8582”N, 75°10’50.5812”W
Landscape/Landform/Microfeature: barrier island, dune field, dune slack
Classification: Siliceous, thermic Typic Psammaquents
Diagnostic Features: Ochric epipedon: 0-16 cm
Sulfidic materials: 56-207 cm
Aquic conditions: starting at 12 cm
Drainage Class: Very poorly
Hydric Soil Status: Hydric, no FI
Vegetation (% cover by species): *Acer rubrum* (60%), *Vaccinium corymbosum* (30%), *Pinus taeda* (3%), *Smilax rotundafolia* (3%), *Ilex opaca* (<1%), *Chasmanthium laxum* (trace)

Described: 8/16/2011, Annie Rossi, Mark Matovich
Observation Method: small pit to 25 cm, auger boring to 207 cm
Elevation: 0.15 m

Horizon	Depth	Texture	Matrix Color	Roots	Redox Features	Rxn w/ ααd	Rxn w/ 30% H_2O_2	pH (field)	Organic Carbon	Other
	cm								g kg^{-1}	
Oi	5	PEAT	10YR 2/1	--	--	--	--	3.56	487.58	
Oe	10	MPT	5YR 2.5/2	--	--	--	--	3.68	317.77	
A1	12	MK LS	10YR 4/2	1f	--	--	--	4.16	63.40	
2A2	16	FS	10YR 3/1	1f	--	--	--	6.63	18.04	
2Cg	56	FS	10YR 5/1.5	--	--	none	--	6.88	0.84	1% OSF, 10YR 3/2
2Cse	117	FS	2.5Y 4/1	--	--	none	2.5Y 5/1	7.19	0.62	5% OSF, 10YR 3/1.5
3Aseb	134	L	2.5Y 3.5/1	--	--	none	2.5Y 4.5/1	7.01	42.04	20% organic fragments, 10YR 3/3 5% OSF, N 2.5
3Oase	146	MUCK	7.5YR 2.5/1.5	--	--	none	--	6.88	249.55	
3A’seb1	156	MK SL	7.5YR 3/2	--	--	none	--	6.94	82.12	
3A’seb2	171	FSL	5Y 3.5/0.5	--	--	none	5Y 4/1	7.00	13.10	10% organic fragments, 10YR 4/4
4Cse	207	FS	5Y 3.5/0.5	--	--	none	2.5Y 5.5/1	7.13	1.49	

BC6 Mid

Site: BC6 High
Lat/Long: 38°08’22.9806”N, 75°10’50.7612”W
Landscape/Landform/Microfeature: barrier island, dune field, dune
Classification: Sandy, siliceous, thermic Haplic Sulfaquents
Diagnostic Features: Ochric epipedon: 0-10 cm
Sulfidic materials: 47-220 cm
Aquic conditions: starting at 47 cm
Drainage Class: Somewhat poorly
Hydric Soil Status: Not hydric, no FI
Vegetation (% cover by species): *Amelanchier canadensis* (80%), *Vaccinium corymbosum* (40%), *Ilex opaca* (10%), *Morella cerifera* (10%), *Pinus taeda* (3%), *Acer rubrum* (3%), *Vitis rotundifolia* (<1%), *Chasmanthium laxum* (<1%)

Described: 8/16/2011, Annie Rossi, Mark Matovich
Observation Method: small pit 47 cm, auger boring 220 cm
Elevation: 0.40 m

Horizon	Depth	Texture	Matrix Color	Roots	Redox Features	Rxn w/ ααd	Rxn w/ 30% H_2O_2	pH (field)	Organic Carbon	Other
	cm								g kg^{-1}	
Oe	3	MPM	7.5YR 2.5/1	--	--	--	--	3.63	458.73	Surface cover: 0.5-1 cm pine needles and leaves
A	10	FS	10YR 3/1	2f, 1m, 1c	--	--	--	4.14	4.49	<2 cm bands of FS, 10YR 2/2, discontinuous
Bw/Bhs	33	FS	10YR 4.5/3	1f, 1c	5%, 10-20 mm, D, 10YR 5/1.5, FED	--	--	4.60	3.34	Bhs part: 10%, <0.5 cm bands and masses, 7.5YR 2.5/2 and 7.5YR 2.5/3, SC
C	47	FS	2.5Y 6/2	1f, 1m	--	--	--	4.18	1.85	1% OSF, 7.5YR 2.5/2 and 10YR 3/4
Cse1	66	S	2.5Y 4.5/1	--	--	weak-mod.	2.5Y 5/1.5	6.30	0.45	
Cse2	138	FS	2.5Y 4/1	--	--	none	2.5Y 6/1	6.57	0.26	bands of FS, 2.5Y 3.5/0.5
2Aseb	157	FSL	2.5Y 3/1	--	--	none	2.5Y 5/1	6.97	26.69	20% organic fragments, 10YR 3/3
2Oase	174	MUCK	7.5YR 2.5/2	--	--	none	--	6.80	176.95	
2A’seb1	185	FSL	7.5YR 3/1.5	--	--	none	--	6.80	60.57	
2A’seb2	198	FSL	5Y 3.5/0.5	--	--	none	--	7.08	21.26	10% organic fragments, 10YR 2/2
3Cse	220	FS	2.5Y 3.5/0.5	--	--	none	--	7.25	0.75	

BC6 High

BC6 Transect

BC6 Low

BC6 Mid

BC6 High

Site: OW1 Low
Lat/Long: 38°09’18.18”N, 75°10’20.8806”W
Landscape/Landform/Microfeature: barrier island, washover fan
Classification: Sandy, siliceous, thermic Haplic Sulfaquents
Diagnostic Features: Ochric epipedon: 0-9 cm
Sulfidic materials: 23-71 cm
Aquic conditions: starting at 20 cm
Drainage Class: Poorly
Hydric Soil Status: Hydric, no FI
Vegetation (% cover by species): *Andropogon virginicus* (70%), *Juncus scirpoides* (40%), *Juncus dichotomus* (30%), *Solidago sempervirens* (30%), *Dichanthelium acuminatum* (3%), *Dichanthelium scabriusculum* (3%), *Leersia virginica* (3%), *Phragmites australis* (3%), *Pluchea odorata* (3%), *Andropogon glomeratus* (<1%), *Baccharis halimifolia* (<1%), *Eupatorium capillifolium* (<1%), *Morella cerifera* (<1%), *Eupatorium hyssopifolium* (trace), *Hypericum gentianoides* (trace), *Juniperus virginiana* (trace), *Mikania scandens* (trace)

Described: 6/29/2011, Annie Rossi, Mark Matovich
Observation Method: small pit to 31 cm, auger boring to 218 cm
Elevation: 0.73 m

Horizon	Depth	Texture	Matrix Color	Roots	Redox Features	Rxn w/ ααd	Rxn w/ 30% H_2O_2	pH (field)	Organic Carbon	Other
	cm								g kg^{-1}	
A	1.5	S	10YR 2/1	--	--	--	--	5.40	35.96	30% OSF of sand grains
CA	9	S	10YR 5.5/3	--	--	--	--	5.20	7.33	2% OSF, 0.2-0.5 cm, 10YR 2/1, SC
C	20	S	10YR 5.5/2	--	--	--	--	5.47	1.12	2% OSF, 0.2-0.5 cm, 10YR 2/2, SC
Cg	23	FS	2.5Y 3.5/1	--	--	--	--	5.01	1.12	
Ab	26	S	10YR 2/2	--	--	--	--	5.06	8.20	
C’g	29	FS	2.5Y 5.5/1	--	--	--	--	4.85	2.21	2% OSF, 10YR 4/2, SC
Aseb	32	S	10YR 3/1.5	--	--	none	--	5.32	8.23	30% organic fragments
Cse	71	S	2.5Y 4.5/1	--	--	strong	--	6.05	0.16	H_2S odor
C’’g1	131	S	2.5Y 4/1	--	--	v.weak	--	8.21	0.24	1-2% gravels <1% shell fragments 0.5-1.0 cm bands of FS, 10YR 2/1
C’’g2	164	S	2.5Y 4.5/1	--	--	v.weak	--	7.77	0.10	
ACb	185	FS	2.5Y 3.5/0.5	--	--	none	--	8.37	0.34	5% shell fragments
C’’’g	218	FS	2.5Y 4.5/1	--	--	none	--	8.43	0.25	

OW1 Low

Site: OW1 Mid
Lat/Long: 38°09’18.2412”N, 75°10’20.9382”W
Landscape/Landform/Microfeature: barrier island, washover fan
Classification: Siliceous, thermic Typic Psammaquents
Diagnostic Features: Ochric epipedon: 0-16 cm
Sulfidic materials: 53-122 cm
Aquic conditions: starting at 39 cm
Drainage Class: Somewhat poorly
Hydric Soil Status: Not hydric, no FI
Vegetation (% cover by species): *Hypericum gentianoides* (40%), *Euthamia caroliniana* (20%), *Solidago sempervirens* (20%), *Juncus dichotomus* (10%), *Andropogon virginicus* (3%), *Panicum virgatum* (3%), *Dichanthelium acuminatum* (<1%), *Eupatorium capillifolium* (<1%), *Eupatorium hyssopifolium* (<1%), *Triplasis purpurea* (<1%), *Ammophila breviligulata* (trace), *Cenchrus tribuloides* (trace), *Eragrostis spectabilis* (trace), *Juncus scirpoides* (trace), *Phragmites australis* (trace), *Pseudognaphalium obtusifolium* (trace)

Described: 6/29/2011, Annie Rossi, Mark Matovich
Observation Method: small pit to 53 cm, auger boring to 250 cm
Elevation: 0.93 m

Horizon	Depth	Texture	Matrix Color	Roots	Redox Features	Rxn w/ ααd	Rxn w/ 30% H_2O_2	pH (field)	Organic Carbon	Other
	cm								g kg^{-1}	
CA	16	S	2.5Y 4.5/1.5	--	--	--	--	5.70	2.59	OSF, 1-2 cm, 10 YR 2/1, SC
C	39	S	2.5Y 6/2.5	--	3%, 10 mm, P, 7.5YR 4/6, F3M	--	--	5.23	0.83	7% OSF, 1 cm, 10YR 3/2 and 10YR 2/1, SC
Cg	53	S	2.5Y 5.5/1	--	--	--	--	5.81	0.41	2% OSF, 1 cm, 2.5Y 4/2, SC
Aseb	57	S	10YR 3/2	--	--	none	--	5.18	10.32	
Cse1	82	S	2.5Y 4.5/1	1f	1%, D 2.5Y 4/3, F3M, RPO	none	--	5.02	0.26	
Cse2	122	S	2.5Y 5/1	--	--	none	--	5.69	0.06	<1% gravels
C’g1	168	COS	2.5Y 5/1	--	--	none	--	8.47	0.35	7% gravels 1-2% shell fragments
C’g2	198	S	2.5Y 4.5/1	--	--	none	--	8.22	0.16	1-2% gravels
C’g3	245	FS	5Y 4/0.5	--	--	none	--	8.53	0.67	
2ACb	250	LFS	5Y 3.5/0.5	--	--	none	--	8.58	3.35	

OW1 Mid

Site: OW1 High
Lat/Long: 38^{o}09’18.4782”N, 75^{o}10’20.7006”W
Landscape/Landform/Microfeature: barrier island, washover fan
Classification: Thermic, uncoated, Aquic Quartzipsamments
Diagnostic Features: Ochric epipedon: 0-5 cm
Aquic conditions: starting at 44 cm
Drainage Class: Moderately well
Hydric Soil Status: Not hydric, no FI
Vegetation (% cover by species): *Solidago sempervirens* (50%), *Euthamia caroliniana* (10%), *Triplasis purpurea* (10%), *Panicum virgatum* (3%), *Baccharis halimifolia* (<1%), *Eupatorium hyssopifolium* (trace), *Spartina patens* (trace)

Described: 2/9/2012, Annie Rossi, Mark Matovich
Observation Method: small pit to 58 cm, auger boring to 198 cm
Elevation: 1.08 m

Horizon	Depth	Texture	Matrix Color	Roots	Redox Features	Rxn w/ ααd	Rxn w/ 30% H_2O_2	pH (field)	Organic Carbon	Other
	cm								g kg^{-1}	
CA	5	S	2.5Y 5/1.5	1f	--	--	--	6.15	0.91	<1% OSF, 10YR 4.5/2, SC
C1	31	S	2.5Y 5/2	1f, 1m	--	--	--	5.94	0.57	
C2	44	S	10YR 4/2	--	--	--	--	5.93	0.80	<1% gravels
Cg	58	S	2.5Y 5/1.5	--	--	--	--	5.56	0.41	5% OSF, root fragments, 10YR 4/2
Ab	62	S	10YR 3/2	--	--	weak	--	5.92	7.08	30% organic fragments <1% gravels
C’g1	83	S	10YR 4/1.5	--	--	weak	--	5.99	0.69	
C’g2	144	S	2.5Y 4.5/1	--	--	v.weak	--	6.56	0.16	
C’g3	161	COS	2.5Y 4/0.5	--	--	none	--	8.17	0.39	12% gravels 1-2% shell fragments
C’g4	183	S	2.5Y 4.5/0.5	--	--	none	--	8.41	0.19	4% gravels 1-2% shell fragments
C’g5	198	S	2.5Y 4.5/0.5	--	--	none	--	8.28	0.21	

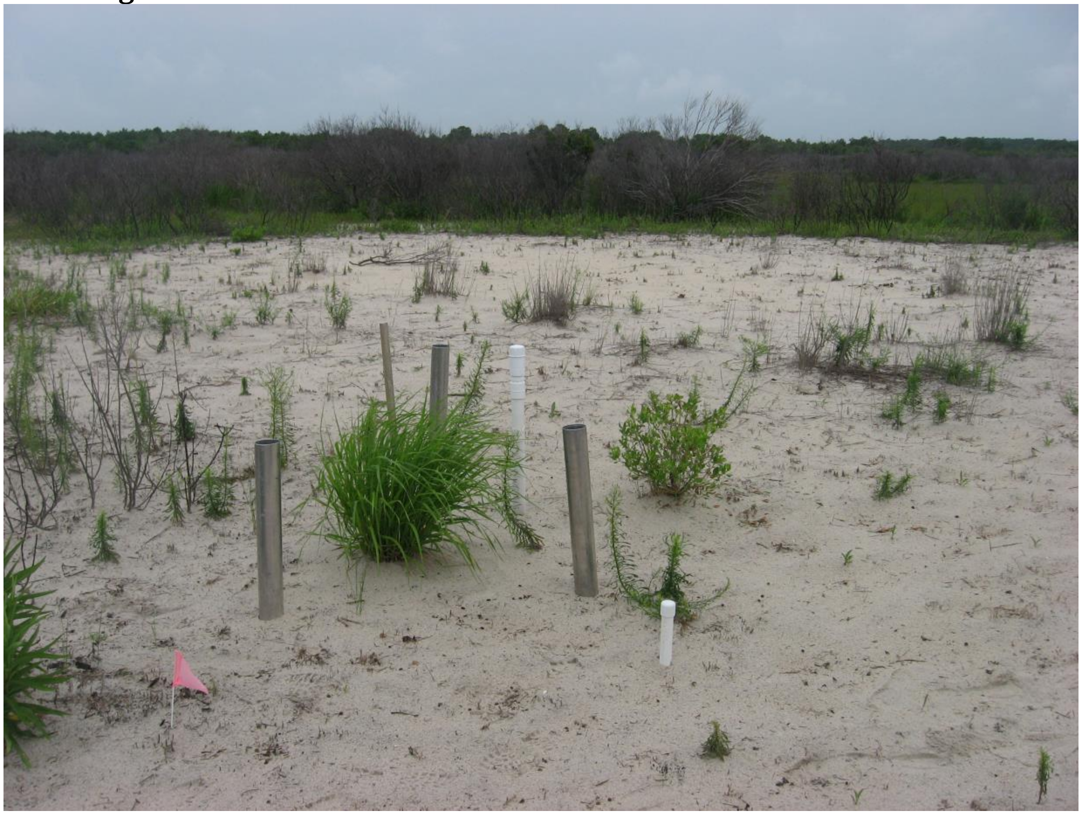
OW1 High

OW1 Transect

OW1 Low

OW1 Mid

OW1 High



Site: OW2 Low
Lat/Long: 38°09’8.7006”N, 75°10’32.8794”W
Landscape/Landform/Microfeature: barrier island, back-barrier flat
Classification: Sandy, siliceous, thermic Haplic Sulfaquents

Described: 6/8/2011, Annie Rossi, Martin Rabenhorst, Mark Matovich
Observation Method: small pit to 42 cm, auger boring to 198 cm
Elevation: 0.39 m

Diagnostic Features: Ochric epipedon: 0-7 cm
Sulfidic materials: 18-129 cm
Aquic conditions: starting at 7 cm
Drainage Class: Very poorly
Hydric Soil Status: Hydric, no FI
Vegetation (% cover by species): *Pluchea odorata* (70%), *Schoenoplectus americanus* (70%), *Setaria parviflora* (40%), *Agrostis gigantean* (30%), *Iva frutescens* (20%), *Fimbristylis caroliniana* (3%), *Fimbristylis castanea* (3%), *Mikania scandens* (3%), *Distichlis spicata* (<1%), *Solidago sempervirens* (<1%), *Phragmites australis* (trace)

Horizon	Depth	Texture	Matrix Color	Roots	Redox Features	Rxn w/ ααd	Rxn w/ 30% H_2O_2	pH (field)	Organic Carbon	Other
	cm								g kg^{-1}	
Oa	2.5	MUCK	7.5YR 2.5/1.5	-	--	--	--	6.23	189.50	
CA	7	FS	2.5Y 5/2.5	2vf, 2f, 2m	--	--	--	6.19	8.42	
Cg	18	FS	2.5Y 4.5/1.5	2f, 2m	--	--	--	6.28	0.84	5% OSF, 0.5-1 cm, 10YR 3.5/3
Cse1	31	FS	2.5Y 4.5/1	1f, 1m	--	--	--	7.10	0.27	
Cse2	79	S	2.5Y 5.5/1	1f, 1m	--	--	--	7.16	0.48	
Cse3	129	S	2.5Y 5/1	-	--	--	--	8.24	0.16	
C’g	175	S	2.5Y 5/1	-	--	--	--	8.57	0.33	1-2% shell fragments
Ab	198	FSL	2.5Y 3/0.5	-	--	--	--	7.34	2.67	1-2% shell fragments

OW2 Low

Site: OW2 Mid
Lat/Long: 38°09’8.65”N, 75°10’31.39”W
Landscape/Landform/Microfeature: barrier island, back-barrier flat
Classification: Siliceous, thermic Typic Psammaquents
Diagnostic Features: Ochric epipedon: 0-7 cm
Sulfidic materials: 192-228 cm
Aquic conditions: starting at 13 cm
Drainage Class: Poorly
Hydric Soil Status: Hydric, A9

Described: 8/17/2011, Annie Rossi, Mark Matovich
Observation Method: small pit to 27 cm, auger boring to 228 cm
Elevation: 0.58 m

Vegetation (% cover by species): *Dichanthelium acuminatum* (70%), *Panicum virgatum* (60%), *Toxicodendron radicans* (40%), *Rubus* spp. (20%), *Eupatorium capillifolium* (10%), *Hypericum gentianoides* (10%), *Andropogon virginicus* (3%), *Eupatorium hyssopifolium* (3%), *Fimbristylis castanea* (3%), *Juncus dichotomus* (3%), *Juncus scirpoides* (3%), *Setaria parviflora* (3%), *Solidago sempervirens* (3%), *Baccharis halimifolia* (<1%), *Eragrostis spectabilis* (<1%), *Nuttallanthus canadensis* (<1%), *Schoenoplectus americanus* (<1%), *Vitis rotundifolia* (<1%), *Cyperus retrorsus* (trace), *Euthamia caroliniana* (trace)

Horizon	Depth	Texture	Matrix Color	Roots	Redox Features	Rxn w/ ααd	Rxn w/ 30% H_2O_2	pH (field)	Organic Carbon	Other
	cm								g kg^{-1}	
Oa	2.5	MUCK	10YR 2/1	2vf, 1f	--	--	--	5.26	151.35	
CA	7	FS	10YR 4/2	1f	--	--	--	5.16	3.12	5% OSF, 10YR 2/2, SC
C	13	S	2.5Y 5/2	1f	--	--	--	5.07	0.80	1% OSF, 1-2 cm, 7.5YR 2.5/2, SC
Cg1	27	S	2.5Y 5.5/1.5	1f	--	--	--	5.06	0.38	
Cg2	60	S	2.5Y 4.5/1	--	--	none	--	6.25	0.48	
Cg3	101	S	2.5Y 5/1	--	--	none	--	7.37	0.19	
Cg4	147	S	2.5Y 4.5/1	--	--	none	2.5Y 5.5/1	7.62	0.24	OSF, possible buried surface at 147 cm, 10YR 2/1
Cg5	192	COS	2.5Y 3.5/1	--	--	none	2.5Y 6/1	7.61	0.57	3% gravels 1% shell fragments
Aseb	228	LFS	2.5Y 2.5/1	--	--	none	2.5Y 3.5/1	7.72	2.98	

OW2 Mid

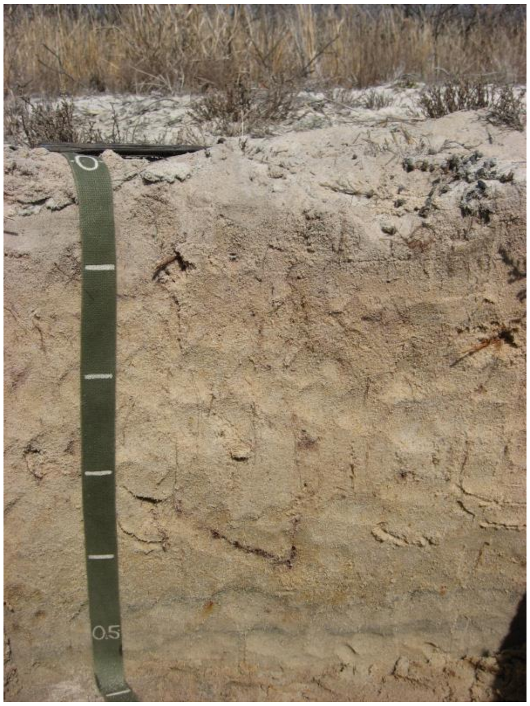
Site: OW2 High
Lat/Long: 38°09’8.5788”N, 75°10’31.1982”W
Landscape/Landform/Microfeature: barrier island, back-barrier flat, dune
Classification: Thermic, uncoated Aquic Quartzipsamments
Diagnostic Features: Ochric epipedon: 0-16 cm
Sulfidic materials: 107-185 cm
Aquic conditions: starting at 52 cm
Drainage Class: Moderately well
Hydric Soil Status: Not hydric, no FI

Described: 3/21/2012, Annie Rossi, Mark Matovich
Observation Method: small pit to 52 cm, auger boring to 218 cm
Elevation: 0.97 m

Vegetation (% cover by species): *Hudsonia tomentosa* (20%), *Rubus* spp. (20%), *Eupatorium hyssopifolium* (10%), *Euthamia caroliniana* (10%), *Juncus scirpoides* (10%), *Panicum virgatum* (10%), *Ammophila breviligulata* (3%), *Andropogon virginicus* (3%), *Dichanthelium acuminatum* (3%), *Fimbristylis castanea* (3%), *Hypericum gentianoides* (3%), *Juncus dichotomus* (3%), *Baccharis halimifolia* (<1%), *Cyperus retrorsus* (<1%), *Lechea maritime* (<1%), *Eupatorium rotundifolium* (trace)

Horizon	Depth	Texture	Matrix Color	Roots	Redox Features	Rxn w/ ααd	Rxn w/ 30% H_2O_2	pH (field)	Organic Carbon	Other
	cm								g kg^{-1}	
CA	16	S	10YR 4/2	2vf, 1f, 1m	--	--	--	5.22	1.70	1% OSF, 0.5 cm, 7.5YR 2.5/3
C1	33	S	10YR 5/2.5	1vf, 1f	--	--	--	4.91	0.63	3% OSF, 0.2-0.5 cm, 10YR 3/2, SC
2C2	43	COS	2.5Y 5/2.5	1f	1%, 10 mm, P, 10YR 5/6, F3M	--	--	5.15	0.31	
2C3	52	S	2.5Y 5/2	1vf	1%, 10 mm, P, 10YR 4/6, F3M	--	--	5.54	0.15	0.5-1.0 cm bands of FS, 2.5Y 4.5/1
2Cg	107	S	2.5Y 5/2	--	--	none	--	6.88	0.72	
2Cse1	151	S	2.5Y 4.5/1	--	--	v.weak	--	7.11	0.24	H_2S odor
2Cse2	185	S	2.5Y 4.5/0.5	--	--	v.weak	2.5Y 5/1	7.22	0.07	
2C’g	218	COS	5Y 5/1	--	--	none	--	7.71	0.38	3% gravels, 1% shell fragments

OW2 High



OW2 Transect

OW2 Low

OW2 Mid

OW2 High

Site: OW3 Low
Lat/Long: 38°09’16.6212”N, 75°10’26.5794”W
Landscape/Landform/Microfeature: barrier island, back-barrier flat
Classification: Siliceous, thermic, Typic Psammaquents
Diagnostic Features: Ochric epipedon: 0-14 cm
Aquic conditions: starting at 14 cm
Drainage Class: Very poorly
Hydric Soil Status: Hydric, no FI
Vegetation (% cover by species): *Spartina patens* (80%), *Lythrum lineare* (60%), *Fimbristylis castanea* (50%), *Iva frutescens* (40%), *Pluchea odorata* (30%), *Baccharis halimifolia* (20%), *Distichlis spicata* (10%), *Schoenoplectus americanus* (10%), *Phragmites australis* (<1%), *Setaria parviflora* (<1%), *Mikania scandens* (trace), *Solidago sempervirens* (trace)

Described: 7/19/2011, Annie Rossi, Judy Turk, Shah Uddin
Observation Method: small pit to 36 cm, auger boring to 238 cm
Elevation: 0.29 m

Horizon	Depth	Texture	Matrix Color	Roots	Redox Features	Rxn w/ ααd	Rxn w/ 30% H_2O_2	pH (field)	Organic Carbon	Other
	cm								g kg^{-1}	
Oa1	3	MUCK	7.5YR 3/2	--	--	--	--	5.26	238.70	
Oa2	6	MUCK	10YR 2.5/2	--	--	--	--	5.16	185.20	
CA	14	COS	10YR 5.5/2	1vf, 1f, 1m	--	--	--	5.07	3.88	1-2% gravels 1-2% shell fragments
Cg1	23	COS	2.5Y 5/1.5	1m	1%, <5 mm, P, 10YR 4/6, F3M, RPO; 4%, <5 mm, D, 10YR 5/4, F3M	--	--	5.06	0.62	1-2% shell fragments 1% gravels
Cg2	103	S	5Y 4.5/1	1f	--	none	--	6.25	0.54	1% shell fragments
Cg3	138	S	5Y 4/1	--	--	none	--	7.37	0.52	
Cg4	174	FS	5Y 3.5/1.5	--	--	none	--	7.62	0.38	1% gravels
Ab	238	LFS	5Y 3.5/0.5	--	--	none	--	7.61	3.04	

OW3 Low

Site: OW3 Mid
Lat/Long: 38^{o}09’17.0994”N, 75^{o}10’27.1194”W
Landscape/Landform/Microfeature: barrier island, back-barrier flat
Classification: Siliceous, thermic, Typic Psammaquents
Diagnostic Features: Ochric epipedon: 0-15 cm
Sulfidic materials: 114-226 cm
Aquic conditions: starting at 15 cm
Drainage Class: Very poorly
Hydric Soil Status: Hydric, no FI
Vegetation (% cover by species): *Eleocharis rostellata* (40%), *Panicum virgatum* (20%), *Phragmites australis* (20%), *Scleria verticillata* (20%), *Fimbristylis caroliniana* (10%), *Fimbristylis castanea* (10%), *Andropogon glomeratus* (3%), *Baccharis halimifolia* (3%), *Dichanthelium acuminatum* (3%), *Eupatorium hyssopifolium* (3%), *Euthamia caroliniana* (3%), *Juncus scirpoides* (3%), *Morella cerifera* (3%), *Setaria parviflora* (3%), *Eragrostis spectabilis* (<1%), *Pluchea odorata* (<1%), *Schoenoplectus americanus* (<1%), *Solidago sempervirens* (trace)

Described: 8/23/2011, Annie Rossi, Mark Matovich
Observation Method: small pit to 15 cm, auger boring to 250 cm
Elevation: 0.33 m

Horizon	Depth	Texture	Matrix Color	Roots	Redox Features	Rxn w/ αα'd	Rxn w/ 30% H_2O_2	pH (field)	Organic Carbon	Other
	cm								g kg^{-1}	
A1	1.5	COS	10YR 2/1	2vf	--	--	--	7.72	40.62	
A2	6	S	10YR 3/2	1vf, 1f	1%, 5-10 mm, D, 7.5YR 3/3 and 7.5YR 3/4, F3M, RPO and MAT	--	--	7.46	5.21	4% gravels
CA	15	S	10YR 4.5/2.5	1f	--	--	--	7.72	0.72	1-2% gravels 1% shell fragments
Cg1	31	COS	10YR 4/1.5	--	--	none	--	7.66	0.39	2% gravels <1% shell fragments
Cg2	77	S	2.5Y 5/1	--	--	none	--	7.78	0.38	1% shell fragments <1% gravels Organic fragments
Cg3	114	COS	2.5Y 4.5/1	--	--	none	--	8.11	0.52	7% gravels 1% shell fragments
Cse1	139	S	2.5Y 4/1.5	--	--	none	2.5Y 5.5/1	7.98	0.29	1% gravels
Cse2	154	FS	2.5Y 3.5/0.5	--	--	none	2.5Y 5/1	8.07	0.34	
Cse3	174	FS	2.5Y 3/0.5	--	--	none	2.5Y 4.5/1	8.27	0.57	
Aseb	199	FSL	2.5Y 3/0.5	--	--	none	--	8.21	4.53	Organic fragments, 10YR 2/2
C’se	226	LFS	2.5Y 3/0.5	--	--	none	--	8.21	2.35	
C’g	250	FS	2.5Y 3/0.5	--	--	none	--	8.40	0.82	<1% shell fragments

OW3 Mid

Site: OW3 High
Lat/Long: 38°09’17.46”N, 75°10’27.7212”W
Landscape/Landform/Microfeature: barrier island, back-barrier flat, dune
Classification: Thermic, uncoated Aquic Quartzipsamments
Diagnostic Features: Ochric epipedon: 0-3 cm
Aquic conditions: starting at 80 cm
Drainage Class: Moderately well
Hydric Soil Status: Not hydric, no FI
Vegetation (% cover by species): *Hudsonia tomentosa* (50%), *Panicum virgatum* (10%), *Ammophila breviligulata* (3%), *Dichanthelium scabriusculum* (3%), *Eupatorium hyssopifolium* (3%), *Euthamia caroliniana* (3%), *Pinus taeda* (3%), *Baccharis halimifolia* (<1%), *Dichanthelium acuminatum* (<1%), *Dichanthelium scoparium* (<1%), *Eragrostis spectabilis* (<1%), *Rubus* spp. (<1%), *Cyperus grayi* (trace), *Juncus dichotomus* (trace), *Morella cerifera* (trace), *Phragmites australis* (trace), *Solidago sempervirens* (trace)

Described: 8/23/2011, Annie Rossi, Mark Matovich
Observation Method: small pit to 74 cm, auger boring to 198 cm
Elevation: 0.90 m

Horizon	Depth	Texture	Matrix Color	Roots	Redox Features	Rxn w/ αα'd	Rxn w/ 30% H_2O_2	pH (field)	Organic Carbon	Other
	cm								g kg^{-1}	
AC	3	S	10YR 3.5/1.5	--	--	--	--	4.48	2.74	
Bw1	11.5	S	10YR 4.5/2.5	1vf	--	--	--	4.59	0.55	
Bw2	36	S	10YR 5/3	1vf	--	--	--	4.87	0.34	1% OSF, 10YR 3/3
Bw3	54	S	10YR 6/3	--	--	--	--	5.79	0.22	
Bw4	74	S	10YR 6/3	--	1-2%, 10 mm, D, 10YR 5/6, F3M	--	--	5.99	0.06	
2Bw5	80	S	10YR 5/3	--	--	none	--	7.48	0.38	3% gravels 2% shell fragments
2Cg	123	S	10YR 5/1.5	--	--	none	--	7.17	0.30	
2Cg/Ab	158	S	2.5Y 5/1	--	--	none	--	7.88	0.35	Ab part: 5%, 10YR 2/2 <1% shell fragments
2C’g1	184	S	2.5Y 4.5/1	--	--	none	--	7.81	0.43	
2C’g2	198	S	2.5Y 3.5/1	--	--	weak	2.5Y 5/1	7.97	0.64	

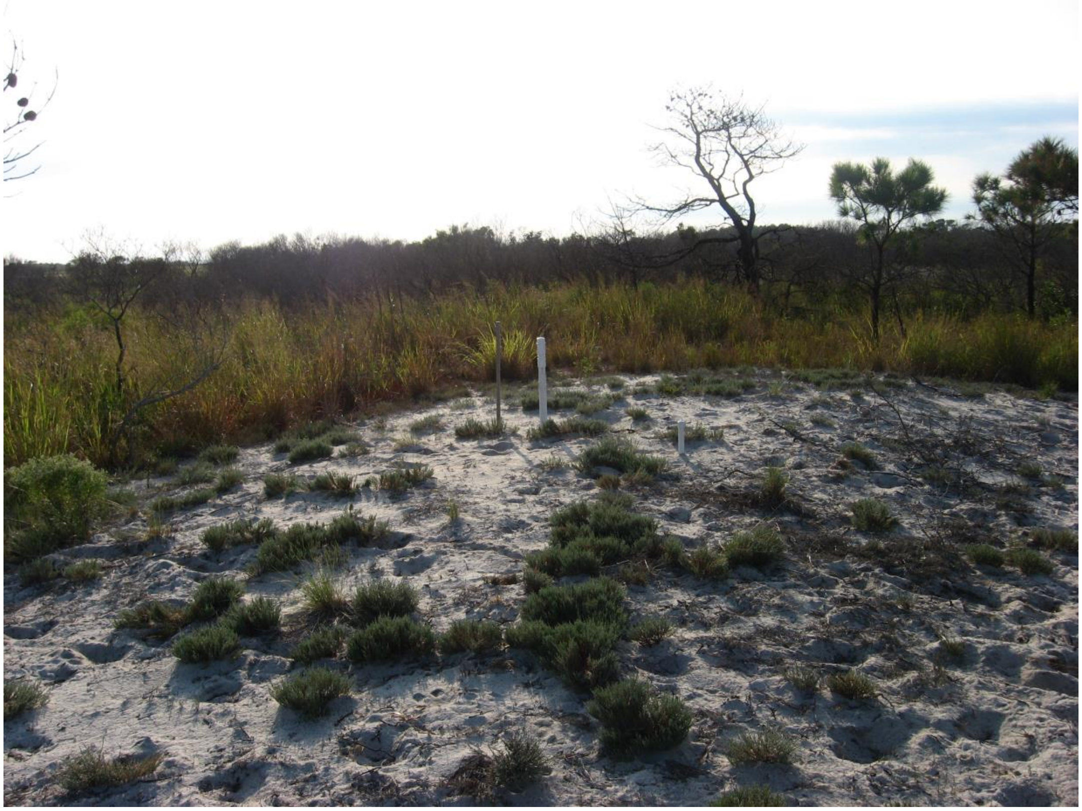
OW3 High

OW3 Transect

OW3 Low

OW3 Mid

OW3 High



Site: OW4 Low
Lat/Long: 38°09’6.7782”N, 75°10’25.3806”W
Landscape/Landform/Microfeature: barrier island, washover fan
Classification: Sandy, siliceous, thermic Haplic Sulfaquents
Diagnostic Features: Ochric epipedon: 0-6 cm
Sulfidic materials: 42-78 cm
Aquic conditions: starting at 11 cm
Drainage Class: Poorly
Hydric Soil Status: Hydric, no FI
Vegetation (% cover by species): *Phragmites australis* (80%), *Baccharis halimifolia* (50%), *Panicum virgatum* (30%), *Solidago sempervirens* (20%), *Juncus scirpoides* (10%), *Andropogon glomeratus* (3%), *Hypericum gentianoides* (3%), *Morella cerifera* (3%), *Schoenoplectus americanus* (3%), *Andropogon virginicus* (<1%), *Eragrostis spectabilis* (<1%), *Euthamia caroliniana* (<1%), *Fimbristylis caroliniana* (<1%), *Pluchea odorata* (<1%)

Described: 6/28/2011, Annie Rossi, Mark Matovich
Observation Method: small pit to 56 cm, auger boring to 205 cm
Elevation: 0.72 m

Horizon	Depth	Texture	Matrix Color	Roots	Redox Features	Rxn w/ αάd	Rxn w/ 30% H_2O_2	pH (field)	Organic Carbon	Other
	cm								g kg^{-1}	
A1	1.5	S	10YR 2/1	--	--	--	--	5.13	5.70	
A2	3.5	S	10YR 2/2	--	--	--	--	5.22	6.33	
AC	6	S	10YR 3/2	--	--	--	--	5.34	1.37	
C	11	S	10YR 4.5/2	--	--	--	--	5.37	0.53	
Cg1	23	S	2.5Y 5.5/1.5	--	--	--	--	4.66	0.53	
Cg2	28	FS	2.5Y 4/1.5	--	--	--	--	4.73	1.54	
Ab	29.5	FSL	10YR 2.5/2	--	--	--	--	6.18	19.43	Plant stem fragments, 1-3 cm,
C’g	32	FS	2.5Y 4.5/1	2f	--	--	--	6.78	2.20	Plant stem fragments, 1-3 cm,
A’b	35	LCOS	10YR 3/2.5	--	--	--	--	6.68	16.35	45% root and stem fragments, 1-3 cm
C’’g	42	COS	2.5Y 5.5/1.5	2f	--	--	--	6.67	0.98	Plant stem fragments, 1-3 cm
Cse1	44	FS	2.5Y 4.5/1	2f, 2m, 2c	--	--	--	6.63	0.43	Plant stem fragments, 1-3 cm
Cse2	78	COS	2.5Y 3/1	1f, 1m, 1c	--	none	--	6.54	0.30	Plant stem fragments, 1-3 cm <1% gravels
C’’’g	164	S	2.5Y 4.5/1	--	--	none	--	7.56	0.48	5% root and stem fragments, 1-3 cm bands of FS, 2.5Y 3/1 H_2S odor
A’’b	183	S	10YR 2/1	--	--	none	--	7.37	40.67	5% organic fragments
C’’’’g	205	FS	2.5Y 4.5/1	--	--	none	--	7.84	0.39	

OW4 Low

Site: OW4 Mid
Lat/Long: 38°09’6.5988”N, 75°10’25.1394”W
Landscape/Landform/Microfeature: barrier island, washover fan
Classification: Sandy, siliceous, thermic Haplic Sulfaquents
Diagnostic Features: Ochric epipedon: 0-2 cm
Sulfidic materials: 42-52 cm
Aquic conditions: starting at 32 cm
Drainage Class: Somewhat poorly
Hydric Soil Status: Hydric, no FI

Described: 8/17/2011, Annie Rossi, Mark Matovich
Observation Method: small pit to 42 cm, auger boring to 220 cm
Elevation: 0.84 m

Vegetation (% cover by species): *Solidago sempervirens* (40%), *Euthamia caroliniana* (20%), *Baccharis halimifolia* (10%), *Hypericum gentianoides* (3%), *Juncus scirpoides* (3%), *Panicum amarum* (3%), *Phragmites australis* (3%), *Ammophila breviligulata* (<1%), *Cenchrus tribuloides* (<1%), *Fimbristylis caroliniana* (<1%), *Fimbristylis castanea* (<1%), *Panicum virgatum* (<1%), *Hypochaeris radicata* (trace)

Horizon	Depth	Texture	Matrix Color	Roots	Redox Features	Rxn w/ ααd	Rxn w/ 30% H_2O_2	pH (field)	Organic Carbon	Other
	cm								g kg^{-1}	
A	2	S	10YR 2/1	1f	--	--	--	6.04	18.96	
C1	25	S	2.5Y 5.5/2	1f, 1m	1%, 2-5 mm, P, 7.5YR 4/6, F3M, RPO	--	--	6.06	0.96	5% OSF, 0.2-0.5 cm, 10YR 2/1, SC
C2	32	S	2.5Y 5.5/2	1f	--	--	--	5.36	0.73	1% OSF, 10YR 3/2, SC
Cg	34	S	2.5Y 4/1.5	1f	--	--	--	5.04	3.56	
Ab	36	FS	10YR 3/1.5	1vf	--	--	--	5.07	13.45	
C’g	39	FS	2.5Y 4.5/1	1vf	--	--	--	5.58	2.46	
A’b	42	S	10YR 2/1.5	1vf	--	--	--	5.90	22.26	
Cse	52	S	2.5Y 6/1	3f	--	none	--	6.71	1.41	
C’’g1	147	S	2.5Y 5/1	--	--	none	2.5Y 6/1.5	7.44	0.21	
C’’g2	200	S	2.5Y 4.5/1	--	--	none	--	7.75	0.09	<1% gravels
C’’g3	220	FS	2.5Y 4.5/0.5	--	--	none	--	7.62	0.21	

OW4 Mid

Site: OW4 High
Lat/Long: 38°09’6.2388”N, 75°10’24.6612”W
Landscape/Landform/Microfeature: barrier island, washover fan
Classification: Siliceous thermic, Typic Psammaquents
Diagnostic Features: Ochric epipedon: 25-29 cm
Sulfidic materials: 68-113 cm
Aquic conditions: starting at 49 cm
Drainage Class: Somewhat poorly
Hydric Soil Status: Not hydric, no FI
Vegetation (% cover by species): *Baccharis halimifolia* (40%), *Solidago sempervirens* (30%), *Panicum amarum* (20%), *Cenchrus tribuloides* (3%), *Euthamia caroliniana* (3%), *Fimbristylis castanea* (3%), *Ammophila breviligulata* (<1%)

Described: 3/21/2012, Annie Rossi, Mark Matovich
Observation Method: small pit to 73 cm, auger boring to 198 cm
Elevation: 1.02 m

Horizon	Depth	Texture	Matrix Color	Roots	Redox Features	Rxn w/ ααd	Rxn w/ 30% H_2O_2	pH (field)	Organic Carbon	Other
	cm								g kg^{-1}	
C	24	S	2.5Y 5/2		--	--	--	7.10	0.32	0.2 cm bands of FS, stratified
Ab1	25	S	10YR 2/1	2f, 2m	--	--	--	7.10	5.32	
Ab2	29	S	10YR 4/2	3f, 1c, 1m, 2vf	1%, 2-10 mm, P, 7.5YR 5/6, F3M, RPO	--	--	6.77	1.67	
Cg1	38	FS	2.5Y 5/2	2f	4%, 2-10 mm, P, 7.5YR 5/6, F3M, RPO	--	--	6.82	0.77	
Cg2	49	S	2.5Y 5.5/2	1f	--	--	--	5.87	0.51	5% OSF, 2-4 cm, 10YR 3/2
Cg3	68	S	2.5Y 4.5/1	2f	--	--	--	6.14	0.53	5% OSF, 2-4 cm, 10YR 3/2
Aseb	73	S	10YR 2.5/2	3vf, 3f, 2m	--	--	--	6.95	10.84	
Cse1	90	FS	10YR 4/1.5		--	weak	--	7.08	0.45	
Cse2	113	COS	2.5Y 4/1		--	none	--	6.54	0.26	<1% gravels
C’g1	137	S	2.5Y 3.5/0.5		--	none	--	7.19	0.10	<1% gravels
C’g2	165	S	2.5Y 4.5/1		--	none	--	7.56	0.10	<1% gravels
C’g3	198	S	5Y 4/0.5		--	none	--	7.45	0.06	<1% gravels

OW4 High

OW4 Transect

OW4 Low

OW4 Mid

OW4 High

Soils were described following the procedures of Schoeneberger (2012). Abbreviations used in the table are as follows:

Texture:

S = sand
FS = fine sand
COS = coarse sand
LS = loamy sand
LFS = loamy fine sand
LCOS = loamy coarse sand
SL = sandy loam
FSL = fine sandy loam
L = loam
CL = clay loam
SCL = sandy clay loam
SICL = silty clay loam
MK = mucky (modifier)
MUCK = muck
PEAT = peat
MPM = moderately decomposed plant material
SPM = slightly decomposed plant material

Roots:

Quantity:
1 = few, < 1 area assessed
2 = common, 1 to < 5 per area assessed
3 = many, ≥ 5 per area assessed
Size:
vf = very fine, < 1 mm diameter, assess area of 1 cm^2
f = fine, 1 to < 2 mm diameter, assess area of 1 cm^2
m = medium, 2 to < 5 mm diameter, assess area of 1 dm^2
c = coarse, 5 to < 10 mm diameter, assess area of 1 dm^2
vc = very coarse, ≥ 10 mm diameter, assess area of 1 m^2

Redox features:

Contrast:
F = faint
D = distinct
P = prominent
Feature:
FED = iron depletions
F3M = iron (Fe^{3+}) concentrations, non-cemented
Location:
RPO = on surfaces along root channels
MAT = in the matrix (not associated with peds/pores)

Rxn w/ ααd:

positive reaction (development of pink or red color) indicates the presence of Fe^{2+}; responses were characterized as very weak, weak, moderate, and strong based on the degree of color change
none = no color development, Fe^{2+} not detected
\- = soil horizon was not saturated, so reaction with ααd was not evaluated

Rxn w/ H_2O_2:

color = color response (change) following application of 30% H_2O_2, positive reaction (color change – increased value and chroma) indicates the presence of monosulfides.

none = no color change, monosulfides are not detected

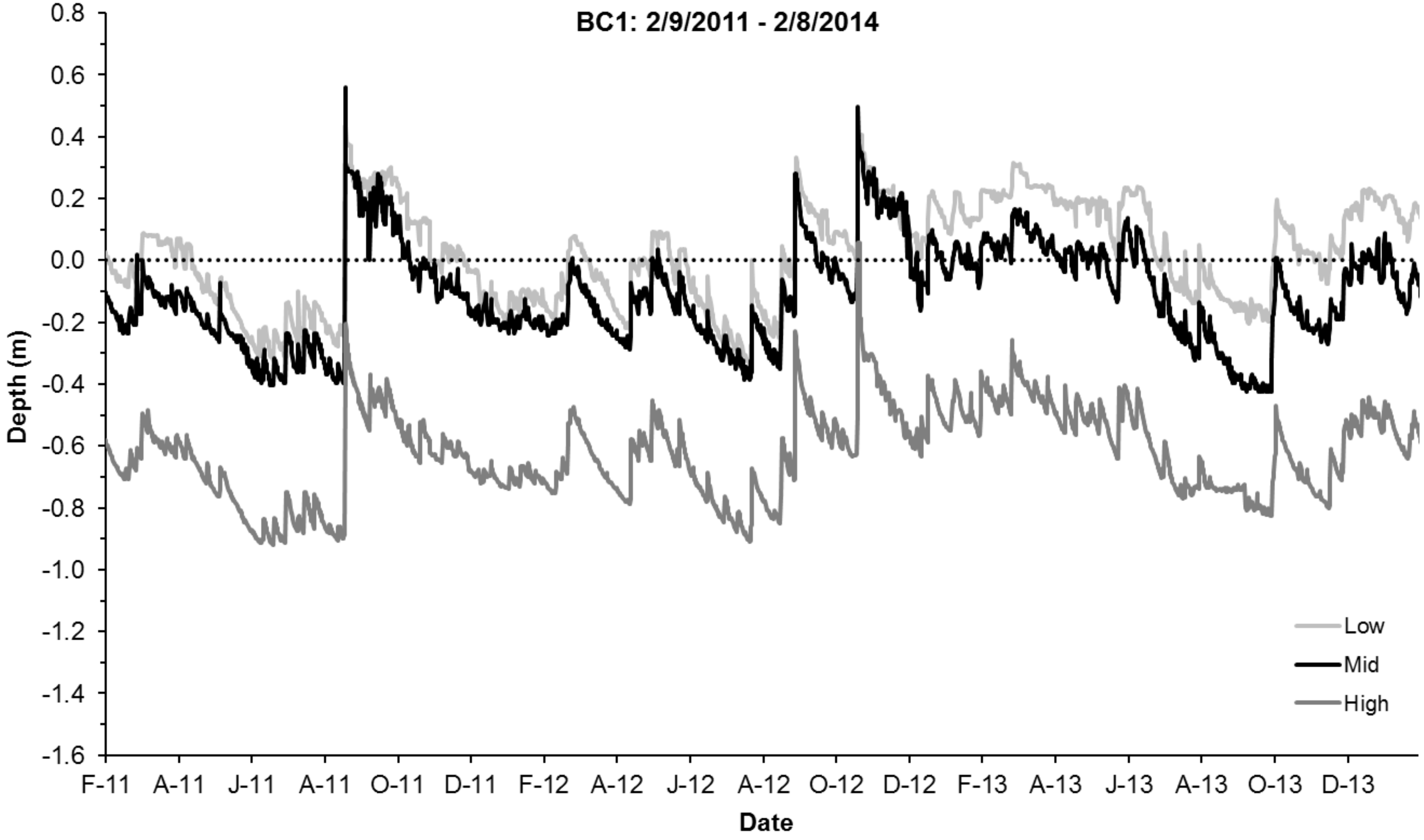
\- = soil horizon was not saturated, so reaction with H_2O_2 was not evaluated

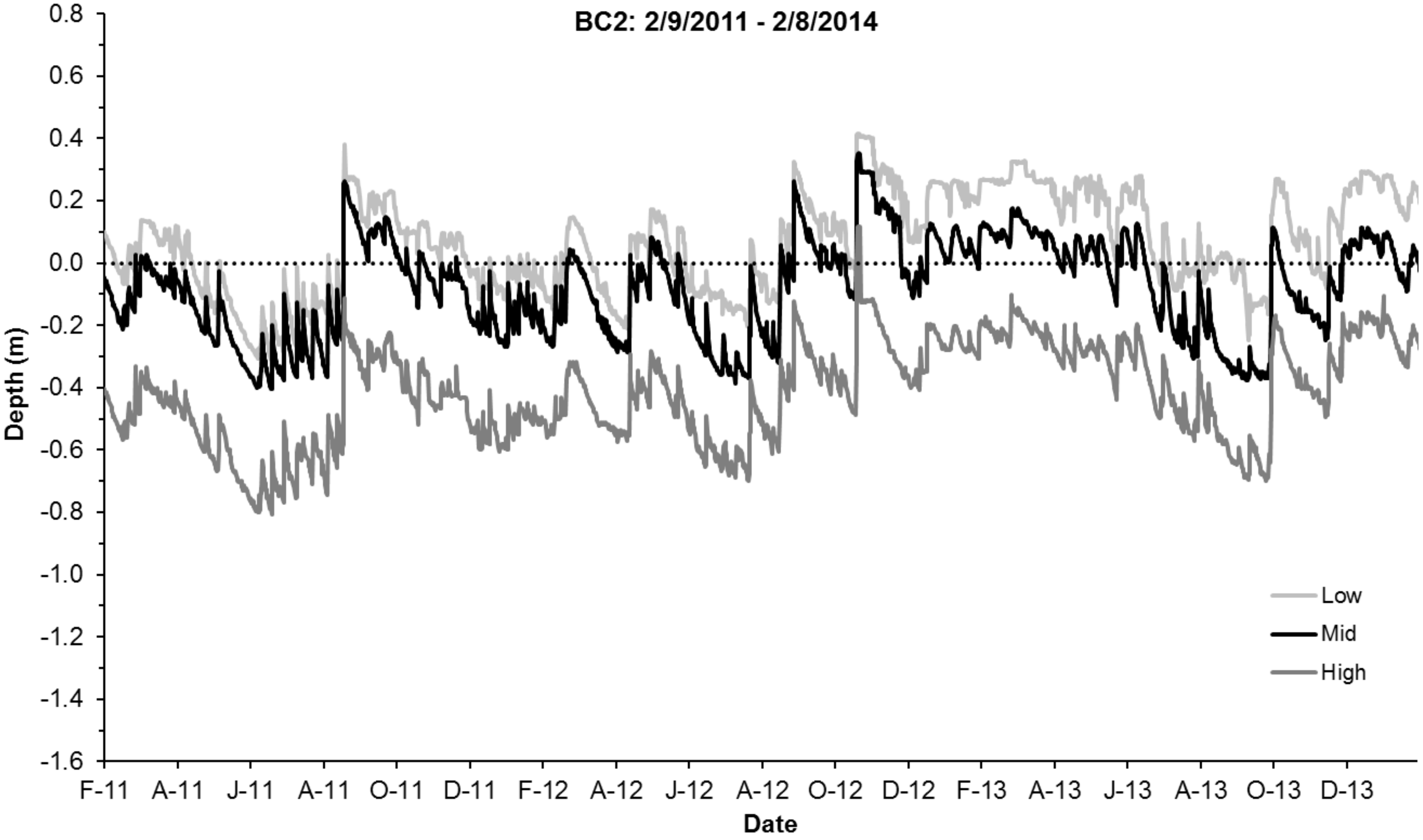
Other Features:

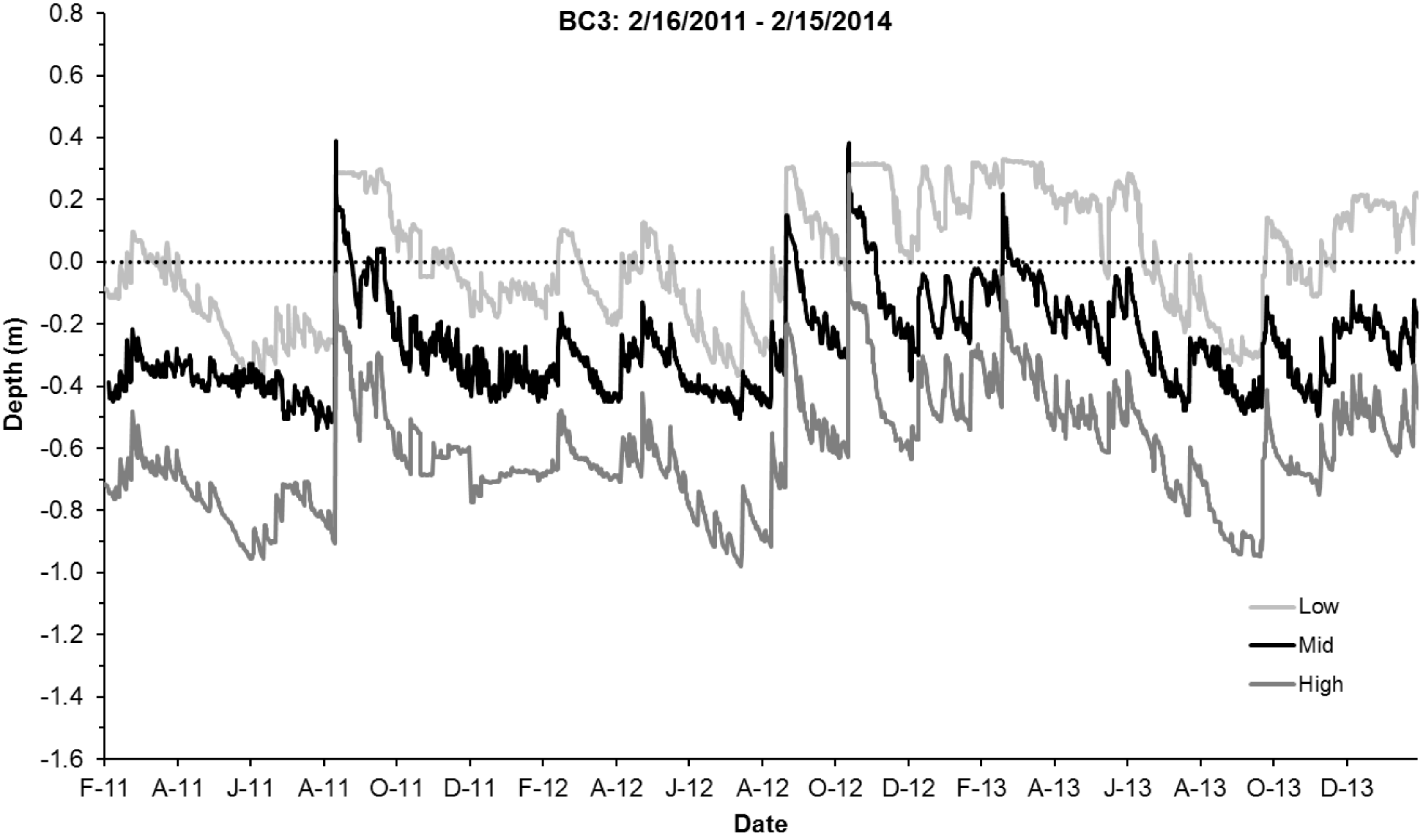
OSF = organic stains, SC = along root channels

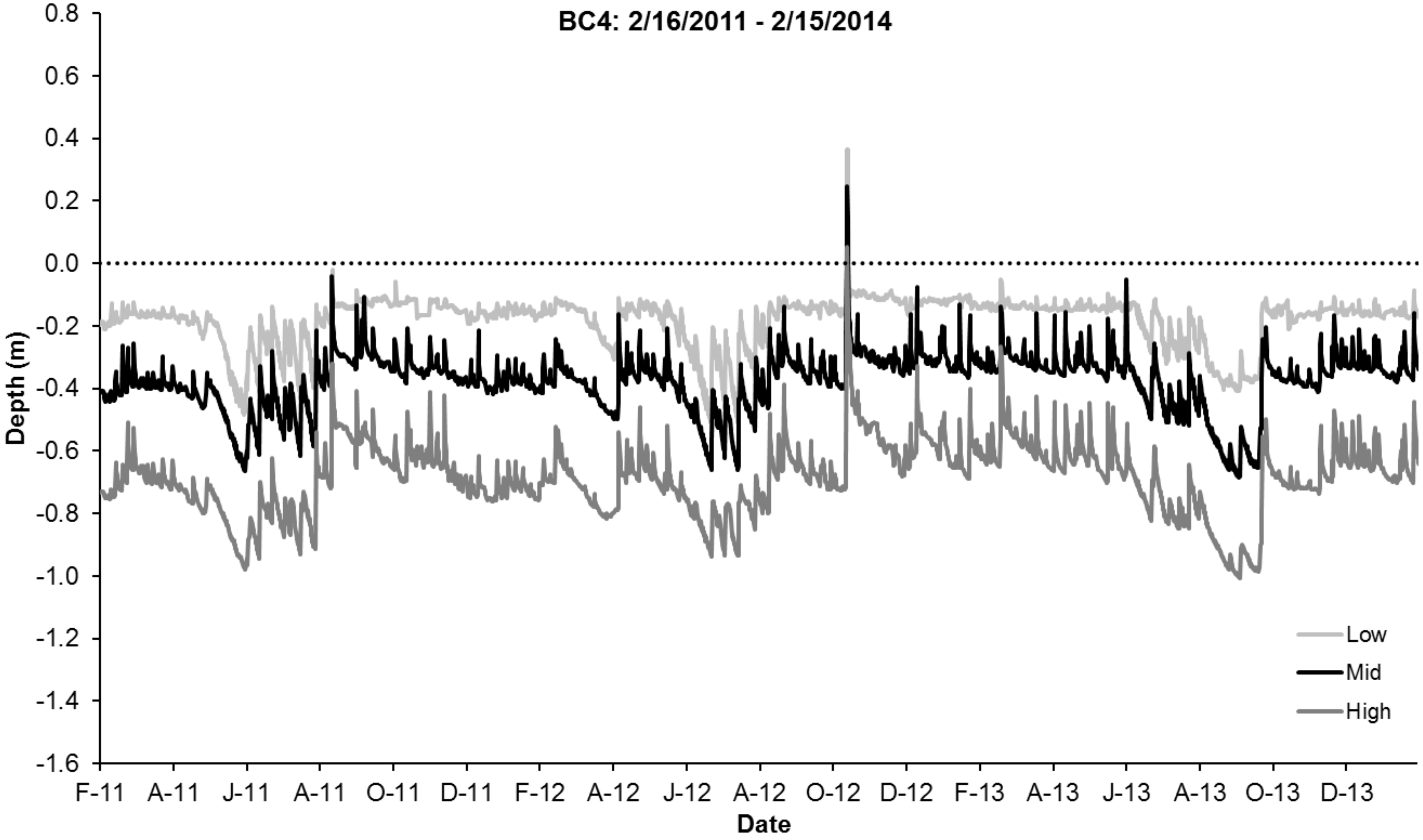
APPENDIX B: WATER TABLE DATA

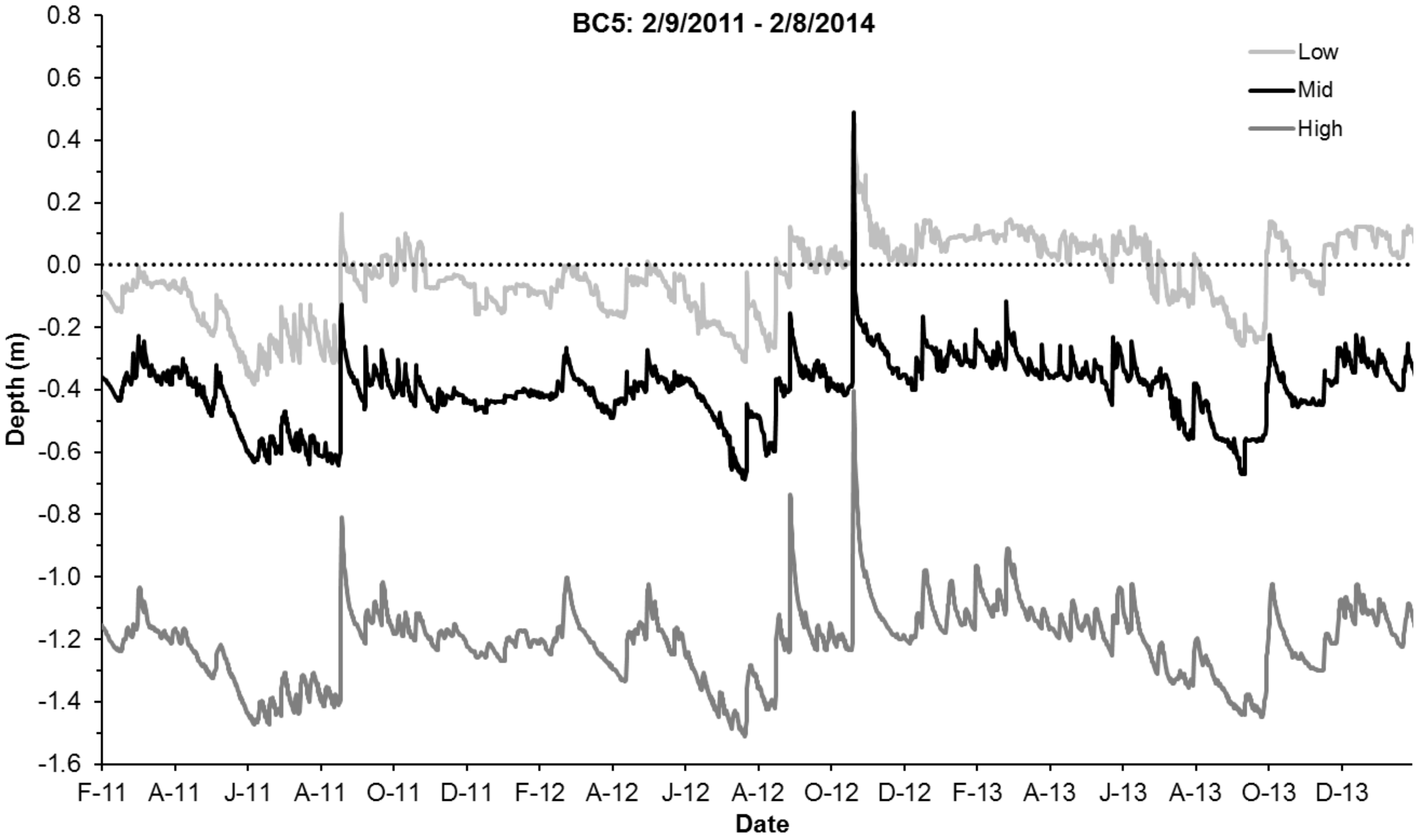
Hydrographs

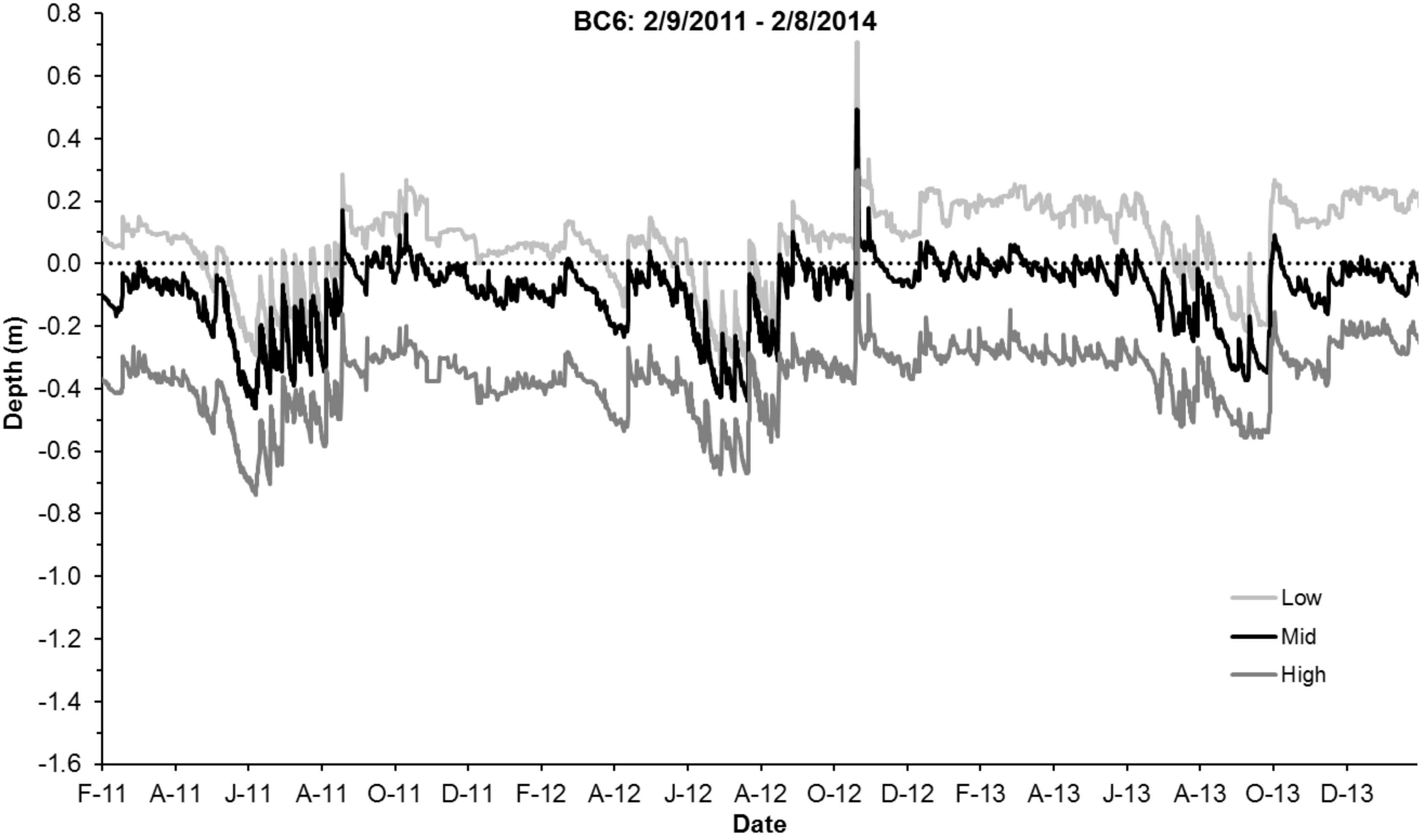


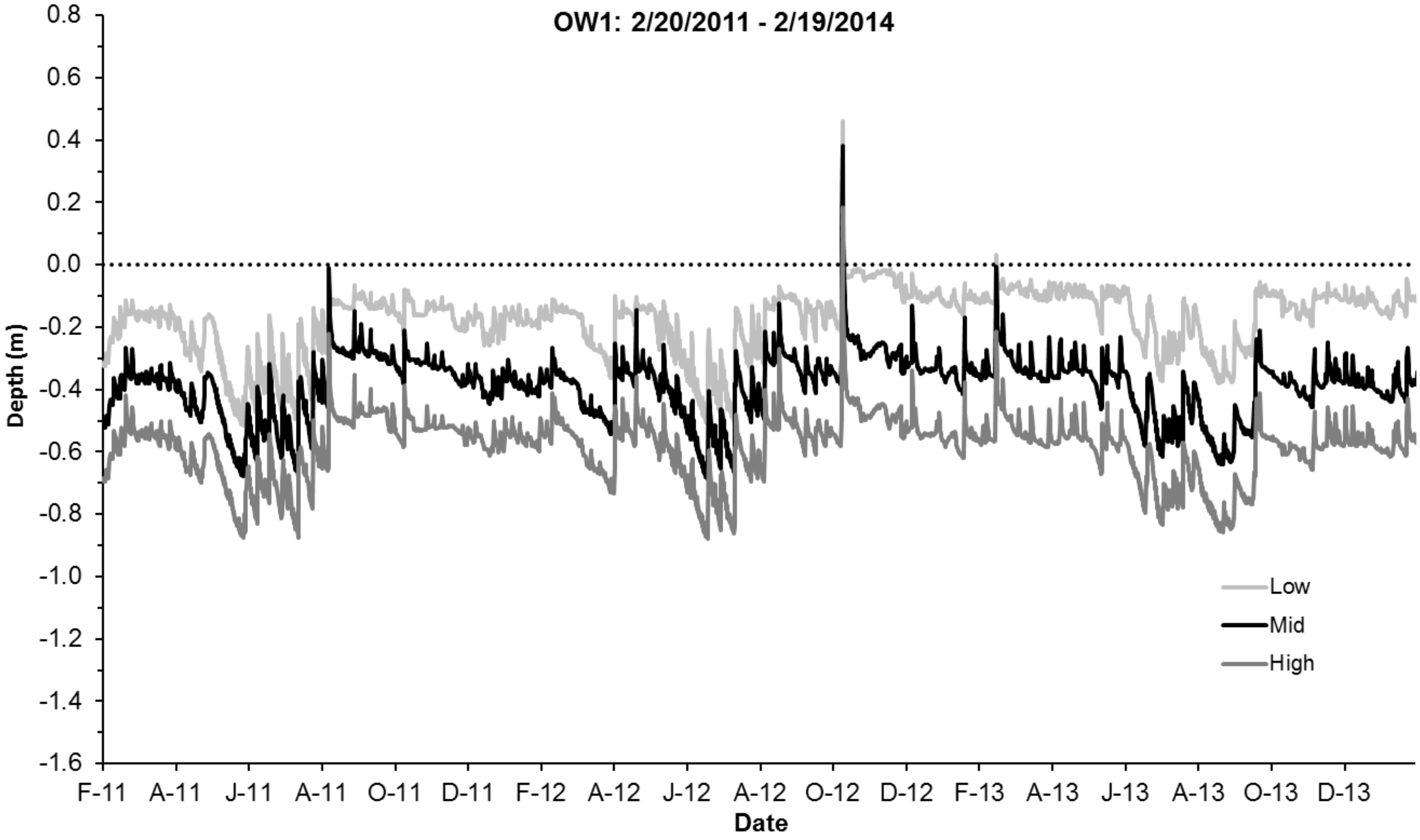

BC2: 2/9/2011 - 2/8/2014
Depth (m)
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
-0.8
-1.0
-1.2
-1.4
-1.6
F-11
A-11
J-11
A-11
O-11
D-11
F-12
A-12
J-12
A-12
O-12
D-12
F-13
A-13
J-13
A-13
O-13
D-13
Date
Low
Mid
High

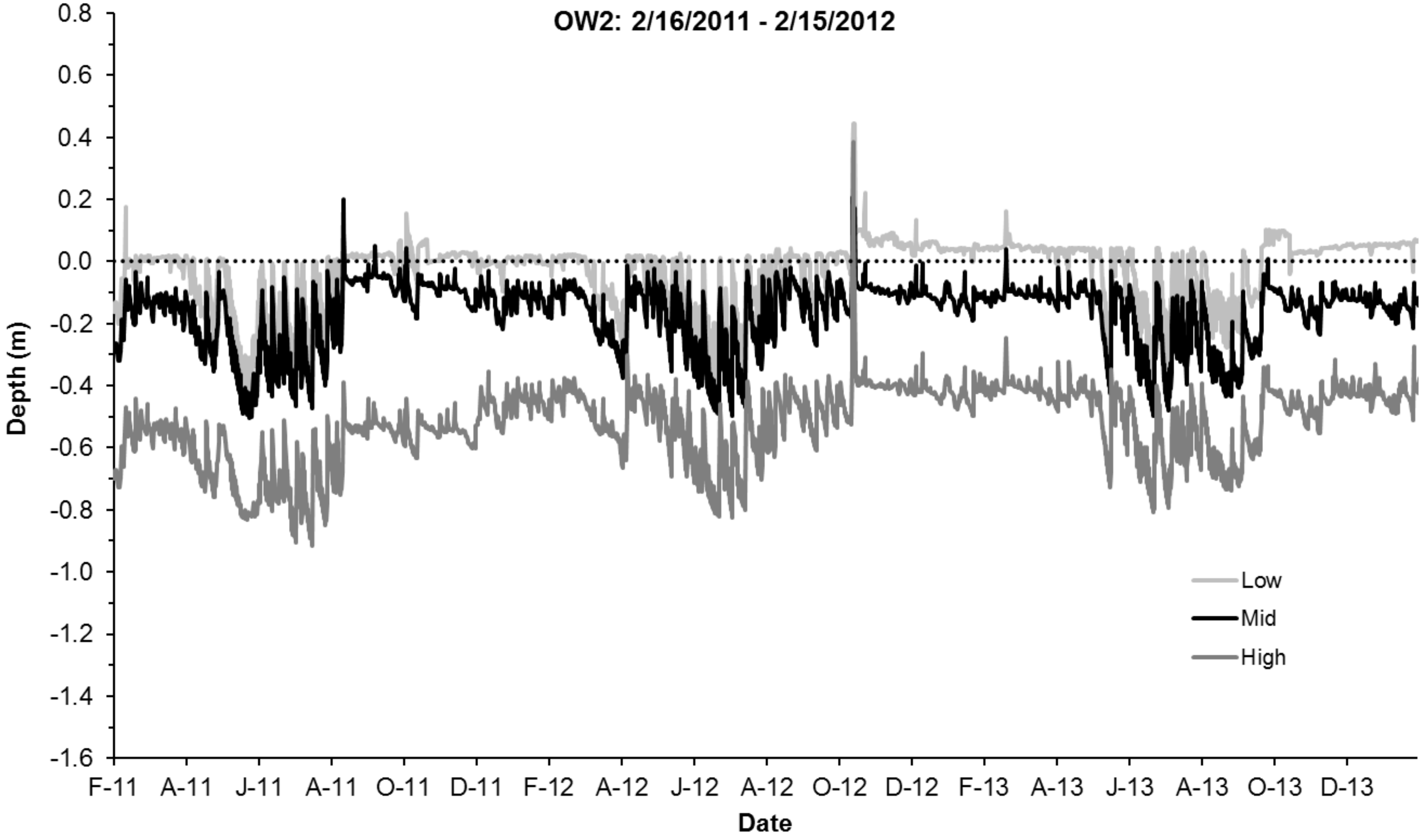

BC3: 2/16/2011 - 2/15/2014
Depth (m)
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
-0.8
-1.0
-1.2
-1.4
-1.6
F-11
A-11
J-11
A-11
O-11
D-11
F-12
A-12
J-12
A-12
O-12
D-12
F-13
A-13
J-13
A-13
O-13
D-13
Date
Low
Mid
High

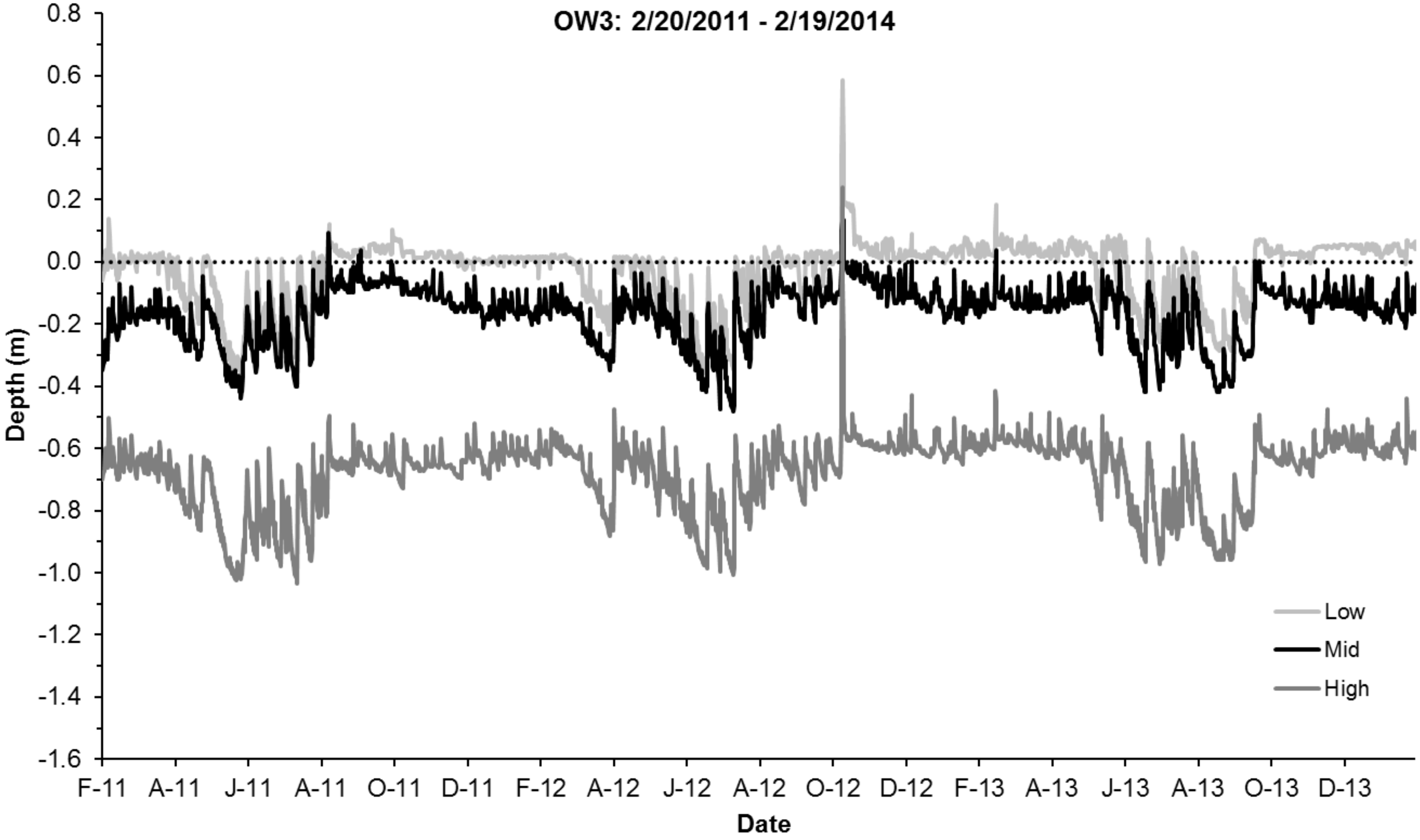

BC4: 2/16/2011 - 2/15/2014
Depth (m)
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
-0.8
-1.0
-1.2
-1.4
-1.6
F-11
A-11
J-11
A-11
O-11
D-11
F-12
A-12
J-12
A-12
O-12
D-12
F-13
A-13
J-13
A-13
O-13
D-13
Date
Low
Mid
High


BC5: 2/9/2011 - 2/8/2014
Low
Mid
High
Depth (m)
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
-0.8
-1.0
-1.2
-1.4
-1.6
F-11
A-11
J-11
A-11
O-11
D-11
F-12
A-12
J-12
A-12
O-12
D-12
F-13
A-13
J-13
A-13
O-13
D-13
Date

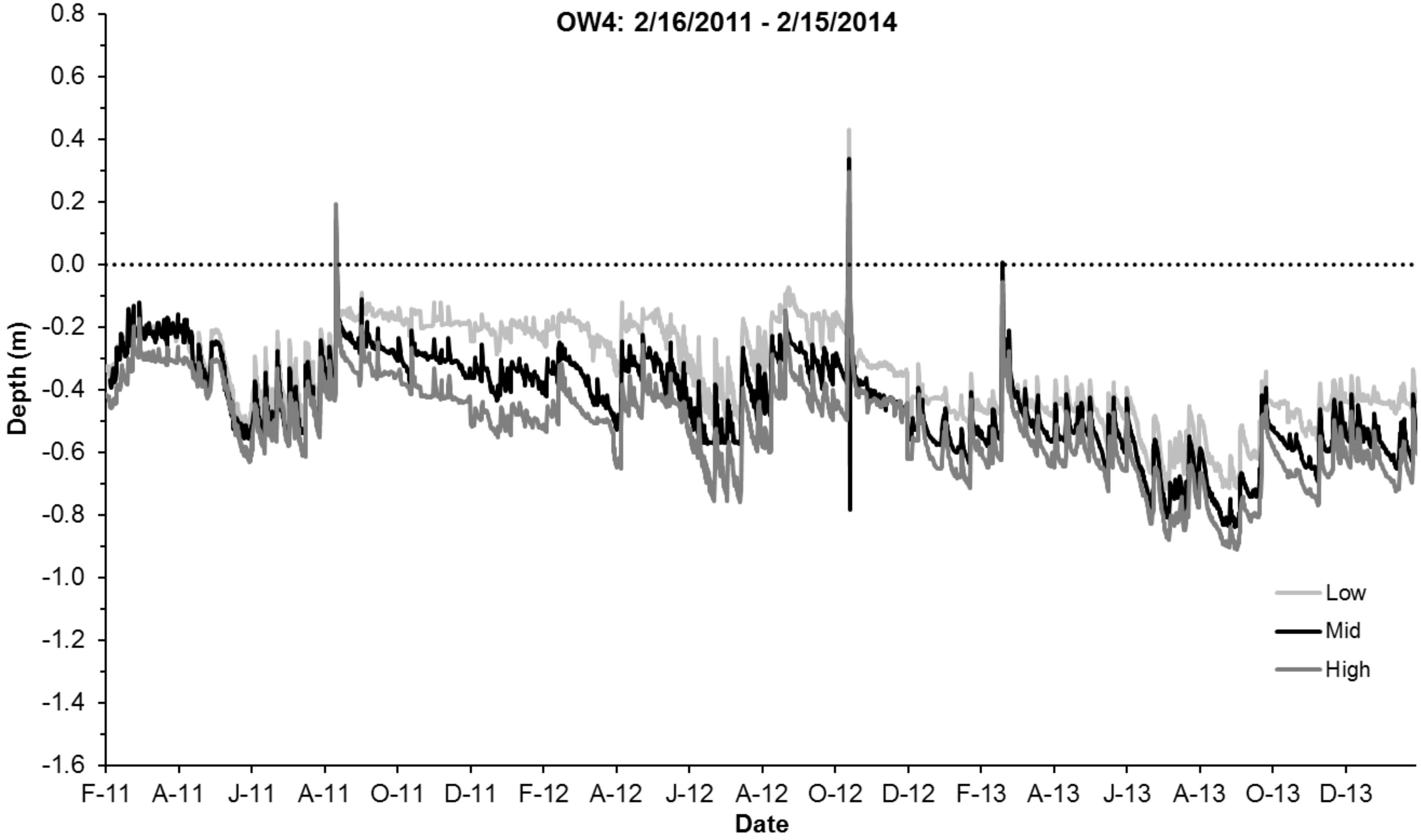

BC6: 2/9/2011 - 2/8/2014
Depth (m)
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
-0.8
-1.0
-1.2
-1.4
-1.6
F-11
A-11
J-11
A-11
O-11
D-11
F-12
A-12
J-12
A-12
O-12
D-12
F-13
A-13
J-13
A-13
O-13
D-13
Date
Low
Mid
High


OW1: 2/20/2011 - 2/19/2014
Depth (m)
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
-0.8
-1.0
-1.2
-1.4
-1.6
Low
Mid
High
F-11
A-11
J-11
A-11
O-11
D-11
F-12
A-12
J-12
A-12
O-12
D-12
F-13
A-13
J-13
A-13
O-13
D-13
Date

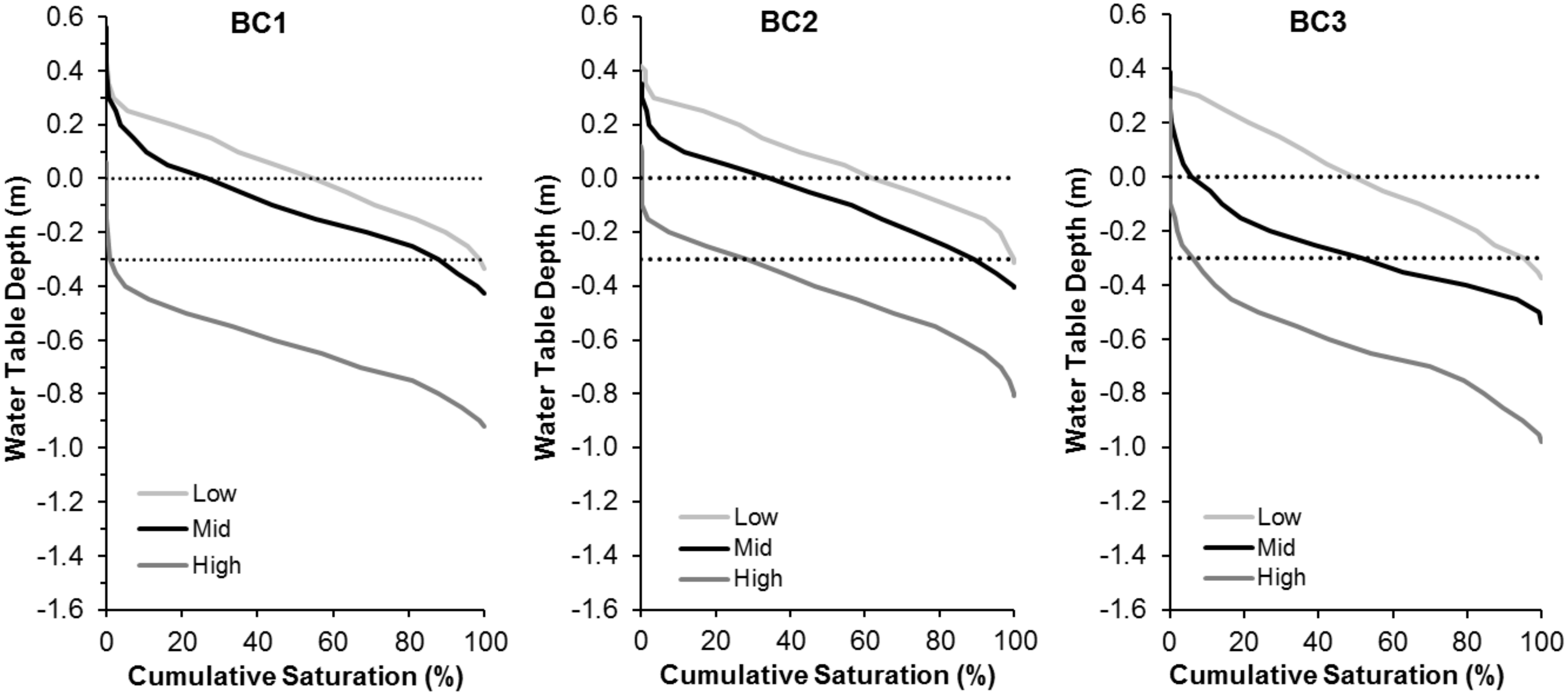

OW2: 2/16/2011 - 2/15/2012
Depth (m)
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
-0.8
-1.0
-1.2
-1.4
-1.6
F-11
A-11
J-11
A-11
O-11
D-11
F-12
A-12
J-12
A-12
O-12
D-12
F-13
A-13
J-13
A-13
O-13
D-13
Date
Low
Mid
High

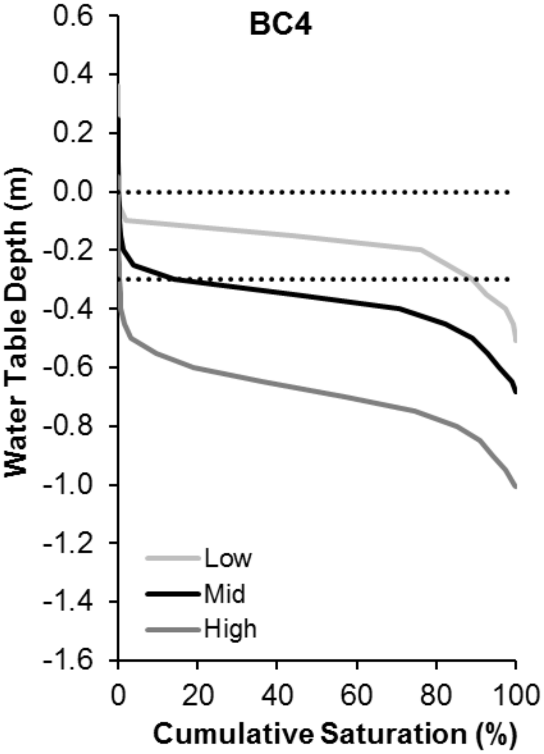


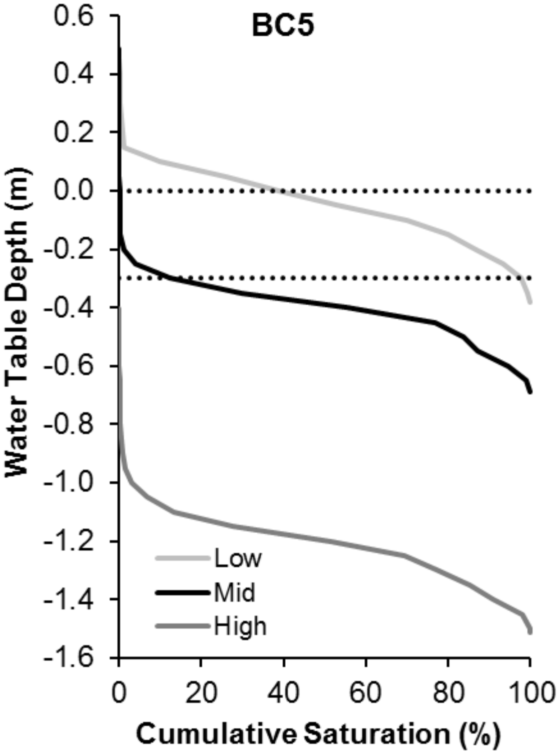
OW3: 2/20/2011 - 2/19/2014
Depth (m)
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
-0.8
-1.0
-1.2
-1.4
-1.6
F-11
A-11
J-11
A-11
O-11
D-11
F-12
A-12
J-12
A-12
O-12
D-12
F-13
A-13
J-13
A-13
O-13
D-13
Date
Low
Mid
High

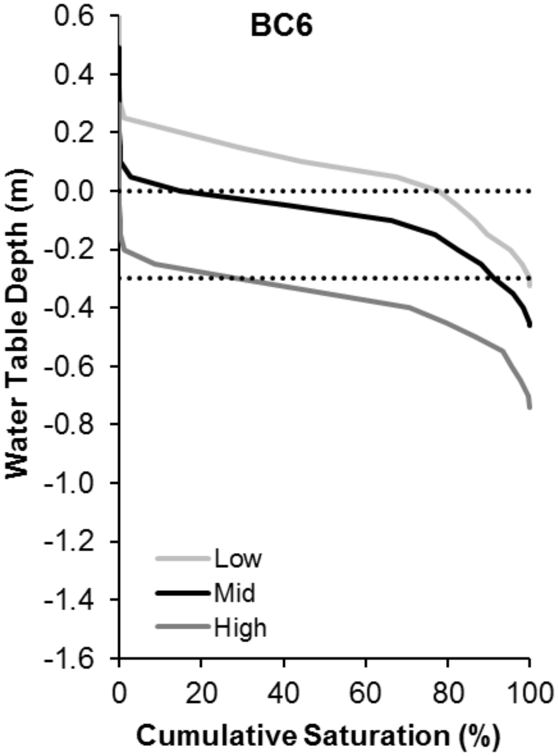

OW4: 2/16/2011 - 2/15/2014
Depth (m)
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
-0.8
-1.0
-1.2
-1.4
-1.6
F-11
A-11
J-11
A-11
O-11
D-11
F-12
A-12
J-12
A-12
O-12
D-12
F-13
A-13
J-13
A-13
O-13
D-13
Date
Low
Mid
High

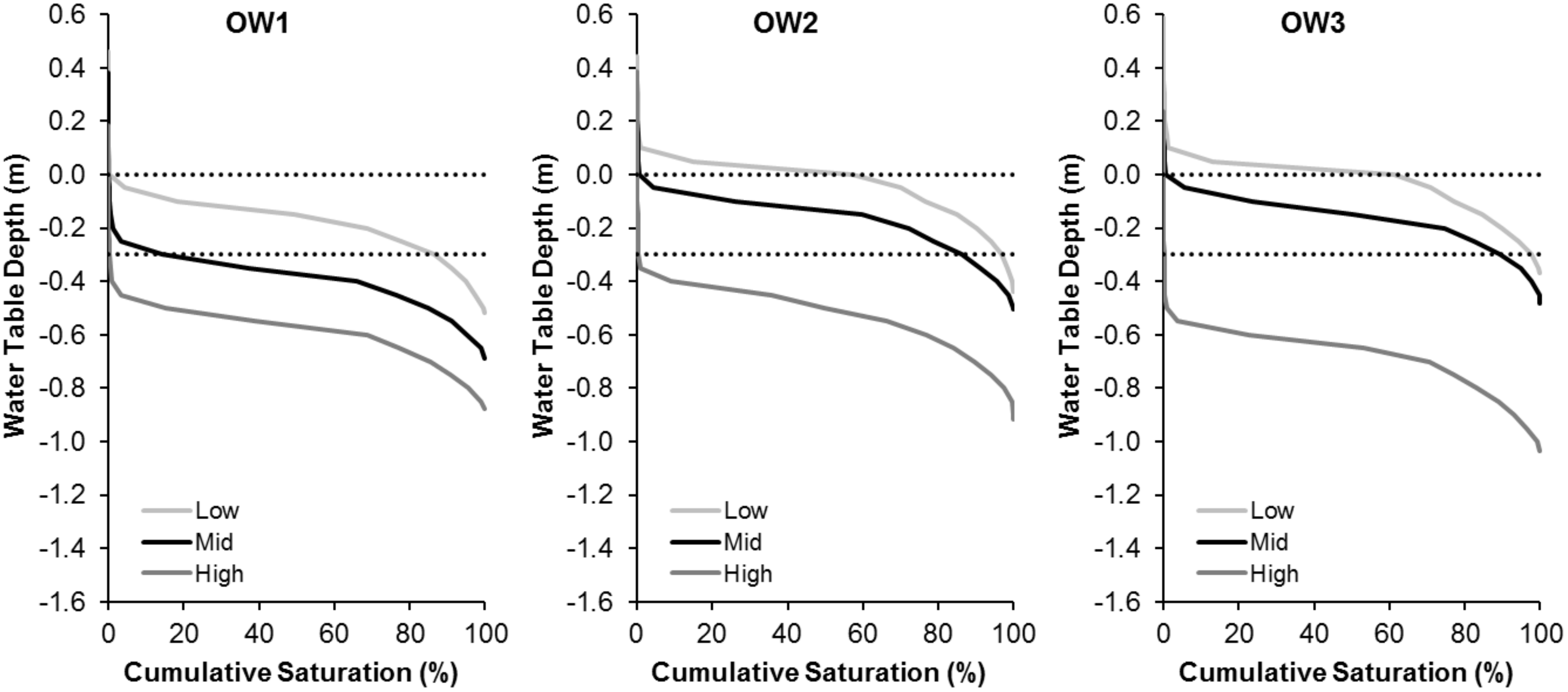
Cumulative Frequency of Saturation

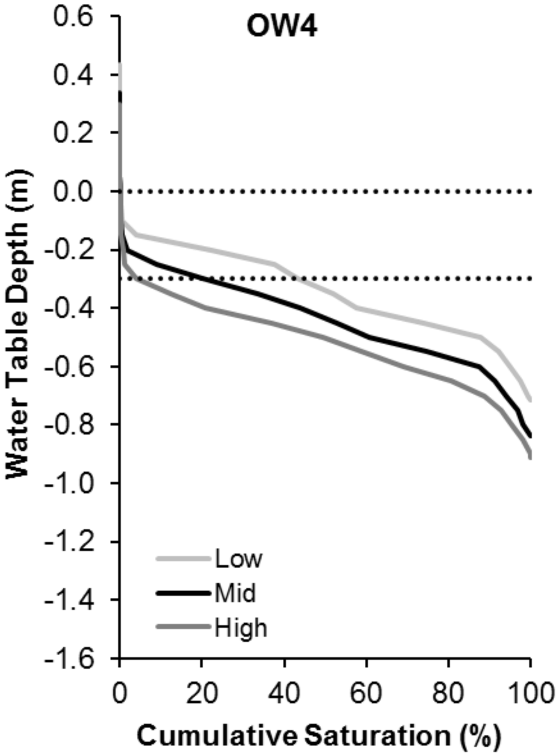



BC4
Water Table Depth (m)
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
-0.8
-1.0
-1.2
-1.4
-1.6
Low
Mid
High
0
20
40
60
80
100
Cumulative Saturation (%)


BC5
Water Table Depth (m)
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
-0.8
-1.0
-1.2
-1.4
-1.6
Low
Mid
High
0
20
40
60
80
100
Cumulative Saturation (%)


BC6
Water Table Depth (m)
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
-0.8
-1.0
-1.2
-1.4
-1.6
Low
Mid
High
0
20
40
60
80
100
Cumulative Saturation (%)


OW1
OW2
OW3
Water Table Depth (m)
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
-0.8
-1.0
-1.2
-1.4
-1.6
0
20
40
60
80
100
Cumulative Saturation (%)
Low
Mid
High


OW4
Water Table Depth (m)
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
-0.8
-1.0
-1.2
-1.4
-1.6
0
20
40
60
80
100
Cumulative Saturation (%)
Low
Mid
High

APPENDIX C: SOIL COLOR MEASUREMENTS

Site	Horizon	Upper Depth	Lower Depth	Moist Field Color†			Dry Digital Color‡			Moist Digital Color‡		
				Hue	Value	Chroma	Hue	Value	Chroma	Hue	Value	Chroma
		------- cm	-------									
BC1 Low	A	0	2	7.5 YR	2.5	2.0	9.2 YR	3.9	1.4	7.8 YR	2.3	1.0
	A/C	2	5	10.0 YR	3.0	3.0	9.1 YR	5.0	1.4	8.1 YR	2.7	1.1
	Cg	5	13	2.5 Y	5.5	1.5	9.4 YR	5.9	1.3	9.7 YR	4.1	1.3
	Cse	13	73	2.5 Y	4.5	1.0	0.2 Y	6.2	1.1	0.8 Y	4.5	1.0
	C'g1	73	104	2.5 Y	5.0	1.0	1.0 Y	6.8	1.1	1.5 Y	4.9	1.1
	C'g2	104	184	2.5 Y	4.5	1.0	0.9 Y	6.2	1.0	1.7 Y	4.5	0.8
	C'g3	184	212	2.5 Y	4.0	1.0	1.9 Y	5.9	0.9	2.4 Y	4.3	0.9
BC1 Mid	A	0	2.0	10.0 YR	2.0	2.0	8.3 YR	4.1	1.3	6.8 YR	2.1	1.1
	C	2	16	10.0 YR	4.5	2.0	9.2 YR	6.4	1.4	9.3 YR	4.5	1.5
	Cg	16	85	2.5 Y	5.5	1.5	9.9 YR	6.9	1.3	0.5 Y	5.0	1.3
	Cse1	85	138	2.5 Y	5.5	1.0	0.7 Y	6.9	1.2	1.4 Y	5.1	1.1
	Cse2	138	234	2.5 Y	4.0	1.0	1.3 Y	6.7	1.4	1.9 Y	5.2	1.4
	Aseb	234	250	2.5 Y	3.0	0.5	3.1 Y	5.1	1.2	2.9 Y	3.5	1.1
BC1 High	CA	0	16	10.0 YR	5.0	2.0	9.4 YR	6.5	1.9	9.4 YR	4.5	2.0
	C1	16	41	10.0 YR	5.5	2.5	9.6 YR	6.9	2.0	10.0 YR	4.9	2.1
	C2	41	60	10.0 YR	5.5	2.0	9.9 YR	6.8	2.1	0.3 Y	4.9	2.1
	C3	60	78	2.5 Y	5.0	2.0	9.9 YR	6.8	2.0	0.3 Y	5.0	2.0
	Cg1	78	131	2.5 Y	4.0	1.5	9.9 YR	6.6	1.8	0.5 Y	5.0	1.7
	Cg2	131	161	2.5 Y	4.0	1.5	1.2 Y	6.2	0.9	1.8 Y	4.6	0.8
	Cg3	161	187	5.0 Y	5.0	1.0	0.7 Y	6.9	1.1	1.2 Y	4.8	1.2
	Cg4	187	213	5.0 Y	3.5	1.0	0.8 Y	6.8	1.2	1.2 Y	5.0	1.2
BC2 Low	Oa	0	2.5	10.0 YR	2.0	2.0	8.6 YR	3.3	1.5	7.5 YR	2.1	1.2
	AC	2.5	4.5	10.0 YR	4.0	2.0	8.9 YR	5.5	1.3	8.7 YR	3.4	1.2

Site	Horizon	Upper Depth	Lower Depth	Moist Field Color[†]			Dry Digital Color[‡]			Moist Digital Color[‡]		
				Hue	Value	Chroma	Hue	Value	Chroma	Hue	Value	Chroma
		------- cm -------										
BC2 Low	Cg1	4.5	18	2.5 Y	5.5	1.5	9.4 YR	6.2	1.5	9.4 YR	4.2	1.5
	Cg2	18	25	2.5 Y	4.5	2.0	9.8 YR	6.2	1.7	9.8 YR	4.3	1.8
	Cg3	25	39	2.5 Y	4.0	2.0	9.7 YR	6.0	1.8	10.0 YR	4.3	1.8
	2CAb	39	56	10.0 YR	3.0	1.5	0.1 Y	5.2	1.3	9.9 YR	3.3	1.2
	2Cg	56	92	2.5 Y	4.5	1.0	1.0 Y	6.2	0.9	1.2 Y	4.4	0.9
	2Cse1	92	127	2.5 Y	4.5	1.0	1.1 Y	6.2	0.9	1.8 Y	4.3	0.8
	2Cse2	127	147	2.5 Y	4.0	1.0	1.2 Y	6.0	0.8	1.5 Y	4.2	0.7
	3Ab1	147	164	5.0 Y	3.0	1.0	1.0 Y	4.2	1.1	9.8 YR	2.4	1.0
	3Ab2	164	171	2.5 Y	2.5	1.0	0.5 Y	3.9	1.1	9.5 YR	2.1	0.9
	3Aseb1	171	183	2.5 Y	3.0	1.0	0.9 Y	4.3	1.2	0.1 Y	2.3	1.1
	3Aseb2	183	198	10.0 YR	2.5	1.5	1.0 Y	4.3	1.1	0.4 Y	2.6	0.9
BC2 Mid	Oa	0	1.5	10.0 YR	2.0	1.0	7.7 YR	2.7	1.4	5.7 YR	1.9	0.7
	A	1.5	8	10.0 YR	4.5	2.0	8.8 YR	5.8	1.3	8.5 YR	3.6	1.2
	Cg1	8	22	10.0 YR	4.5	1.5	9.5 YR	6.5	1.5	10.0 YR	4.5	1.5
	Cg2	22	28	10.0 YR	4.5	1.5	9.7 YR	6.2	1.6	10.0 YR	4.4	1.6
	Cg3	28	60	2.5 Y	4.5	2.0	0.2 Y	6.2	1.6	0.4 Y	3.8	1.5
	Ab	60	70	2.5 Y	3.0	1.0	0.6 Y	4.9	1.3	0.1 Y	2.9	1.0
	Cse1	70	94	10.0 YR	4.5	1.0	1.2 Y	5.9	1.0	1.1 Y	4.0	1.0
	2Cse2	94	106	2.5 Y	4.5	1.0	1.3 Y	6.1	0.7	1.7 Y	4.1	0.6
	2Cse3	106	153	2.5 Y	4.0	1.0	1.7 Y	6.1	0.7	1.8 Y	4.3	0.8
	2ACseb	153	165	10.0 YR	4.0	1.0	1.1 Y	5.1	1.1	0.9 Y	3.4	0.9
	3Aseb1	165	174	2.5 Y	3.5	1.0	1.9 Y	4.5	1.1	0.5 Y	2.2	0.6
	3Aseb2	174	186	10.0 YR	2.0	2.0	0.5 Y	3.4	1.0	9.4 YR	1.8	0.9
	3Aseb3	186	197	2.5 Y	3.0	1.0	0.7 Y	3.8	1.2	9.7 YR	2.3	1.1
	3Aseb4	197	212	2.5 Y	3.0	1.5	2.4 Y	4.6	1.1	1.2 Y	2.5	0.9

Site	Horizon	Upper Depth	Lower Depth	Moist Field Color[†]			Dry Digital Color[‡]			Moist Digital Color[‡]		
				Hue	Value	Chroma	Hue	Value	Chroma	Hue	Value	Chroma
		------- cm -------										
BC2 High	CA	0	19	10.0 YR	4.5	2.0	9.4 YR	6.2	2.1	9.4 YR	3.2	1.7
	Bw1	19	29	2.5 Y	6.0	3.0	9.5 YR	6.6	2.3	9.8 YR	4.6	2.3
	Bw2	29	63	10.0 YR	5.5	2.5	9.7 YR	6.5	2.2	9.9 YR	4.4	2.2
	Cg	63	77	2.5 Y	4.5	1.5	0.2 Y	6.7	1.7	0.5 Y	4.7	1.7
	2Cg/Ab	77	123	10.0 YR	4.0	1.5	10.0 YR	5.5	1.6	9.9 YR	3.4	1.4
	2Cse1	123	159	2.5 Y	4.0	1.0	0.8 Y	5.7	1.0	0.8 Y	3.8	0.9
	2Cse2	159	185	2.5 Y	4.5	1.0	0.8 Y	5.9	1.0	1.5 Y	4.1	0.8
	2ACseb	185	198	2.5 Y	3.0	1.0	0.8 Y	5.1	1.1	0.4 Y	3.3	0.9
	3Aseb	198	214	2.5 Y	3.0	0.5	1.8 Y	4.6	1.1	0.5 Y	2.5	0.9
	3Oa	214	220	10.0 YR	2.0	2.0	9.8 YR	3.1	1.3	9.4 YR	1.8	1.2
BC3 Low	A	0	1.5	10.0 YR	3.0	2.0	9.4 YR	3.6	1.7	8.3 YR	2.5	1.5
	AC	1.5	6.5	10.0 YR	4.0	2.0	9.2 YR	5.2	1.3	8.9 YR	4.3	1.5
	Cg1	6.5	22	2.5 Y	5.5	1.5	9.4 YR	6.2	1.3	9.4 YR	5.4	1.6
	Cg2	22	32.5	2.5 Y	4.0	1.0	9.7 YR	6.3	1.2	9.7 YR	5.7	1.5
	Cg3	32.5	101	2.5 Y	4.5	1.0	10.0 YR	6.2	1.2	0.4 Y	5.6	1.5
	Cse1	101	115	2.5 Y	3.0	1.0	1.3 Y	5.9	1.0	1.4 Y	4.7	0.8
	Cse2	115	182	2.5 Y	4.5	1.0	1.4 Y	6.2	0.9	1.7 Y	4.9	0.8
	Cse3	182	224	2.5 Y	2.5	1.0	1.9 Y	5.7	0.7	1.6 Y	4.5	0.6
	2Aseb	224	238	N	3.0	0.0	4.5 Y	4.6	0.8	4.5 Y	3.0	0.6
BC3 Mid	AC	0	8	10.0 YR	3.5	1.5	9.4 YR	5.4	1.7	8.8 YR	3.3	1.4
	C1	8	31	10.0 YR	5.0	1.5	9.6 YR	6.6	1.6	9.7 YR	4.9	1.7
	C2	31	48	2.5 Y	4.5	1.5	9.6 YR	6.3	1.3	0.1 Y	4.5	1.3
	Cg1	48	64	2.5 Y	4.5	1.0	9.4 YR	6.6	1.2	9.6 YR	4.8	1.2
	Cg2	64	76	10.0 YR	4.0	1.5	9.5 YR	6.2	1.2	9.8 YR	4.4	1.1
	Ab/Cg	76	87	2.5 Y	3.0	1.0	9.5 YR	5.4	1.2	9.4 YR	3.8	1.1

		Upper	Lower	Moist Field Color[†]			Dry Digital Color[‡]			Moist Digital Color[‡]		
Site	Horizon	Depth	Depth	Hue	Value	Chroma	Hue	Value	Chroma	Hue	Value	Chroma
		------- cm -------										
BC3 Mid	Cse1	87	105	10.0 YR	5.0	1.0	9.4 YR	6.6	1.2	9.7 YR	4.9	1.2
	Cse2	105	235	2.5 Y	4.5	1.0	1.2 Y	6.7	1.5	1.3 Y	4.9	1.4
	2Aseb	235	240	2.5 Y	2.5	1.0	2.4 Y	5.5	1.4	2.2 Y	3.8	1.2
BC3 High	AC	0	6	10.0 YR	3.0	1.0	9.4 YR	5.3	1.6	8.5 YR	3.1	1.0
	CA	6	14	10.0 YR	3.5	2.0	8.8 YR	6.0	1.8	8.3 YR	4.1	1.6
	C1	14	26	10.0 YR	5.0	2.0	9.1 YR	6.4	1.8	9.1 YR	4.5	1.8
	C2	26	50	2.5 Y	5.5	2.0	9.7 YR	6.8	2.0	10.0 YR	4.6	2.0
	Cg	50	59	2.5 Y	5.5	1.0	9.7 YR	6.6	1.3	0.4 Y	4.6	1.3
	Cse1	59	73	2.5 Y	4.5	1.0	0.2 Y	6.6	1.2	0.7 Y	4.5	1.0
	Cse2	73	112	2.5 Y	5.0	1.5	9.7 YR	5.8	1.3	9.7 YR	3.8	1.2
	Cse3	112	135	2.5 Y	4.5	1.5	0.1 Y	6.3	1.2	0.5 Y	4.3	1.1
	Cse4	135	238	2.5 Y	4.5	1.0	0.7 Y	6.4	0.9	1.1 Y	4.6	0.9
	2Aseb	238	250	5.0 Y	4.0	1.0	3.6 Y	5.2	0.8	3.4 Y	3.5	0.6
BC4 Low	Oa	0	5	7.5 YR	2.5	1.0	7.5 YR	3.3	1.7	4.7 YR	1.6	1.2
	A	5	9.5	10.0 YR	2.0	2.0	8.6 YR	4.8	1.4	8.5 YR	3.3	1.2
	CA	9.5	17	10.0 YR	3.0	1.5	9.1 YR	5.8	1.5	9.1 YR	3.9	1.4
	Cg	17	25	2.5 Y	4.5	2.0	9.4 YR	6.3	1.5	9.4 YR	4.1	1.4
	Ab	25	26	2.5 Y	2.5	1.0	9.4 YR	4.7	1.3	9.4 YR	2.9	1.2
	C'g	26	28	2.5Y	4.5	1.0						
	A'b	28	30	2.5 Y	2.5	1.0	9.4 YR	4.7	1.2	9.4 YR	2.9	1.0
	C'g	30	46	2.5 Y	5.0	2.0	9.3 YR	6.1	1.6	9.2 YR	4.2	1.7
	Cse1	46	67	10.0 YR	4.0	1.5	9.4 YR	6.0	1.5	9.4 YR	4.2	1.5
	Cse2	67	89	2.5 Y	4.5	1.0	9.6 YR	6.4	1.6	9.5 YR	4.5	1.5
	Cse3	89	130	2.5 Y	3.5	1.0	0.3 Y	6.5	1.8	0.7 Y	4.7	1.7
	C'"g	130	180	2.5 Y	3.5	0.5	1.2 Y	6.6	1.2	1.4 Y	4.7	1.3

				Moist Field Color[†]			Dry Digital Color[‡]			Moist Digital Color[‡]		
Site	Horizon	Upper Depth	Lower Depth	Hue	Value	Chroma	Hue	Value	Chroma	Hue	Value	Chroma
		------- cm -------										
BC4 Mid	A	0	10	10.0 YR	2.0	2.0	7.9 YR	4.4	1.3	5.3 YR	2.2	0.8
	CA	10	22	10.0 YR	4.0	2.0	9.2 YR	6.0	1.6	9.1 YR	4.0	1.6
	C	22	43	10.0 YR	4.0	1.5	9.4 YR	6.4	1.5	9.6 YR	4.4	1.4
	Cg	43	45	2.5 Y	3.0	1.0	0.1 Y	5.0	1.1	9.9 YR	3.6	1.2
	ACb	45	71	10.0 YR	4.0	1.5	9.4 YR	5.3	1.8	9.4 YR	3.8	1.7
	Cse	71	120	2.5 Y	4.0	1.5	9.4 YR	6.1	1.7	9.4 YR	4.4	1.7
	C'g1	120	177	2.5 Y	4.5	1.0	0.7 Y	6.3	1.3	1.1 Y	4.2	1.3
	C'g2	177	212	2.5 Y	4.0	1.0	1.2 Y	6.4	1.3	1.6 Y	4.5	1.4
BC4 High	A	0	2.5	10.0 YR	2.0	2.0	8.3 YR	4.2	1.6	6.0 YR	2.4	1.0
	CA	2.5	10	10.0 YR	4.0	2.0	8.7 YR	5.8	2.0	8.3 YR	3.7	1.7
	C1	10	21	10.0 YR	4.0	2.0	9.0 YR	6.2	2.2	9.0 YR	4.1	1.9
	C2	21	32	10.0 YR	4.5	2.5	9.4 YR	6.4	2.0	9.4 YR	4.4	2.1
	Ab	32	38	7.5 YR	3.0	2.0	9.2 YR	5.5	1.6	9.1 YR	3.5	1.4
	ACb	38	43	10.0 YR	5.5	2.0	9.4 YR	5.7	1.6	9.4 YR	3.7	1.5
	C'	43	52	10.0 YR	5.5	2.0	9.4 YR	6.3	2.0	9.4 YR	4.4	2.0
	Cg1	52	70	10.0 YR	5.0	2.0	9.7 YR	6.4	1.5	9.9 YR	4.3	1.5
	Cg2	70	76	2.5 Y	4.0	1.0	0.7 Y	5.7	1.2	0.8 Y	4.0	1.1
	Cg3	76	113	10.0 YR	4.0	1.5	0.5 Y	6.3	1.3	0.9 Y	4.4	1.2
	Cg4	113	136	10.0 YR	4.5	1.5	0.2 Y	6.4	1.7	0.5 Y	4.2	1.5
	AC'b	136	156	2.5 Y	3.0	2.0	9.6 YR	5.7	1.8	9.6 YR	3.8	1.6
	C'g1	156	182	2.5 Y	4.0	1.0	0.7 Y	6.5	1.3	1.2 Y	4.4	1.2
	C'g2	182	198	2.5 Y	3.0	1.0	1.1 Y	6.2	1.5	1.6 Y	4.3	1.4
BC5 Low	Oe	0	13	5.0 YR	2.5	2.0	7.1 YR	2.6	2.5	3.5 YR	2.0	1.1
	A	13	20	10.0 YR	2.5	1.5	9.4 YR	4.7	1.4	8.4 YR	2.5	1.1
	Cg1	20	30	2.5 Y	4.5	2.0	9.4 YR	6.0	1.9	9.4 YR	4.4	1.9

		Upper	Lower	Moist Field Color†			Dry Digital Color‡			Moist Digital Color‡		
Site	Horizon	Depth	Depth	Hue	Value	Chroma	Hue	Value	Chroma	Hue	Value	Chroma
		------- cm -------										
BC5 Low	Cg2	30	56	2.5 Y	4.5	1.5	9.9 YR	6.3	1.5	0.1 Y	4.6	1.6
	Cg3	56	82	2.5 Y	4.5	1.0	0.9 Y	6.0	1.0	1.2 Y	4.5	1.0
	2Ab1	82	99	7.5 YR	2.5	2.0	9.8 YR	3.8	1.3	9.0 YR	1.7	0.9
	2Ab2	99	109	7.5 YR	2.5	1.0	9.4 YR	2.9	1.0	8.6 YR	1.5	0.7
	3Cg	109	157	10.0 YR	4.5	1.5	9.6 YR	5.8	1.4	9.7 YR	3.8	1.3
	3Cse1	157	177	2.5 Y	3.5	1.0	1.5 Y	5.4	0.9	1.3 Y	3.4	0.8
	3Cse2	177	198	2.5 Y	3.5	1.0	1.1 Y	5.3	0.9	1.4 Y	3.7	0.8
BC5 Mid	Oe	0	13	5.0 YR	2.5	2.0	7.0 YR	3.1	2.8	5.1 YR	2.4	2.0
	A	13	24	10.0 YR	4.5	1.5	8.9 YR	5.0	1.4	8.4 YR	3.4	1.2
	C1	24	51	10.0 YR	5.5	2.0	9.0 YR	6.1	1.9	8.8 YR	4.3	2.0
	C2	51	65	2.5 Y	5.5	2.0	9.4 YR	6.6	1.9	9.4 YR	4.7	1.9
	C3	65	92	10.0 YR	5.0	2.0	9.4 YR	6.3	1.7	9.4 YR	4.5	1.7
	Cse	92	119	2.5 Y	5.0	1.0	10.0 YR	6.6	1.2	0.6 Y	4.6	1.1
	2Ab1	119	131	10.0 YR	2.0	2.0	9.7 YR	3.7	1.3	8.6 YR	1.7	1.0
	2Ab2	131	136	10.0 YR	2.0	1.0	9.6 YR	2.8	0.9	9.0 YR	1.7	0.7
	3Ab3	136	152	10.0 YR	3.0	1.0	9.4 YR	3.7	1.2	9.0 YR	2.2	0.7
	3ACb	152	170	2.5 Y	3.5	1.5	9.3 YR	5.5	1.3	9.4 YR	3.5	1.0
	3Cg	170	196	2.5 Y	4.5	1.5	9.4 YR	6.1	1.2	9.4 YR	4.3	1.2
BC5 High	Oi	0	2.5	7.5 YR	2.5	2.0	7.2 YR	3.5	2.6	5.9 YR	2.7	2.1
	Oe	2.5	6	5.0 YR	2.5	1.0	6.9 YR	3.2	2.4	5.3 YR	2.3	1.9
	AE	6	19	10.0 YR	4.0	2.0	9.2 YR	5.6	1.4	8.8 YR	3.8	1.3
	A	19	30	7.5 YR	3.0	1.5	9.3 YR	5.5	1.4	9.3 YR	3.6	1.3
	Bw1	30	77	10.0 YR	5.5	3.0	9.6 YR	6.6	2.5	9.6 YR	4.8	2.6
	Bw2	77	98	10.0 YR	6.0	2.5	9.8 YR	6.8	2.3	10.0 YR	5.1	2.5
	Bw3	98	145	10.0 YR	4.0	2.5	10.0 YR	6.7	2.2	9.8 YR	5.0	2.4

		Upper	Lower	Moist Field Color[†]			Dry Digital Color[‡]			Moist Digital Color[‡]		
Site	Horizon	Depth	Depth	Hue	Value	Chroma	Hue	Value	Chroma	Hue	Value	Chroma
		------- cm -------										
BC5 High	C	145	171	2.5 Y	5.0	2.0	9.8 YR	6.8	1.9	0.2 Y	5.3	2.1
	Cse	171	198	2.5 Y	4.0	0.5	1.5 Y	6.4	0.7	2.1 Y	4.5	0.7
	2Ab1	198	216	5.0 Y	3.0	1.0	0.8 Y	4.5	1.3	9.7 YR	2.4	1.0
	3Ab2	216	232	10.0 YR	2.0	1.0	9.4 YR	3.7	1.0	9.3 YR	2.1	0.8
	3Cg	232	268	10.0 YR	4.0	1.5	9.5 YR	5.9	1.4	9.7 YR	3.9	1.2
BC6 Low	Oe	0	2	7.5 YR	2.5	1.0	8.3 YR	3.2	1.6	6.5 YR	1.7	1.0
	Oa	2	5	5.0 YR	2.5	1.5	8.0 YR	2.8	1.6	6.0 YR	1.6	1.1
	A1	5	7	2.5 Y	4.0	1.0	0.4 Y	5.0	1.6	9.8 YR	2.9	1.3
	A2	7	9.5	2.5 Y	2.8	1.0	10.0 YR	3.9	1.1	9.4 YR	2.4	0.9
	2Cg1	9.5	20	2.5 Y	5.5	2.0	9.2 YR	5.8	1.8	9.0 YR	3.8	1.7
	2Cg2	20	33	2.5 Y	5.0	1.5	9.7 YR	6.1	1.6	9.7 YR	4.2	1.5
	2Cg3	33	78	2.5 Y	4.5	1.0	0.5 Y	6.1	1.1	0.8 Y	4.1	1.0
	2Cg4	78	93	2.5 Y	5.0	1.0	9.8 YR	6.1	1.1	0.5 Y	4.2	1.1
	3Ab	93	110	2.5 Y	3.5	1.0	1.2 Y	4.5	1.3	9.6 YR	2.1	1.0
	3Oa	110	117	7.5 YR	2.5	1.5	9.8 YR	2.9	1.1	9.4 YR	1.7	0.8
	3A'b1	117	128	2.5 Y	3.5	1.0	0.5 Y	3.5	1.0	9.4 YR	2.2	0.9
	3A'b2	128	142	2.5 Y	3.5	1.0	0.3 Y	3.8	1.2	9.4 YR	1.9	0.9
	3Aseb	142	168	5.0 Y	4.0	1.0	2.9 Y	4.7	1.0	2.5 Y	2.8	0.8
	4Cse	168	210	2.5 Y	4.5	0.5	3.0 Y	5.7	0.8	3.5 Y	3.9	0.7
BC6 Mid	Oi	0	5	10.0 YR	2.0	1.0	6.8 YR	2.9	2.2	4.5 YR	1.7	1.6
	Oe	5	10	5.0 YR	2.5	2.0	6.8 YR	3.0	2.7	6.6 YR	2.4	2.0
	A1	10	12	10.0 YR	3.0	1.0	8.9 YR	4.1	1.7	8.3 YR	2.4	1.5
	2A2	12	16	10.0 YR	3.0	1.0	9.4 YR	5.4	1.3	9.4 YR	3.5	1.2
	2Cg	16	56	10.0 YR	5.0	1.5	9.4 YR	6.3	1.4	9.6 YR	4.4	1.5
	2Cse	56	117.0	2.5 Y	4.0	1.0	9.6 YR	6.3	1.5	9.7 YR	4.5	1.4

		Upper	Lower	Moist Field Color†			Dry Digital Color‡			Moist Digital Color‡		
Site	Horizon	Depth	Depth	Hue	Value	Chroma	Hue	Value	Chroma	Hue	Value	Chroma
		------- cm	-------									
BC6 Mid	3Aseb	117	134.0	2.5 Y	3.5	1.0	9.7 YR	4.5	1.5	9.4 YR	2.5	1.1
	3Oase	134	146	7.5 YR	2.5	1.5	8.4 YR	2.8	1.4	6.2 YR	1.9	0.6
	3A'seb1	146	156	7.5 YR	3.0	2.0	8.8 YR	3.7	1.5	7.8 YR	2.0	0.9
	3A'seb2	156	171	5.0 Y	3.5	0.5	1.9 Y	4.9	1.2	1.6 Y	3.2	1.1
	4Cse	171	207	5.0 Y	3.5	0.5	1.6 Y	5.5	1.3	1.9 Y	3.8	1.3
BC6 High	Oe	0	3	7.5 YR	2.5	1.0	7.0 YR	3.0	2.3	6.1 YR	2.1	1.9
	A	3	10	10.0 YR	3.0	1.0	8.7 YR	4.8	1.4	8.0 YR	3.0	1.1
	Bw/Bhs	10	33	10.0 YR	4.5	3.0	8.4 YR	5.4	1.9	7.9 YR	3.4	1.7
	C	33	47	2.5 Y	6.0	2.0	9.4 YR	6.5	1.7	9.4 YR	4.8	1.9
	Cse1	47	66	2.5 Y	4.5	1.0	9.4 YR	6.5	1.6	9.7 YR	4.6	1.6
	Cse2	66	138	2.5 Y	4.0	1.0	0.3 Y	6.6	1.5	0.4 Y	4.7	1.4
	2Aseb	138	157	2.5 Y	3.0	1.0	0.3 Y	4.4	1.4	9.7 YR	2.9	1.2
	2Oase	157	174	7.5 YR	2.5	2.0	8.8 YR	3.2	1.3	6.3 YR	1.5	0.8
	2A'seb1	174	185	7.5 YR	3.0	1.5	9.6 YR	4.1	1.4	9.4 YR	2.3	1.1
	2A'seb2	185	198	5.0 Y	3.5	0.5	1.8 Y	4.7	1.2	1.1 Y	2.9	1.1
	3Cse	198	220	2.5 Y	3.5	0.5	2.0 Y	6.0	1.5	2.3 Y	4.4	1.4
OW1 Low	A	0	1.5	10.0 YR	2.0	1.0	9.4 YR	4.7	1.2	8.6 YR	2.7	0.8
	CA	1.5	9	10.0 YR	5.5	3.0	9.0 YR	5.8	1.8	8.1 YR	3.5	1.5
	C	9	20	10.0 YR	5.5	2.0	9.3 YR	6.6	1.6	9.4 YR	4.7	1.5
	Cg	20	23	2.5 Y	3.5	1.0	9.7 YR	5.8	1.5	9.7 YR	3.8	1.4
	Ab	23	26	10.0 YR	2.0	2.0	9.3 YR	4.7	1.4	8.5 YR	2.9	1.1
	C'g	26	29	2.5 Y	5.5	1.0	9.5 YR	6.4	1.4	9.7 YR	4.5	1.4
	Aseb	29	32	10.0 YR	3.0	1.5	9.6 YR	5.3	1.4	9.4 YR	3.5	1.3
	Cse	32	71	2.5 Y	4.5	1.0	0.5 Y	6.5	1.1	1.2 Y	4.5	1.1
	C"g1	71	131	2.5 Y	4.0	1.0	1.1 Y	6.5	1.2	1.9 Y	4.7	1.1

Site	Horizon	Upper Depth	Lower Depth	Moist Field Color[†]			Dry Digital Color[‡]			Moist Digital Color[‡]		
				Hue	Value	Chroma	Hue	Value	Chroma	Hue	Value	Chroma
		------- cm -------										
OW1 Low	C"g2	131	164	2.5 Y	4.5	1.0	1.4 Y	6.7	0.9	2.1 Y	4.9	1.0
	ACb	164	185	2.5 Y	3.5	0.5	2.9 Y	6.1	1.0	3.4 Y	4.1	0.9
	C'''g	185	218	2.5 Y	4.5	1.0	2.5 Y	6.2	0.9	3.0 Y	4.5	0.8
OW1 Mid	CA	0	16	2.5 Y	4.5	1.5	9.7 YR	5.8	1.6	9.3 YR	3.5	1.3
	C	16	39	2.5 Y	6.0	2.5	9.2 YR	5.9	1.8	9.4 YR	3.8	1.5
	Cg	39	53	2.5 Y	5.5	1.0	9.4 YR	6.5	1.3	9.5 YR	4.3	1.3
	Aseb	53	57	10.0 YR	3.0	2.0	9.4 YR	4.6	1.3	9.1 YR	3.0	1.1
	Cse1	57	82	2.5 Y	4.5	1.0	9.9 YR	6.6	1.3	0.5 Y	4.5	1.2
	Cse2	82	122	2.5 Y	5.0	1.0	0.5 Y	6.7	1.0	1.2 Y	4.7	1.0
	C'g1	122	168	2.5 Y	5.0	1.0	1.7 Y	6.2	1.1	2.0 Y	4.3	1.0
	C'g2	168	198	2.5 Y	4.5	1.0	2.2 Y	6.3	0.9	2.7 Y	4.2	0.8
	C'g3	198	245	5.0 Y	4.0	0.5	3.4 Y	5.5	0.8	3.6 Y	4.0	0.8
	2ACb	245	250	5.0 Y	3.5	0.5	3.4 Y	4.8	1.0	3.1 Y	3.0	0.9
OW1 High	CA	0	5	2.5 Y	5.0	1.5	9.7 YR	6.1	1.6	9.7 YR	4.7	1.6
	C1	5	31	2.5 Y	5.0	2.0	9.4 YR	6.4	1.8	9.4 YR	4.6	1.8
	C2	31	44	10.0 YR	4.0	2.0	9.1 YR	6.2	1.9	9.1 YR	4.5	1.9
	Cg	44	58	2.5 Y	5.0	1.5	9.4 YR	6.8	1.3	9.4 YR	4.8	1.2
	Ab	58	62	10.0 YR	3.0	2.0	9.0 YR	5.2	1.4	8.5 YR	3.3	1.2
	C'g1	62	83	10.0 YR	4.0	1.5	9.4 YR	6.3	1.3	9.4 YR	4.3	1.3
	C'g2	83	144	2.5 Y	4.5	1.0	0.3 Y	6.6	1.0	1.0 Y	4.9	1.0
	C'g3	144	161	2.5 Y	4.0	0.5	1.1 Y	6.3	1.2	1.2 Y	4.4	1.0
	C'g4	161	183	2.5 Y	4.5	0.5	0.8 Y	6.7	0.9	2.0 Y	4.6	0.8
	C'g5	183	198	2.5 Y	4.5	0.5	1.0 Y	6.8	0.9	2.5 Y	4.5	0.7
OW2 Low	Oa	0	2.5	7.5 YR	2.5	1.5	8.6 YR	2.9	1.9	7.5 YR	1.7	1.6
	CA	2.5	7	2.5 Y	5.0	2.5	9.4 YR	5.7	1.9	9.2 YR	3.4	1.7

		Upper	Lower	Moist Field Color†			Dry Digital Color‡			Moist Digital Color‡		
Site	Horizon	Depth	Depth	Hue	Value	Chroma	Hue	Value	Chroma	Hue	Value	Chroma
		------- cm -------										
OW2 Low	Cg	7	18	2.5 Y	4.5	1.5	10.0 YR	6.2	1.7	0.2 Y	4.1	1.6
	Cse1	18	31	2.5 Y	4.5	1.0	1.2 Y	6.5	1.2	1.3 Y	4.4	1.2
	Cse2	31	79	2.5 Y	5.5	1.0	0.8 Y	6.5	1.2	1.0 Y	4.5	1.2
	Cse3	79	129	2.5 Y	5.0	1.0	1.2 Y	6.6	0.9	1.9 Y	4.5	0.8
	C'g	129	175	2.5 Y	5.0	1.0	2.0 Y	6.5	0.8	2.3 Y	4.8	0.8
	Ab	175	198	2.5 Y	3.0	0.5	4.1 Y	4.9	1.0	4.0 Y	3.1	0.8
OW2 Mid	Oa	0	2.5	10.0 YR	2.0	1.0	8.2 YR	2.9	1.8	6.1 YR	2.1	0.9
	CA	2.5	7	10.0 YR	4.0	2.0	9.0 YR	6.0	1.5	8.4 YR	3.9	1.4
	C	7	13	2.5 Y	5.0	2.0	9.4 YR	6.4	1.6	9.4 YR	4.6	1.6
	Cg1	13	27	2.5 Y	5.5	1.5	9.4 YR	6.9	1.6	9.4 YR	5.2	1.8
	Cg2	27	60	2.5 Y	4.5	1.0	9.8 YR	6.8	1.7	0.4 Y	5.1	1.8
	Cg3	60	101	2.5 Y	5.0	1.0	0.4 Y	6.7	1.8	0.8 Y	4.9	1.7
	Cg4	101	147	2.5 Y	4.5	1.0	0.6 Y	6.6	1.5	1.1 Y	4.8	1.4
	Cg5	147	192	2.5 Y	3.5	1.0	0.7 Y	6.1	1.0	0.7 Y	4.3	1.0
	Aseb	192	228	2.5 Y	2.5	1.0	3.1 Y	5.1	1.3	3.1 Y	3.4	1.2
OW2 High	CA	0	16	10.0 YR	4.0	2.0	9.4 YR	6.3	2.1	9.4 YR	4.4	2.1
	C1	16	33	10.0 YR	5.0	2.5	9.4 YR	6.8	2.2	9.5 YR	5.1	2.4
	2C2	33	43	2.5 Y	5.0	2.5	9.7 YR	6.7	2.2	9.9 YR	4.8	2.3
	2C3	43	52	2.5 Y	5.0	2.0	0.1 Y	7.0	1.8	0.4 Y	5.0	1.8
	2Cg	52	107	2.5 Y	5.0	2.0	9.7 YR	7.0	1.7	9.7 YR	5.0	1.9
	2Cse1	107	151	2.5 Y	4.5	1.0	0.3 Y	6.5	1.3	0.8 Y	4.5	1.3
	2Cse2	151	185	2.5 Y	4.5	0.5	0.7 Y	6.4	1.1	1.2 Y	4.5	0.9
	2C'g	185	218	5.0 Y	5.0	1.0	1.0 Y	6.5	1.0	1.4 Y	4.3	0.8
OW3 Low	Oa1	0	3	7.5 YR	3.0	2.0	9.0 YR	3.7	2.1	8.3 YR	2.8	1.4
	Oa2	3	6	10.0 YR	2.5	2.0	9.4 YR	4.0	1.9	8.3 YR	3.0	1.6

Site	Horizon	Upper Depth	Lower Depth	Moist Field Color†			Dry Digital Color‡			Moist Digital Color‡		
				Hue	Value	Chroma	Hue	Value	Chroma	Hue	Value	Chroma
		------- cm	-------									
OW3 Low	CA	6	14	10.0 YR	5.5	2.0	9.4 YR	6.2	1.6	9.6 YR	4.6	1.6
	Cg1	14	23	2.5 Y	5.0	1.5	9.7 YR	6.5	1.3	0.4 Y	4.8	1.4
	Cg2	23	103	5.0 Y	4.5	1.0	0.6 Y	6.7	0.8	1.8 Y	4.8	0.8
	Cg3	103	138	5.0 Y	4.0	1.0	2.3 Y	6.3	0.9	2.8 Y	4.5	0.8
	Cg4	138	174	5.0 Y	3.5	1.5	3.0 Y	5.9	0.9	3.7 Y	4.0	0.7
	Ab	174	238	5.0 Y	3.5	0.5	3.3 Y	4.9	1.0	3.3 Y	3.4	0.9
OW3 Mid	A1	0	1.5	10.0 YR	2.0	1.0	9.5 YR	4.3	1.4	9.0 YR	2.4	1.0
	A2	1.5	6	10.0 YR	3.0	2.0	9.4 YR	4.8	1.9	9.1 YR	3.2	1.6
	CA	6	15	10.0 YR	4.5	2.5	9.4 YR	5.8	2.3	9.2 YR	4.1	2.3
	Cg1	15	31	10.0 YR	4.0	1.5	0.5 Y	6.3	1.5	0.6 Y	4.5	1.5
	Cg2	31	77	2.5 Y	5.0	1.0	1.2 Y	6.7	1.0	1.6 Y	5.0	1.0
	Cg3	77	114	2.5 Y	4.5	1.0	1.2 Y	6.5	0.9	1.9 Y	4.6	0.9
	Cse1	114	139	2.5 Y	4.0	1.5	2.5 Y	6.3	0.9	2.7 Y	4.5	0.9
	Cse2	139	154	2.5 Y	3.5	0.5	3.1 Y	6.1	0.9	3.1 Y	4.4	0.9
	Cse3	154	174	2.5 Y	3.0	0.5	3.7 Y	5.7	1.0	3.8 Y	4.2	1.0
	Aseb	174	199	2.5 Y	3.0	0.5	3.7 Y	4.9	1.1	3.4 Y	3.2	1.0
	C'se	199	226	2.5 Y	3.0	0.5	3.0 Y	5.0	1.3	2.9 Y	3.5	1.3
	C'g	226	250	2.5 Y	3.0	0.5	4.1 Y	5.4	1.0	4.1 Y	3.8	0.9
OW3 High	AC	0	3	10.0 YR	3.5	1.5	9.3 YR	6.0	1.8	9.0 YR	3.9	1.6
	Bw1	3	11.5	10.0 YR	4.5	2.5	9.4 YR	6.2	2.1	9.3 YR	4.1	2.0
	Bw2	11.5	36	10.0 YR	5.0	3.0	9.4 YR	6.5	2.4	9.4 YR	4.8	2.6
	Bw3	36	54	10.0 YR	6.0	3.0	9.9 YR	6.7	2.4	9.9 YR	5.3	2.7
	Bw4	54	74	10.0 YR	6.0	3.0	9.9 YR	7.0	2.1	0.2 Y	5.1	2.2
	2Bw5	74	80	10.0 YR	5.0	3.0	9.7 YR	6.8	2.0	9.9 YR	4.9	2.2
	2Cg	80	123	10.0 YR	5.0	1.5	0.2 Y	7.0	1.7	0.4 Y	5.2	1.9

		Upper	Lower	Moist Field Color[†]			Dry Digital Color[‡]			Moist Digital Color[‡]		
Site	Horizon	Depth	Depth	Hue	Value	Chroma	Hue	Value	Chroma	Hue	Value	Chroma
		------- cm -------										
OW3 High	2Cg/Ab	123	158	2.5 Y	5.0	1.0	0.9 Y	6.5	1.0	1.2 Y	5.0	1.1
	2C'g1	158	184	2.5 Y	4.5	1.0	1.1 Y	6.7	0.9	1.7 Y	4.7	0.8
	2C'g2	184	198	2.5 Y	3.5	1.0	2.5 Y	6.1	1.0	2.9 Y	4.4	1.0
OW4 Low	A1	0	1.5	10.0 YR	2.0	1.0	8.8 YR	3.2	1.6	7.8 YR	2.2	1.3
	A2	1.5	3.5	10.0 YR	2.0	2.0	9.3 YR	5.4	1.7	8.5 YR	3.3	1.5
	AC	3.5	6	10.0 YR	3.0	2.0	9.3 YR	6.0	1.7	9.0 YR	4.0	1.6
	C	6	11	10.0 YR	4.5	2.0	9.3 YR	6.3	1.7	9.3 YR	4.3	1.6
	Cg1	11	23	2.5 Y	5.5	1.5	9.4 YR	6.6	1.5	9.4 YR	4.6	1.5
	Cg2	23	28	2.5 Y	4.0	1.5	9.6 YR	6.3	1.3	9.7 YR	4.3	1.3
	Ab	28	29.5	10.0 YR	2.5	2.0	9.4 YR	4.7	1.7	9.4 YR	3.0	1.3
	C'g	29.5	32	2.5 Y	4.5	1.0	9.9 YR	6.0	1.3	0.1 Y	4.0	1.1
	A'b	32	35	10.0 YR	3.0	2.5	9.4 YR	4.3	1.5	9.0 YR	2.9	1.3
	C"g	35	42	2.5 Y	5.5	1.5	9.7 YR	5.8	1.4	9.7 YR	4.0	1.3
	Cse1	42	44	2.5 Y	4.5	1.0	0.6 Y	6.2	1.0	1.2 Y	4.0	1.0
	Cse2	44	78	2.5 Y	3.0	1.0	1.1 Y	6.2	1.0	1.6 Y	4.1	0.9
	C'"g	78	164	2.5 Y	4.5	1.0	1.2 Y	6.0	0.9	1.8 Y	4.5	0.8
	A"b	164	183	10.0 YR	2.0	1.0	8.9 YR	3.6	0.7	6.9 YR	2.2	0.4
	C""g	183	205	2.5 Y	4.5	1.0	0.4 Y	6.3	0.9	1.7 Y	4.3	0.7
OW4 Mid	A	0	2	10.0 YR	2.0	1.0	9.4 YR	4.6	1.3	9.0 YR	2.8	0.8
	C1	2	25	2.5 Y	5.5	2.0	9.0 YR	6.3	1.7	8.8 YR	4.6	1.8
	C2	25	32	2.5 Y	5.5	2.0	9.4 YR	6.7	1.4	9.4 YR	5.3	1.6
	Cg	32	34	2.5 Y	4.0	1.5	9.4 YR	6.4	1.4	9.3 YR	4.6	1.6
	Ab	34	36	10.0 YR	3.0	1.5	9.4 YR	5.1	1.3	9.4 YR	3.3	1.4
	C'g	36	39	2.5 Y	4.5	1.0	9.7 YR	6.3	1.1	0.3 Y	4.4	1.0
	A'b	39	42	10.0 YR	2.0	1.5	9.5 YR	5.1	1.3	9.4 YR	3.2	1.1

		Upper	Lower	Moist Field Color[†]			Dry Digital Color[‡]			Moist Digital Color[‡]		
Site	Horizon	Depth	Depth	Hue	Value	Chroma	Hue	Value	Chroma	Hue	Value	Chroma
		------- cm	-------									
OW4 Mid	Cse	42	52	2.5 Y	6.0	1.0	9.7 YR	6.1	1.2	10.0 YR	4.5	1.3
	C"g1	52	147	2.5 Y	5.0	1.0	0.7 Y	6.3	0.9	1.4 Y	4.9	1.0
	C"g2	147	200	2.5 Y	4.5	1.0	0.3 Y	6.6	1.0	1.1 Y	5.2	1.2
	C"g3	200	220	2.5 Y	4.5	0.5	1.9 Y	6.2	0.8	2.9 Y	4.5	0.8
OW4 High	C	0	24	2.5 Y	5.0	2.0	0.2 Y	6.8	1.7	0.5 Y	5.1	1.8
	Ab1	24	25	10.0 YR	2.0	1.0	9.4 YR	4.5	1.3	8.1 YR	2.6	0.9
	Ab2	25	29	10.0 YR	4.0	2.0	9.4 YR	6.2	1.7	9.3 YR	4.1	1.7
	Cg1	29	38	2.5 Y	5.0	2.0	9.4 YR	6.3	1.7	9.4 YR	4.4	1.7
	Cg2	38	49	2.5 Y	5.5	2.0	9.0 YR	6.2	1.6	8.7 YR	4.3	1.6
	Cg3	49	68	2.5 Y	4.5	1.0	9.4 YR	6.6	1.3	9.4 YR	4.7	1.4
	Aseb	68	73	10.0 YR	2.5	2.0	9.4 YR	4.7	1.2	9.1 YR	2.8	1.0
	Cse1	73	90	10.0 YR	4.0	1.5	0.5 Y	6.4	1.3	0.7 Y	4.3	1.2
	Cse2	90	113	2.5 Y	4.0	1.0	0.5 Y	6.2	1.4	0.8 Y	4.3	1.2
	C'g1	113	137	2.5 Y	3.5	0.5	1.0 Y	6.3	1.1	1.7 Y	4.4	0.9
	C'g2	137	165	2.5 Y	4.5	1.0	0.8 Y	6.5	1.0	1.7 Y	4.7	1.0
	C'g3	165	198	5.0 Y	4.0	0.5	1.0 Y	6.7	1.1	1.5 Y	4.8	1.1

[†] Field colors were measured in the field using an X-Rite Munsell Soil Color Book (X-Rite Incorporated, Grand Rapids, MI). Measurements of value and chroma were made to the half unit, interpolating between chips.

[‡] Digital measurements were made on homogenized, air-dried and remoistened samples in the laboratory using a digital colorimeter (Konica-Minolta Chroma Meter CR300, Minolta Corporation, Ramsey, NJ)

APPENDIX D: PARTICLE SIZE ANALYSIS

Site	Horizon	Upper Depth	Lower Depth	Sand						Silt	Clay	Silt + Clay	Organic Carbon	Texture Class
				Total	VCOS	COS	MS	FS	VFS					
		----- cm -----		--- % ---										
BC1 Low	A	0	2	98.8	0.0	1.6	43.5	52.4	1.3			1.2	2.39	FS
	A/C	2	5	100.0	0.0	1.8	46.9	50.8	0.4			0.0	0.91	FS
	Cg	5	13	100.0	0.0	7.6	76.3	16.1	0.0			0.0	0.10	S
	Cse	13	73	99.9	0.0	8.8	58.6	32.3	0.1			0.1	0.02	S
	C'g1	73	104	100.0	0.9	9.1	51.0	38.4	0.5			0.0	0.01	S
	C'g2	104	184	99.4	0.4	8.2	58.8	31.5	0.5			0.6	0.03	S
	C'g3	184	212	100.0	0.0	3.1	65.9	31.0	0.0			0.0	0.02	S
BC1 Mid	A	0	2.0	98.4	0.0	1.4	40.9	55.0	1.0			1.6	3.41	FS
	C	2	16	100.0	0.0	3.8	52.8	43.1	0.3			0.0	0.10	S
	Cg	16	85	100.0	0.3	8.0	64.6	26.9	0.1			0.0	0.02	S
	Cse1	85	138	100.0	0.7	4.5	41.6	52.1	1.1			0.0	0.01	FS
	Cse2	138	234	99.7	0.5	4.9	57.8	35.9	0.6			0.3	0.01	S
	Aseb	234	250	91.5	0.0	1.8	22.1	58.8	8.8	5.6	3.0		0.21	FS
BC1 High	CA	0	16	100.0	0.0	0.4	46.0	53.4	0.2			0.0	0.10	FS
	C1	16	41	100.0	0.1	1.2	53.9	44.7	0.1			0.0	0.03	S
	C2	41	60	99.9	0.1	5.3	59.4	34.9	0.2			0.1	0.02	S
	C3	60	78	100.0	0.0	6.2	40.6	52.9	0.3			0.0	0.01	FS
	Cg1	78	131	100.0	0.0	7.2	64.1	28.3	0.4			0.0	0.01	S
	Cg2	131	161	99.8	0.3	8.5	63.3	27.4	0.3			0.2	0.01	S
	Cg3	161	187	100.0	0.2	5.6	46.5	46.7	1.0			0.0	0.01	S
	Cg4	187	213	99.8	0.1	5.5	39.1	53.7	1.3			0.2	0.01	FS
BC2 Low	Oa	0	2.5										15.64	MUCK
	AC	2.5	4.5	99.8	0.0	2.5	44.7	52.1	0.5			0.2	0.27	FS

		Upper	Lower	Sand								Silt +	Organic	Texture
Site	Horizon	Depth	Depth	Total	VCOS	COS	MS	FS	VFS	Silt	Clay	Clay	Carbon	Class
		----- cm -----		--- % ---										
BC2 Low	Cg1	4.5	18	100.0	0.0	3.6	53.0	43.0	0.3			0.0	0.10	S
	Cg2	18	25	100.0	0.3	6.7	57.8	35.1	0.1			0.0	0.04	S
	Cg3	25	39	100.0	0.0	7.9	58.2	33.7	0.2			0.0	0.06	S
	2CAb	39	56	99.6	0.0	1.4	29.7	64.3	4.1			0.4	0.23	FS
	2Cg	56	92	99.8	0.3	4.9	44.8	48.7	1.1			0.2	0.03	S
	2Cse1	92	127	99.8	3.6	22.1	50.4	23.1	0.6			0.2	0.01	COS
	2Cse2	127	147	99.4	4.4	25.5	47.1	21.2	1.1			0.6	0.02	COS
	3Ab1	147	164	39.2	0.9	3.2	10.8	11.5	12.8	44.6	16.2		6.31	L
	3Ab2	164	171	43.9	2.8	8.8	18.9	11.3	2.1	33.6	22.5		5.25	L
	3Aseb1	171	183	42.3	0.3	1.8	9.8	25.3	5.0	37.9	19.8		4.24	L
	3Aseb2	183	198	69.4	0.9	5.7	23.5	35.4	3.9	17.7	12.8		2.28	FSL
BC2 Mid	Oa	0	1.5										20.12	MUCK
	A	1.5	8	100.0	0.0	6.5	51.0	42.2	0.3			0.0	0.52	S
	Cg1	8	22	100.0	0.2	7.6	58.1	34.1	0.0			0.0	0.06	S
	Cg2	22	28	99.7	0.2	9.0	57.6	32.5	0.4			0.3	0.04	S
	Cg3	28	60	100.0	0.1	3.3	42.9	53.1	0.6			0.0	0.05	FS
	Ab	60	70	97.2	0.1	1.7	32.1	56.7	6.6	1.8	1.0		0.30	FS
	Cse1	70	94	99.6	0.6	12.3	42.5	43.1	1.1			0.4	0.05	S
	2Cse2	94	106	99.9	0.5	4.1	45.7	48.8	0.7			0.1	0.02	S
	2Cse3	106	153	99.9	3.5	16.7	44.9	34.2	0.6			0.1	0.01	S
	2ACseb	153	165	96.9	0.7	5.3	36.9	47.6	6.5			3.1	0.18	S
	3Aseb1	165	174	36.3	0.8	1.9	9.9	13.8	9.9	39.7	24.0		4.34	L
	3Aseb2	174	186	29.4	1.4	1.6	7.6	11.0	7.8	40.0	30.6		10.22	MK CL
	3Aseb3	186	197	21.8	1.0	1.5	5.8	10.6	2.9	48.0	30.2		7.21	CL
	3Aseb4	197	212	53.6	0.4	0.6	8.0	39.8	4.8	30.8	15.6		2.25	FSL

		Upper	Lower	Sand								Silt +	Organic	Texture
Site	Horizon	Depth	Depth	Total	VCOS	COS	MS	FS	VFS	Silt	Clay	Clay	Carbon	Class
		----- cm -----		-- % --										
BC2 High	CA	0	19	100.0	0.0	9.5	62.3	28.1	0.2			0.0	0.16	S
	Bw1	19	29	99.7	0.0	6.3	55.8	37.4	0.2			0.3	0.03	S
	Bw2	29	63	100.0	0.4	9.4	65.0	24.9	0.2			0.0	0.02	S
	Cg	63	77	100.0	0.2	5.1	57.4	37.2	0.1			0.0	0.01	S
	2Cg/Ab	77	123	98.9	0.0	1.9	33.8	59.1	4.0			1.1	0.20	FS
	2Cse1	123	159	99.8	2.3	14.9	42.0	39.9	0.6			0.2	0.06	S
	2Cse2	159	185	99.4	5.9	24.5	42.0	26.7	0.2			0.6	0.02	COS
	2ACseb	185	198	97.4	0.9	9.1	44.2	37.8	5.3			2.6	0.22	S
	3Aseb	198	214	29.7	0.4	1.8	4.9	9.4	13.2	49.0	21.3		3.92	L
	3Oa	214	220										18.95	MUCK
BC3 Low	A	0	1.5	87.8	1.6	9.7	47.2	25.9	3.4			12.2	9.54	MK S
	AC	1.5	6.5	99.5	0.2	6.7	58.7	33.4	0.4			0.5	0.64	S
	Cg1	6.5	22	100.0	0.2	11.5	74.8	13.5	0.0			0.0	0.06	S
	Cg2	22	32.5	100.0	0.7	21.2	71.1	6.9	0.0			0.0	0.02	S
	Cg3	32.5	101	100.0	0.3	13.7	74.9	11.2	0.0			0.0	0.01	S
	Cse1	101	115	99.3	0.2	11.8	62.7	24.2	0.4			0.7	0.01	S
	Cse2	115	182	99.6	0.0	4.5	61.6	33.4	0.1			0.4	0.01	S
	Cse3	182	224	99.6	0.0	8.3	52.1	38.9	0.3			0.4	0.01	S
	2Aseb	224	238	86.0	0.1	2.0	20.1	57.1	6.6	7.9	6.1		0.28	LFS
BC3 Mid	AC	0	8	99.5	0.3	9.5	54.8	34.4	0.5			0.5	0.54	S
	C1	8	31	100.0	0.4	19.6	70.0	9.9	0.0			0.0	0.09	S
	C2	31	48	100.0	0.0	8.3	73.1	18.6	0.0			0.0	0.03	S
	Cg1	48	64	100.0	0.0	3.1	64.5	32.4	0.0			0.0	0.02	S
	Cg2	64	76	99.4	0.0	2.9	49.1	46.8	0.6			0.6	0.04	S
	Ab/Cg	76	87	99.2	0.0	0.9	35.1	61.4	1.8			0.8	0.13	FS

Site	Horizon	Upper Depth	Lower Depth	Sand						Silt	Clay	Silt + Clay	Organic Carbon	Texture Class
				Total	VCOS	COS	MS	FS	VFS					
		----- cm -----		-- % --										
BC3 Mid	Cse1	87	105	99.7	0.0	0.8	47.2	51.3	0.4			0.3	0.02	FS
	Cse2	105	235	99.5	0.0	4.6	57.5	37.3	0.1			0.5	0.01	S
	2Aseb	235	240	96.1	0.0	3.0	42.5	48.7	1.9	0.9	2.9		0.14	S
BC3 High	AC	0	6	99.0	0.0	4.8	56.4	36.5	1.3			1.0	0.54	S
	CA	6	14	100.0	0.2	5.2	50.3	44.0	0.3			0.0	0.21	S
	C1	14	26	99.8	0.3	6.6	65.7	27.2	0.0			0.2	0.07	S
	C2	26	50	100.0	0.0	2.0	53.3	44.5	0.2			0.0	0.05	S
	Cg	50	59	99.7	0.2	7.9	60.0	31.3	0.3			0.3	0.03	S
	Cse1	59	73	100.0	0.0	7.6	73.6	18.8	0.0			0.0	0.02	S
	Cse2	73	112	99.6	0.0	3.8	59.1	36.4	0.2			0.4	0.08	S
	Cse3	112	135	99.7	0.1	1.9	45.2	51.8	0.7			0.3	0.06	FS
	Cse4	135	238	100.0	0.3	8.6	60.5	30.6	0.0			0.0	0.04	S
	2Aseb	238	250	95.8	0.0	1.7	28.9	59.3	6.0			4.2	0.11	FS
BC4 Low	Oa	0	5										18.06	MUCK
	A	5	9.5	97.8	0.7	7.4	51.7	35.5	2.5			2.2	0.67	S
	CA	9.5	17	100.0	1.3	9.7	62.4	26.5	0.2			0.0	0.41	S
	Cg	17	25	99.3	0.1	1.6	28.1	66.7	2.8			0.7	0.13	FS
	Ab	25	26	91.3	0.2	0.7	12.3	64.3	13.8			8.7	0.94	FS
	C'g	26	28	91.3	0.2	0.7	12.3	64.3	13.8			8.7	0.10	FS
	A'b	28	30	96.3	1.0	9.1	50.4	32.2	3.6			3.7	2.24	S
	C'g	30	46	100.0	0.0	3.7	58.2	37.8	0.3			0.0	0.25	S
	Cse1	46	67	99.5	1.4	8.7	44.1	43.7	1.6			0.5	0.09	S
	Cse2	67	89	99.7	0.3	3.7	44.5	50.5	0.7			0.3	0.03	FS
	Cse3	89	130	100.0	0.0	1.8	21.3	75.8	1.1			0.0	0.03	FS
	C'''g	130	180	100.0	0.0	2.5	41.4	55.8	0.3			0.0	0.04	FS

Site	Horizon	Upper Depth	Lower Depth	Sand Total	VCOS	COS	MS	FS	VFS	Silt	Clay	Silt + Clay	Organic Carbon	Texture Class
		----- cm -----		-- % --										
BC4 Mid	A	0	10	96.3	0.0	2.3	28.2	55.7	10.1			3.7	3.32	FS
	CA	10	22	99.8	0.4	2.1	42.8	52.6	1.8			0.2	0.21	FS
	C	22	43	100.0	0.1	2.1	38.8	57.3	1.6			0.0	0.05	FS
	Cg	43	45	93.7	1.7	16.5	35.7	35.4	4.5			6.3	0.06	S
	ACb	45	71	96.1	0.1	3.9	28.6	58.8	4.7			3.9	0.22	FS
	Cse	71	120	99.6	1.4	13.7	54.5	29.7	0.3			0.4	0.04	S
	C'g1	120	177	99.7	0.4	5.0	40.3	53.5	0.5			0.3	0.05	FS
	C'g2	177	212	100.0	0.1	2.5	45.3	51.6	0.5			0.0	0.07	FS
BC4 High	A	0	2.5	98.3	0.6	13.2	53.7	28.6	2.1			1.7	1.15	S
	CA	2.5	10	99.8	1.2	16.2	49.8	30.8	1.8			0.2	0.16	S
	C1	10	21	99.9	0.7	14.0	62.0	22.9	0.2			0.1	0.05	S
	C2	21	32	99.9	0.2	2.1	60.0	37.3	0.2			0.1	0.04	S
	Ab	32	38	97.8	0.0	0.7	34.4	59.8	2.9			2.2	0.11	FS
	ACb	38	43	98.9	0.1	1.0	43.2	52.8	1.8			1.1	0.05	FS
	C'	43	52	99.9	0.0	2.3	52.1	45.5	0.0			0.1	0.04	S
	Cg1	52	70	99.4	0.0	0.9	29.6	68.1	0.8			0.6	0.05	FS
	Cg2	70	76	95.3	0.5	2.1	15.7	63.8	13.2			4.7	0.15	FS
	Cg3	76	113	99.0	2.3	10.3	37.9	47.7	0.8			1.0	0.04	S
	Cg4	113	136	99.9	1.7	11.9	46.3	39.6	0.4			0.1	0.02	S
	AC'b	136	156	100.0	2.0	14.3	63.9	19.5	0.2			0.0	0.01	S
	C'g1	156	182	99.7	0.1	5.9	45.3	47.7	0.7			0.3	0.02	S
	C'g2	182	198	100.0	3.0	40.3	39.2	17.3	0.2			0.0	0.03	COS
BC5 Low	Oe	0	13										45.76	MPT
	A	13	20	98.7	0.1	1.8	42.9	53.3	0.6			1.3	1.00	FS
	Cg1	20	30	99.9	0.0	2.3	47.2	50.1	0.2			0.1	0.09	FS

Site	Horizon	Upper Depth	Lower Depth	Sand Total	VCOS	COS	MS	FS	VFS	Silt	Clay	Silt + Clay	Organic Carbon	Texture Class
		----- cm -----		--- % ---										
BC5 Low	Cg2	30	56	100.0	0.1	2.7	44.4	52.6	0.2			0.0	0.06	FS
	Cg3	56	82	99.8	0.0	4.4	36.9	57.6	0.9			0.2	0.03	FS
	2Ab1	82	99	12.0	1.8	0.8	1.9	3.8	3.6	56.0	32.0		14.17	MK SICL
	2Ab2	99	109	76.3	0.8	1.5	30.8	41.5	1.8	10.4	13.3		4.46	FSL
	3Cg	109	157	99.9	0.2	1.5	30.8	66.3	1.1			0.1	0.11	FS
	3Cse1	157	177	99.3	0.4	1.8	22.4	72.3	2.3			0.7	0.12	FS
	3Cse2	177	198	99.6	1.8	12.7	47.8	36.8	0.4			0.4	0.02	S
BC5 Mid	Oe	0	13										45.76	MPT
	A	13	24	99.8	0.1	1.3	32.4	65.4	0.6			0.2	1.70	FS
	C1	24	51	100.0	0.0	1.7	41.2	56.9	0.2			0.0	0.19	FS
	C2	51	65	99.7	0.3	6.5	52.7	40.1	0.0			0.3	0.04	S
	C3	65	92	100.0	0.1	3.7	49.0	47.1	0.1			0.0	0.08	S
	Cse	92	119	99.8	0.0	5.8	42.5	51.1	0.4			0.2	0.02	FS
	2Ab1	119	131	33.3	1.6	1.0	6.8	13.1	10.9	43.5	23.2		11.52	MK L
	2Ab2	131	136	82.2	1.9	2.3	26.1	50.1	1.8	8.3	9.5		3.99	LFS
	3Ab3	136	152	93.9	0.4	1.6	25.8	63.7	2.4	4.0	2.1		0.92	FS
	3ACb	152	170	99.8	0.1	1.0	27.3	70.1	1.2			0.2	0.18	FS
	3Cg	170	196	100.0	0.5	6.2	54.8	38.3	0.1			0.0	0.08	S
BC5 High	Oi	0	2.5										48.58	SPM
	Oe	2.5	6										24.58	MPM
	AE	6	19	99.9	0.0	1.8	41.4	56.2	0.5			0.1	0.31	FS
	A	19	30	99.9	0.4	2.3	45.4	51.5	0.4			0.1	0.21	FS
	Bw1	30	77	100.0	0.0	1.5	55.2	43.2	0.1			0.0	0.02	S
	Bw2	77	98	100.0	0.0	2.5	56.6	40.8	0.1			0.0	0.01	S
	Bw3	98	145	100.0	0.0	1.3	40.5	58.2	0.0			0.0	0.03	FS

		Upper	Lower	Sand								Silt +	Organic	Texture
Site	Horizon	Depth	Depth	Total	VCOS	COS	MS	FS	VFS	Silt	Clay	Clay	Carbon	Class
		----- cm -----		--- % ---										
BC5 High	C	145	171	100.0	0.0	1.5	50.0	48.5	0.0			0.0	0.01	S
	Cse	171	198	99.8	0.1	3.0	26.9	69.6	0.2			0.2	0.02	FS
	2Ab1	198	216	71.2	1.0	0.9	10.9	53.5	4.8	21.9	6.9		4.57	FSL
	3Ab2	216	232	82.8	0.5	2.9	23.7	53.1	2.6	9.6	7.6		6.71	MK LFS
	3Cg	232	268	99.6	0.5	3.8	28.3	65.7	1.3			0.4	0.13	FS
BC6 Low	Oe	0	2										29.80	MPT
	Oa	2	5										20.14	MUCK
	A1	5	7	73.9	0.0	0.2	1.2	29.6	42.9	21.3	4.8		6.30	MK VFSL
	A2	7	9.5	82.1	0.3	2.3	33.6	40.5	5.4	11.8	6.1		2.36	LS
	2Cg1	9.5	20	99.6	0.0	3.7	47.8	47.8	0.3			0.4	0.26	S
	2Cg2	20	33	99.5	0.3	4.4	36.7	56.3	1.8			0.5	0.10	FS
	2Cg3	33	78	99.4	0.7	8.9	36.5	52.2	1.1			0.6	0.04	FS
	2Cg4	78	93	99.7	0.2	2.4	51.0	45.1	1.0			0.3	0.04	S
	3Ab	93	110	42.6	0.6	0.7	5.8	16.3	19.2	36.9	20.5		4.57	L
	3Oa	110	117										22.87	MUCK
	3A'b1	117	128	76.5	1.5	3.1	30.2	34.3	7.3	12.1	11.4		3.79	FSL
	3A'b2	128	142	55.7	0.7	2.1	14.9	30.4	7.6	23.3	21.1		8.31	MK SCL
	3Aseb	142	168	76.1	0.3	0.9	7.1	53.5	14.3	19.5	4.4		1.15	LFS
	4Cse	168	210	99.2	0.0	1.0	18.3	76.9	2.9			0.8	0.04	FS
BC6 Mid	Oi	0	5										48.76	PEAT
	Oe	5	10										31.78	MPT
	A1	10	12	82.4	1.0	2.4	25.1	35.6	18.3	12.2	5.4		6.34	LS
	2A2	12	16	98.5	0.0	2.1	38.5	56.5	1.5			1.5	1.80	FS
	2Cg	16	56	99.8	0.0	2.8	46.7	50.0	0.3			0.2	0.08	FS
	2Cse	56	117	99.7	0.0	5.1	42.2	51.2	1.1			0.3	0.06	FS

		Upper	Lower	Sand								Silt +	Organic	Texture
Site	Horizon	Depth	Depth	Total	VCOS	COS	MS	FS	VFS	Silt	Clay	Clay	Carbon	Class
		----- cm -----		-- % --										
BC6 Mid	3Aseb	117	134	50.0	0.5	0.6	2.8	16.3	29.8	31.5	18.5		4.20	L
	3Oase	134	146										24.96	MUCK
	3A'seb1	146	156	63.7	2.7	4.9	27.9	25.3	2.9	19.1	17.2		8.21	MK SL
	3A'seb2	156	171	67.7	0.7	1.8	6.6	43.3	15.3	26.2	6.0		1.31	FSL
	4Cse	171	207	95.8	0.2	0.7	15.0	71.6	8.3	4.1	0.1		0.15	FS
BC6 High	Oe	0	3										45.87	MPM
	A	3	10	98.8	0.0	1.5	38.2	57.6	1.5			1.2	0.45	FS
	Bw/Bhs	10	33	99.8	0.0	1.7	40.5	56.9	0.6			0.2	0.33	FS
	C	33	47	100.0	0.1	0.8	35.2	63.4	0.5			0.0	0.19	FS
	Cse1	47	66	99.8	0.7	11.6	47.7	39.1	0.7			0.2	0.05	S
	Cse2	66	138	99.8	0.5	3.8	33.3	60.9	1.2			0.2	0.03	FS
	2Aseb	138	157	64.3	0.6	0.8	7.9	32.4	22.6	23.0	12.7		2.67	SL
	2Oase	157	174										17.70	MUCK
	2A'seb1	174	185	70.6	1.2	3.4	23.0	37.3	5.7	17.2	12.2		6.06	SL
	2A'seb2	185	198	60.5	0.9	0.7	6.4	42.6	9.9	27.6	12.0		2.13	SL
	3Cse	198	220	98.2	0.1	0.5	17.7	73.0	6.9			1.8	0.08	FS
OW1 Low	A	0	1.5	97.6	0.4	5.3	62.3	26.9	2.8			2.4	3.60	S
	CA	1.5	9	100.0	1.0	6.7	65.0	27.1	0.2			0.0	0.73	S
	C	9	20	99.8	0.7	9.3	64.9	24.9	0.1			0.2	0.11	S
	Cg	20	23	97.3	0.8	3.6	21.7	64.8	6.4			2.7	0.11	FS
	Ab	23	26	93.9	1.2	3.1	39.7	46.4	3.4	4.3	1.8		0.82	S
	C'g	26	29	100.0	0.0	0.3	33.0	64.8	1.9			0.0	0.22	FS
	Aseb	29	32	99.1	0.6	4.2	49.8	43.3	1.2			0.9	0.82	S
	Cse	32	71	99.9	0.8	9.2	64.4	25.1	0.3			0.1	0.02	S
	C"g1	71	131	100.0	5.1	25.0	55.0	14.8	0.0			0.0	0.02	S

Site	Horizon	Upper Depth	Lower Depth	Sand						Silt	Clay	Silt + Clay	Organic Carbon	Texture Class
				Total	VCOS	COS	MS	FS	VFS					
		----- cm -----		-- % --										
OW1 Low	C"g2	131	164	100.0	0.7	5.3	50.5	42.6	0.9			0.0	0.01	S
	ACb	164	185	99.6	0.0	2.1	26.9	67.6	2.9			0.4	0.03	FS
	C"'g	185	218	100.0	0.0	0.9	20.8	77.3	1.0			0.0	0.03	FS
OW1 Mid	CA	0	16	100.0	0.3	9.4	63.3	25.9	1.1			0.0	0.26	S
	C	16	39	100.0	7.4	25.3	52.6	14.5	0.2			0.0	0.08	S
	Cg	39	53	100.0	0.0	1.0	55.1	43.4	0.5			0.0	0.04	S
	Aseb	53	57	95.0	1.6	10.1	52.1	30.8	0.5	3.2	1.8		1.03	S
	Cse1	57	82	100.0	0.2	2.9	51.9	44.5	0.5			0.0	0.03	S
	Cse2	82	122	100.0	1.7	10.9	59.2	28.3	0.0			0.0	0.01	S
	C'g1	122	168	99.9	20.9	45.3	28.1	5.5	0.0			0.1	0.04	COS
	C'g2	168	198	100.0	3.0	5.5	40.7	50.3	0.4			0.0	0.02	S
	C'g3	198	245	99.1	0.0	0.4	7.1	88.2	3.3			0.9	0.07	FS
	2ACb	245	250	80.2	0.1	1.4	11.0	57.6	10.1	13.6	6.2		0.33	LFS
OW1 High	CA	0	5	99.9	1.2	17.4	60.8	19.4	1.1			0.1	0.09	S
	C1	5	31	99.8	2.0	26.5	59.7	11.6	0.0			0.2	0.06	S
	C2	31	44	100.0	14.6	24.6	50.4	10.5	0.0			0.0	0.08	S
	Cg	44	58	100.0	0.0	3.0	65.3	31.6	0.1			0.0	0.04	S
	Ab	58	62	98.6	0.9	9.8	53.0	34.1	0.8			1.4	0.71	S
	C'g1	62	83	99.9	0.2	8.0	59.1	32.3	0.3			0.1	0.07	S
	C'g2	83	144	100.0	1.9	9.6	62.0	26.3	0.2			0.0	0.02	S
	C'g3	144	161	100.0	21.1	32.0	37.1	9.7	0.0			0.0	0.04	COS
	C'g4	161	183	100.0	5.1	11.7	51.5	31.2	0.4			0.0	0.02	S
	C'g5	183	198	99.9	1.0	7.0	57.7	33.9	0.2			0.1	0.02	S
OW2 Low	Oa	0	2.5										18.95	MUCK
	CA	2.5	7	99.7	0.0	0.4	12.1	85.0	2.2			0.3	0.84	FS

		Upper	Lower	Sand								Silt +	Organic	Texture
Site	Horizon	Depth	Depth	Total	VCOS	COS	MS	FS	VFS	Silt	Clay	Clay	Carbon	Class
		----- cm -----		-- % --										
OW2 Low	Cg	7	18	100.0	0.2	2.0	25.6	70.8	1.4			0.0	0.08	FS
	Cse1	18	31	100.0	0.8	6.6	22.8	67.7	2.1			0.0	0.03	FS
	Cse2	31	79	100.0	1.2	9.9	59.5	28.8	0.6			0.0	0.05	S
	Cse3	79	129	99.9	0.4	9.9	64.3	25.1	0.1			0.1	0.02	S
	C'g	129	175	99.9	1.1	6.5	62.5	29.5	0.3			0.1	0.03	S
	Ab	175	198	86.8	0.0	0.4	4.9	66.2	15.2	9.1	4.1		0.27	LFS
OW2 Mid	Oa	0	2.5										15.14	MUCK
	CA	2.5	7	100.0	0.2	6.9	33.7	51.9	2.1			0.0	0.31	FS
	C	7	13	100.0	0.5	5.5	35.1	58.2	0.7			0.0	0.08	S
	Cg1	13	27	100.0	2.0	12.1	49.9	35.7	0.2			0.0	0.04	S
	Cg2	27	60	100.0	0.3	3.9	70.2	25.4	0.2			0.0	0.05	S
	Cg3	60	101	100.0	2.5	21.6	49.3	26.5	0.1			0.0	0.02	S
	Cg4	101	147	100.0	2.7	20.5	53.8	22.8	0.1			0.0	0.02	S
	Cg5	147	192	99.9	0.4	8.1	55.7	35.3	0.5			0.1	0.06	COS
	Aseb	192	228	84.5	13.2	26.0	46.0	14.5	0.2	11.2	4.3		0.30	LFS
OW2 High	CA	0	16	100.0	0.4	14.4	54.3	30.7	0.2			0.0	0.17	S
	C1	16	33	100.0	0.2	11.5	62.8	25.4	0.1			0.0	0.06	S
	2C2	33	43	100.0	2.7	36.6	43.7	16.9	0.1			0.0	0.03	COS
	2C3	43	52	100.0	0.2	9.0	57.7	32.5	0.6			0.0	0.01	S
	2Cg	52	107	100.0	1.3	11.0	58.0	29.3	0.3			0.0	0.07	S
	2Cse1	107	151	100.0	1.7	16.8	62.2	19.0	0.2			0.0	0.02	S
	2Cse2	151	185	100.0	1.2	15.3	66.6	16.5	0.3			0.0	0.01	S
	2C'g	185	218	99.9	11.7	35.1	47.3	5.8	0.0			0.1	0.04	COS
OW3 Low	Oa1	0	3										23.87	MUCK
	Oa2	3	6										18.52	MUCK

Site	Horizon	Upper Depth	Lower Depth	Sand						Silt	Clay	Silt + Clay	Organic Carbon	Texture Class
				Total	VCOS	COS	MS	FS	VFS					
		----- cm -----		--- % ---										
OW3 Low	CA	6	14	100.0	3.9	45.7	33.4	16.8	0.2			0.0	0.39	COS
	Cg1	14	23	100.0	5.1	49.0	37.1	8.7	0.0			0.0	0.06	COS
	Cg2	23	103	100.0	3.7	22.3	53.3	20.4	0.3			0.0	0.05	S
	Cg3	103	138	99.8	0.4	3.6	54.2	40.8	0.8			0.2	0.05	S
	Cg4	138	174	98.8	0.1	0.8	16.7	77.1	4.0			1.2	0.04	FS
	Ab	174	238	83.7	0.0	0.5	4.0	64.7	14.5	10.7	5.7		0.30	LFS
OW3 Mid	A1	0	1.5	95.0	1.2	26.3	48.8	16.8	1.9			5.0	4.06	COS
	A2	1.5	6	99.7	3.9	18.9	55.8	20.7	0.5			0.3	0.52	S
	CA	6	15	100.0	3.1	36.1	51.1	9.7	0.0			0.0	0.07	S
	Cg1	15	31	99.9	5.1	27.0	42.2	25.1	0.4			0.1	0.04	COS
	Cg2	31	77	100.0	4.5	27.4	52.9	15.1	0.0			0.0	0.04	S
	Cg3	77	114	99.6	15.3	35.7	42.0	6.6	0.0			0.4	0.05	COS
	Cse1	114	139	99.7	2.4	7.4	49.9	38.5	1.4			0.3	0.03	S
	Cse2	139	154	99.6	0.3	2.5	33.5	59.3	3.9			0.4	0.03	FS
	Cse3	154	174	97.5	0.0	1.2	22.9	67.8	5.5			2.5	0.06	FS
	Aseb	174	199	71.7	0.0	0.1	3.5	53.3	14.8	19.3	9.0		0.45	FSL
	C'se	199	226	85.1	0.0	0.2	3.9	67.8	13.2	10.0	4.9		0.24	LFS
	C'g	226	250	95.2	0.2	0.8	4.7	80.9	8.6			4.8	0.08	FS
OW3 High	AC	0	3	100.0	0.1	8.6	60.3	30.7	0.3			0.0	0.27	S
	Bw1	3	11.5	99.9	0.3	11.1	69.4	19.1	0.0			0.1	0.06	S
	Bw2	11.5	36	100.0	2.0	22.5	51.8	23.6	0.2			0.0	0.03	S
	Bw3	36	54	99.9	2.2	31.1	52.4	14.2	0.0			0.1	0.02	S
	Bw4	54	74	100.0	0.2	2.8	49.1	47.6	0.3			0.0	0.01	S
	2Bw5	74	80	100.0	5.4	14.3	50.4	29.8	0.1			0.0	0.04	S
	2Cg	80	123	100.0	2.8	13.0	51.9	32.1	0.2			0.0	0.03	S

		Upper	Lower	Sand								Silt +	Organic	Texture
Site	Horizon	Depth	Depth	Total	VCOS	COS	MS	FS	VFS	Silt	Clay	Clay	Carbon	Class
		----- cm -----		------------------	------------------	------------------	------------------	%	------------------	------------------	------------------	------------------	------------------	
OW3 High	2Cg/Ab	123	158	100.0	3.3	19.8	60.8	16.1	0.0			0.0	0.03	S
	2C'g1	158	184	99.9	2.8	18.5	54.9	23.5	0.2			0.1	0.04	S
	2C'g2	184	198	99.8	0.3	5.4	52.5	40.5	1.1			0.2	0.06	S
OW4 Low	A1	0	1.5	92.6	4.1	17.6	56.2	14.2	0.5	2.4	5.0		0.57	MK S
	A2	1.5	3.5	98.8	1.0	10.0	63.4	23.1	1.2			1.2	0.63	S
	AC	3.5	6	100.0	0.6	10.9	64.8	23.4	0.2			0.0	0.14	S
	C	6	11	99.4	1.0	21.0	66.0	11.3	0.0			0.6	0.05	S
	Cg1	11	23	100.0	1.2	8.9	48.7	41.0	0.2			0.0	0.05	S
	Cg2	23	28	99.7	0.0	0.2	16.8	80.3	2.4			0.3	0.15	FS
	Ab	28	29.5	78.3	3.9	2.4	15.7	50.3	5.8	12.3	9.5		1.94	FSL
	C'g	29.5	32	99.4	0.1	0.3	23.5	69.6	5.9			0.6	0.22	FS
	A'b	32	35	86.6	4.2	28.2	32.0	20.8	1.4	6.5	6.9		1.63	LCOS
	C"g	35	42	100.0	1.6	33.7	40.7	23.6	0.4			0.0	0.10	COS
	Cse1	42	44	100.0	0.1	5.8	36.5	56.3	1.3			0.0	0.04	FS
	Cse2	44	78	100.0	2.3	29.3	34.3	33.4	0.6			0.0	0.03	COS
	C'"g	78	164	100.0	0.8	13.9	64.7	20.5	0.1			0.0	0.05	S
	A"b	164	183	91.4	1.8	17.4	67.3	4.8	0.1	2.2	6.4		4.07	S
	C""g	183	205	99.8	0.2	1.8	38.6	57.9	1.3			0.2	0.04	FS
OW4 Mid	A	0	2	98.3	0.4	9.4	64.8	22.5	1.3			1.7	1.90	S
	C1	2	25	100.0	0.6	6.7	66.7	25.9	0.2			0.0	0.10	S
	C2	25	32	100.0	1.1	16.9	68.8	13.2	0.0			0.0	0.07	S
	Cg	32	34	99.8	0.8	18.5	60.0	19.5	1.0			0.2	0.36	S
	Ab	34	36	96.6	0.1	3.3	27.8	59.8	5.6			3.4	1.35	FS
	C'g	36	39	99.7	0.0	0.4	30.7	65.4	3.1			0.3	0.25	FS
	A'b	39	42	99.0	0.5	16.9	52.9	28.0	0.7			1.0	2.23	S

		Upper	Lower	Sand								Silt +	Organic	Texture
Site	Horizon	Depth	Depth	Total	VCOS	COS	MS	FS	VFS	Silt	Clay	Clay	Carbon	Class
		----- cm -----		--- % ---										
OW4 Mid	Cse	42	52	100.0	0.1	14.2	59.2	26.2	0.3			0.0	0.14	S
	C"g1	52	147	100.0	1.0	16.8	58.1	23.9	0.2			0.0	0.02	S
	C"g2	147	200	100.0	3.0	19.3	67.3	10.4	0.0			0.0	0.01	S
	C"g3	200	220	99.7	0.1	0.6	25.8	70.7	2.4			0.3	0.02	FS
OW4 High	C	0	24	100.0	0.5	6.0	73.0	20.4	0.1			0.0	0.03	S
	Ab1	24	25	96.6	0.5	7.7	46.4	39.9	2.2			3.4	0.53	S
	Ab2	25	29	100.0	0.7	5.7	45.0	47.9	0.7			0.0	0.17	S
	Cg1	29	38	99.9	0.3	2.4	31.5	64.9	0.7			0.1	0.08	FS
	Cg2	38	49	100.0	1.3	39.5	54.3	4.8	0.0			0.0	0.05	S
	Cg3	49	68	100.0	0.1	2.1	58.5	38.6	0.7			0.0	0.05	S
	Aseb	68	73	97.9	1.0	9.5	37.5	47.8	2.0			2.1	1.08	S
	Cse1	73	90	100.0	0.4	3.2	32.5	62.9	1.0			0.0	0.04	FS
	Cse2	90	113	99.9	3.0	49.5	34.0	13.4	0.0			0.1	0.03	COS
	C'g1	113	137	99.9	1.5	10.3	52.7	34.7	0.6			0.1	0.01	S
	C'g2	137	165	100.0	1.2	14.3	65.3	19.1	0.1			0.0	0.01	S
	C'g3	165	198	99.9	1.4	11.5	61.5	25.1	0.3			0.1	0.01	S

APPENDIX E: IRON EXTRACTIONS

Site	Horizon	Upper Depth	Lower Depth	Pre-Treatment Color Hue	Pre-Treatment Color Value	Pre-Treatment Color Chroma	Post-Treatment Color Hue	Post-Treatment Color Value	Post-Treatment Color Chroma	DCB Extractable Iron†
		------ cm ------								g kg^{-1}
BC1 Low	A	0	2	8.2 YR	2.5	1.1	9.2 YR	2.8	1.2	1.11
	A/C	2	5	8.5 YR	3.4	1.2	9.4 YR	3.6	1.5	0.32
	Cg	5	13	9.6 YR	4.5	1.2	1.2 Y	4.7	0.9	0.08
	Cse	13	73	0.3 Y	4.9	1.1	1.7 Y	4.6	0.7	0.08
	C'g1	73	104	1.2 Y	5.3	1.1	3.3 Y	4.8	0.6	bdl
	C'g2	104	184							
	C'g3	184	212							
BC1 Mid	A	0	2.0	7.2 YR	2.6	1.1	7.8 YR	3.0	1.5	0.46
	C	2	16	9.3 YR	4.8	1.6	0.4 Y	4.7	1.1	bdl
	Cg	16	85	0.2 Y	5.2	1.4	1.5 Y	4.8	0.7	bdl
	Cse1	85	138	1.3 Y	5.2	1.2	2.9 Y	4.7	0.7	0.08
	Cse2	138	234							
	Aseb	234	250							
BC1 High	CA	0	16	9.4 YR	4.7	2.0	0.6 Y	4.9	1.1	0.14
	C1	16	41	9.8 YR	5.2	2.2	0.7 Y	5.1	0.9	0.15
	C2	41	60	0.3 Y	5.1	2.1	0.8 Y	5.0	0.8	0.16
	C3	60	78	0.1 Y	5.3	2.1	1.1 Y	5.0	0.8	0.16
	Cg1	78	131	0.4 Y	5.0	1.8	1.1 Y	4.8	0.8	0.16
	Cg2	131	161							
	Cg3	161	187							
	Cg4	187	213							
BC2 Low	Oa	0	2.5							
	AC	2.5	4.5	8.7 YR	3.6	1.2	9.4 YR	4.5	1.3	0.10

Site	Horizon	Upper Depth	Lower Depth	Pre-Treatment Color			Post-Treatment Color			DCB Extractable Iron†
				Hue	Value	Chroma	Hue	Value	Chroma	
		------ cm ------								g kg^{-1}
BC2 Low	Cg1	4.5	18	9.4 YR	4.7	1.6	0.1 Y	4.8	1.2	bdl
	Cg2	18	25	9.4 YR	4.7	1.8	1.1 Y	4.8	1.0	bdl
	Cg3	25	39	9.4 YR	4.7	1.9	1.2 Y	4.8	1.0	bdl
	2CAb	39	56	9.4 YR	3.7	1.2	1.1 Y	3.8	1.1	bdl
	2Cg	56	92	1.1 Y	4.6	1.0	2.3 Y	4.5	0.6	0.19
	2Cse1	92	127	1.1 Y	5.1	1.1	1.6 Y	4.9	0.7	0.19
	2Cse2	127	147							
	3Ab1	147	164							
	3Ab2	164	171							
	3Aseb1	171	183							
	3Aseb2	183	198							
BC2 Mid	Oa	0	1.5	8.3 YR	4.2	1.4	9.4 YR	4.5	1.3	bdl
	A	1.5	8	9.4 YR	5.0	1.5	0.6 Y	4.9	0.9	bdl
	Cg1	8	22	9.5 YR	4.9	1.6	1.2 Y	4.9	0.8	bdl
	Cg2	22	28	9.7 YR	4.6	1.7	1.4 Y	4.8	0.8	bdl
	Cg3	28	60	9.8 YR	3.4	1.1	1.4 Y	3.5	1.0	0.14
	Ab	60	70	1.0 Y	4.5	1.1	2.4 Y	4.6	0.8	0.14
	Cse1	70	94	1.2 Y	4.6	0.7	1.8 Y	4.1	0.4	0.24
	2Cse2	94	106	1.5 Y	4.9	1.0	2.1 Y	4.7	0.6	0.25
	2Cse3	106	153							
	2ACseb	153	165							
	3Aseb1	165	174							
	3Aseb2	174	186							
	3Aseb3	186	197							
	3Aseb4	197	212							

		Upper Depth	Lower Depth	Pre-Treatment Color			Post-Treatment Color			DCB Extractable Iron†
Site	Horizon			Hue	Value	Chroma	Hue	Value	Chroma	
		------ cm ------								g kg^{-1}
BC2 High	CA	0	19	9.4 YR	4.8	2.1	0.9 Y	4.8	1.0	0.20
	Bw1	19	29	9.4 YR	5.1	2.3	1.6 Y	5.1	0.9	0.23
	Bw2	29	63	9.6 YR	4.9	2.2	1.6 Y	5.0	0.9	0.19
	Cg	63	77	0.3 Y	5.2	1.8	1.2 Y	4.8	0.7	bdl
	2Cg/Ab	77	123	9.5 YR	3.8	1.4	0.9 Y	4.2	1.1	0.12
	2Cse1	123	159	0.7 Y	4.4	1.1	1.9 Y	4.7	0.8	0.19
	2Cse2	159	185							
	2ACseb	185	198							
	3Aseb	198	214							
	3Oa	214	220							
BC3 Low	A	0	1.5	9.4 YR	2.7	1.7	1.5 Y	3.2	1.0	1.85
	AC	1.5	6.5	8.8 YR	3.6	1.2	9.4 YR	3.6	1.3	0.16
	Cg1	6.5	22	9.4 YR	4.7	1.2	0.5 Y	4.8	0.9	bdl
	Cg2	22	32.5	9.5 YR	4.9	1.2	0.6 Y	4.9	0.8	bdl
	Cg3	32.5	101	9.8 YR	5.1	1.3	1.0 Y	4.9	0.8	bdl
	Cse1	101	115	1.5 Y	4.7	0.9	1.5 Y	4.5	0.6	0.21
	Cse2	115	182							
	Cse3	182	224							
	2Aseb	224	238							
BC3 Mid	AC	0	8	9.1 YR	3.9	1.6	9.8 YR	3.9	1.4	0.20
	C1	8	31	9.7 YR	5.3	1.8	1.3 Y	4.9	0.9	bdl
	C2	31	48	9.9 YR	4.7	1.3	1.1 Y	4.5	0.7	bdl
	Cg1	48	64	9.9 YR	4.8	1.2	1.3 Y	4.8	0.7	bdl
	Cg2	64	76	9.6 YR	4.4	1.2	1.5 Y	4.4	0.6	bdl
	Ab/Cg	76	87	9.5 YR	3.7	1.0	0.9 Y	4.0	0.7	bdl

		Upper	Lower	Pre-Treatment Color			Post-Treatment Color			DCB Extractable
Site	Horizon	Depth	Depth	Hue	Value	Chroma	Hue	Value	Chroma	Iron†
		------ cm ------								g kg^{-1}
	Cse1	87	105	10.0 YR	5.0	1.3	1.1 Y	4.9	0.7	bdl
	Cse2	105	235							
	2Aseb	235	240							
BC3 High	AC	0	6	9.1 YR	3.7	1.3	9.3 YR	3.5	1.5	0.20
	CA	6	14	8.5 YR	4.3	1.9	9.4 YR	4.2	1.3	0.17
	C1	14	26	9.2 YR	4.7	1.9	0.5 Y	4.9	1.1	bdl
	C2	26	50	9.9 YR	5.0	2.1	1.3 Y	4.9	0.9	bdl
	Cg	50	59	0.2 Y	4.9	1.4	1.0 Y	4.8	0.8	bdl
	Cse1	59	73	0.4 Y	4.9	1.2	0.6 Y	4.6	0.7	bdl
	Cse2	73	112	9.5 YR	4.1	1.4	0.9 Y	4.3	0.8	bdl
	Cse3	112	135							
	Cse4	135	238							
	2Aseb	238	250							
BC4 Low	Oa	0	5	5.3 YR	1.9	1.0	6.4 YR	2.2	0.9	2.56
	A	5	9.5	8.0 YR	2.8	1.1	9.2 YR	3.1	1.0	0.28
	CA	9.5	17	9.2 YR	3.9	1.4	9.7 YR	4.3	1.0	bdl
	Cg	17	25	9.4 YR	4.6	1.5	1.0 Y	4.7	1.0	bdl
	Ab	25	26	9.2 YR	3.1	1.0	0.9 Y	3.3	0.8	0.17
	C'g	26	28	9.2 YR	3.1	1.0	0.9 Y	3.3	0.8	0.17
	A'b	28	30	9.0 YR	3.1	0.9	0.4 Y	3.1	0.8	bdl
	C'g	30	46	9.1 YR	4.5	1.7	0.5 Y	4.7	1.2	bdl
	Cse1	46	67	9.4 YR	4.0	1.4	1.3 Y	4.5	0.9	0.36
	Cse2	67	89	0.1 Y	4.5	1.5	2.0 Y	4.9	0.8	0.41
	Cse3	89	130	0.8 Y	4.6	1.7	2.9 Y	4.8	0.9	0.29
	C'''g	130	180							

Site	Horizon	Upper Depth	Lower Depth	Pre-Treatment Color Hue	Pre-Treatment Color Value	Pre-Treatment Color Chroma	Post-Treatment Color Hue	Post-Treatment Color Value	Post-Treatment Color Chroma	DCB Extractable Iron†
		------ cm ------								g kg^{-1}
BC4 Mid	A	0	10	6.5 YR	2.6	0.9	7.3 YR	2.4	0.9	0.62
	CA	10	22	9.2 YR	4.1	1.6	10.0 YR	4.3	1.1	0.22
	C	22	43	9.9 YR	4.3	1.3	0.8 Y	4.5	0.8	bdl
	Cg	43	45	9.8 YR	3.0	0.9	0.9 Y	3.2	0.6	bdl
	ACb	45	71	9.4 YR	3.5	1.5	1.4 Y	4.0	1.1	bdl
	Cse	71	120	9.4 YR	4.1	1.6	1.6 Y	5.0	0.9	0.16
	C'g1	120	177							
	C'g2	177	212							
BC4 High	A	0	2.5	6.3 YR	2.5	1.1	7.0 YR	2.3	1.0	0.39
	CA	2.5	10	8.2 YR	3.7	1.7	9.4 YR	4.3	1.4	0.21
	C1	10	21	8.9 YR	4.2	2.0	9.9 YR	4.7	1.2	0.19
	C2	21	32	9.4 YR	4.4	2.0	0.3 Y	4.9	1.0	0.22
	Ab	32	38	9.1 YR	3.4	1.4	0.1 Y	4.0	0.9	0.37
	ACb	38	43	9.4 YR	3.7	1.5	0.8 Y	4.3	0.8	0.34
	C'	43	52	9.4 YR	4.4	2.0	1.1 Y	4.8	1.0	0.22
	Cg1	52	70	10.0 YR	4.4	1.5	1.8 Y	4.8	0.9	0.13
	Cg2	70	76	0.9 Y	3.6	1.1	2.1 Y	3.9	0.7	bdl
	Cg3	76	113	0.9 Y	4.3	1.3	2.0 Y	4.7	0.9	bdl
	Cg4	113	136							
	AC'b	136	156							
	C'g1	156	182							
	C'g2	182	198							
BC5 Low	Oe	0	13							
	A	13	20	8.5 YR	2.8	1.1	9.5 YR	3.0	0.9	bdl
	Cg1	20	30	9.3 YR	4.7	1.9	0.7 Y	4.9	1.1	bdl

Site	Horizon	Upper Depth	Lower Depth	Pre-Treatment Color Hue	Pre-Treatment Color Value	Pre-Treatment Color Chroma	Post-Treatment Color Hue	Post-Treatment Color Value	Post-Treatment Color Chroma	DCB Extractable Iron†
		------ cm ------								g kg^{-1}
BC5 Low	Cg2	30	56	9.6 YR	5.1	1.7	1.7 Y	5.0	0.9	bdl
	Cg3	56	82	1.0 Y	4.8	1.2	2.1 Y	4.8	0.8	0.21
	2Ab1	82	99	7.9 YR	2.3	0.9	9.1 YR	2.3	0.9	0.42
	2Ab2	99	109	7.5 YR	2.1	0.6	7.8 YR	2.1	0.5	0.59
	3Cg	109	157							
	3Cse1	157	177							
	3Cse2	177	198							
BC5 Mid	Oe	0	13							
	A	13	24	8.6 YR	3.3	1.1	9.7 YR	4.0	1.0	0.17
	C1	24	51	9.3 YR	4.1	1.8	0.3 Y	5.0	1.1	bdl
	C2	51	65	9.4 YR	4.6	2.1	0.8 Y	5.3	1.0	bdl
	C3	65	92	9.4 YR	4.4	1.8	1.2 Y	5.2	1.0	bdl
	Cse	92	119	0.8 Y	4.5	1.3	1.8 Y	5.0	0.8	0.13
	2Ab1	119	131							
	2Ab2	131	136							
	3Ab3	136	152							
	3ACb	152	170							
	3Cg	170	196							
BC5 High	Oi	0	2.5							
	Oe	2.5	6							
	AE	6	19	9.0 YR	3.6	1.3	9.8 YR	4.1	1.1	0.17
	A	19	30	9.0 YR	3.6	1.3	0.2 Y	4.1	0.9	0.26
	Bw1	30	77	9.5 YR	5.1	2.6	1.8 Y	4.9	0.9	0.23
	Bw2	77	98	9.7 YR	5.4	2.5	1.3 Y	5.1	1.0	0.17
	Bw3	98	145	9.6 YR	5.3	2.5	1.7 Y	5.1	1.0	0.20

Site	Horizon	Upper Depth	Lower Depth	Pre-Treatment Color Hue	Pre-Treatment Color Value	Pre-Treatment Color Chroma	Post-Treatment Color Hue	Post-Treatment Color Value	Post-Treatment Color Chroma	DCB Extractable Iron†
		------ cm ------								g kg^{-1}
	C	145	171	9.7 YR	5.5	2.1	1.5 Y	5.2	0.9	0.16
	Cse	171	198	1.0 Y	4.9	0.8	1.8 Y	4.5	0.6	0.26
	2Ab1	198	216							
	3Ab2	216	232							
	3Cg	232	268							
BC6 Low	Oe	0	2							
	Oa	2	5							
	A1	5	7	9.5 YR	3.1	1.2	1.2 Y	3.4	1.0	0.24
	A2	7	9.5	9.4 YR	2.6	0.8	0.1 Y	2.7	0.7	0.15
	2Cg1	9.5	20	9.0 YR	4.0	1.7	0.5 Y	4.9	1.4	bdl
	2Cg2	20	33	9.4 YR	4.2	1.5	1.5 Y	4.6	1.0	bdl
	2Cg3	33	78	0.7 Y	4.3	1.1	1.9 Y	4.6	0.8	0.23
	2Cg4	78	93	10.0 YR	4.3	1.1	0.7 Y	4.7	0.9	0.19
	3Ab	93	110	9.5 YR	2.6	0.9	0.8 Y	2.8	0.9	0.44
	3Oa	110	117							
	3A'b1	117	128							
	3A'b2	128	142							
	3Aseb	142	168							
	4Cse	168	210							
BC6 Mid	Oi	0	5							
	Oe	5	10							
	A1	10	12	7.2 YR	2.7	1.4	9.9 YR	2.9	0.9	0.21
	2A2	12	16	9.1 YR	3.9	1.2	0.3 Y	3.7	0.9	bdl
	2Cg	16	56	9.4 YR	4.9	1.5	0.5 Y	4.7	1.0	bdl
	2Cse	56	117	9.5 YR	4.9	1.4	1.6 Y	4.8	0.8	0.41

Site	Horizon	Upper Depth	Lower Depth	Pre-Treatment Color Hue	Pre-Treatment Color Value	Pre-Treatment Color Chroma	Post-Treatment Color Hue	Post-Treatment Color Value	Post-Treatment Color Chroma	DCB Extractable Iron†
		------ cm ------								g kg^{-1}
BC6 Mid	3Aseb	117	134							
	3Oase	134	146							
	3A'seb1	146	156							
	3A'seb2	156	171							
	4Cse	171	207							
BC6 High	Oe	0	3							
	A	3	10	7.9 YR	3.7	1.2	9.6 YR	3.5	1.0	0.35
	Bw/Bhs	10	33	7.6 YR	4.0	1.7	10.0 YR	4.5	1.2	0.40
	C	33	47	9.1 YR	5.2	1.9	1.2 Y	5.0	0.9	0.12
	Cse1	47	66	9.4 YR	4.7	1.5	2.3 Y	4.8	0.7	0.15
	Cse2	66	138	0.1 Y	5.3	1.5	2.7 Y	4.8	0.7	0.44
	2Aseb	138	157							
	2Oase	157	174							
	2A'seb1	174	185							
	2A'seb2	185	198							
	3Cse	198	220							
OW1 Low	A	0	1.5	8.2 YR	2.6	0.8	8.6 YR	2.6	1.0	0.47
	CA	1.5	9	8.5 YR	4.3	1.8	9.8 YR	4.6	1.4	0.19
	C	9	20	9.3 YR	5.1	1.6	0.4 Y	5.1	1.0	bdl
	Cg	20	23	9.5 YR	4.1	1.4	0.9 Y	4.0	1.1	0.21
	Ab	23	26	8.5 YR	2.8	1.1	8.9 YR	2.9	1.3	0.61
	C'g	26	29	9.4 YR	4.6	1.5	1.5 Y	4.8	0.9	0.13
	Aseb	29	32	9.4 YR	3.8	1.2	0.1 Y	3.8	1.3	0.38
	Cse	32	71	0.8 Y	5.0	1.2	1.6 Y	5.0	0.8	0.12
	C"g1	71	131	1.2 Y	4.9	1.2	1.1 Y	4.5	0.8	0.12

Site	Horizon	Upper Depth	Lower Depth	Pre-Treatment Color			Post-Treatment Color			DCB Extractable Iron†
				Hue	Value	Chroma	Hue	Value	Chroma	
		------ cm ------								g kg^{-1}
OW1 Low	C"g2	131	164							
	ACb	164	185							
	C"'g	185	218							
OW1 Mid	CA	0	16	9.5 YR	3.9	1.3	0.2 Y	4.5	1.1	0.17
	C	16	39	9.4 YR	4.2	1.6	10.0 YR	4.6	1.3	0.12
	Cg	39	53	9.4 YR	4.7	1.4	0.5 Y	4.8	1.0	bdl
	Aseb	53	57	9.2 YR	2.8	1.0	9.8 YR	3.2	1.2	bdl
	Cse1	57	82	0.3 Y	4.7	1.3	1.1 Y	5.0	0.9	0.18
	Cse2	82	122	1.2 Y	5.0	1.2	1.5 Y	5.1	0.8	bdl
	C'g1	122	168							
	C'g2	168	198							
	C'g3	198	245							
	2ACb	245	250							
OW1 High	CA	0	5	9.9 YR	4.2	1.5	0.6 Y	4.8	1.1	0.17
	C1	5	31	9.7 YR	4.5	1.8	0.5 Y	4.8	1.1	0.17
	C2	31	44	9.4 YR	4.4	1.8	9.7 YR	4.7	1.4	0.13
	Cg	44	58	9.5 YR	4.9	1.4	9.8 YR	4.9	0.9	bdl
	Ab	58	62	8.7 YR	3.3	1.3	9.2 YR	3.4	1.4	0.14
	C'g1	62	83	9.4 YR	4.2	1.3	9.9 YR	4.7	1.1	bdl
	C'g2	83	144	0.5 Y	4.9	1.1	1.1 Y	4.9	0.8	bdl
	C'g3	144	161							
	C'g4	161	183							
	C'g5	183	198							
OW2 Low	Oa	0	2.5							
	CA	2.5	7	9.2 YR	3.6	1.6	0.8 Y	4.2	1.5	0.16

Site	Horizon	Upper Depth	Lower Depth	Pre-Treatment Color			Post-Treatment Color			DCB Extractable Iron†
				Hue	Value	Chroma	Hue	Value	Chroma	
		------ cm ------								g kg^{-1}
OW2 Low	Cg	7	18	9.4 YR	4.7	1.8	2.3 Y	4.7	1.1	0.18
	Cse1	18	31	0.8 Y	4.9	1.3	3.2 Y	4.5	0.7	0.15
	Cse2	31	79	0.5 Y	4.9	1.3	2.3 Y	4.8	0.8	bdl
	Cse3	79	129	1.0 Y	5.0	0.9	1.7 Y	4.8	0.7	bdl
	C'g	129	175							
	Ab	175	198							
OW2 Mid	Oa	0	2.5	6.7 YR	2.2	0.9	6.1 YR	2.1	0.7	1.19
	CA	2.5	7	8.5 YR	3.8	1.5	9.4 YR	4.1	1.4	bdl
	C	7	13	9.4 YR	4.5	1.7	0.4 Y	5.0	1.2	bdl
	Cg1	13	27	9.5 YR	5.1	1.8	1.2 Y	5.4	1.0	bdl
	Cg2	27	60	0.4 Y	4.8	1.6	1.9 Y	5.0	0.9	0.15
	Cg3	60	101	1.1 Y	4.7	1.7	2.7 Y	5.1	0.7	0.22
	Cg4	101	147							
	Cg5	147	192							
	Aseb	192	228							
OW2 High	CA	0	16	9.4 YR	4.3	2.1	0.6 Y	5.1	1.2	0.25
	C1	16	33	9.5 YR	4.9	2.3	1.0 Y	5.3	1.0	0.21
	2C2	33	43	9.8 YR	5.0	2.4	1.3 Y	5.0	1.0	0.24
	2C3	43	52	0.3 Y	5.3	2.0	1.6 Y	5.2	0.9	0.18
	2Cg	52	107	0.1 Y	5.4	2.0	1.3 Y	5.3	1.0	0.18
	2Cse1	107	151	1.0 Y	5.0	1.4	1.7 Y	5.0	0.7	0.18
	2Cse2	151	185							
	2C'g	185	218							
OW3 Low	Oa1	0	3							
	Oa2	3	6							

Site	Horizon	Upper Depth	Lower Depth	Pre-Treatment Color Hue	Pre-Treatment Color Value	Pre-Treatment Color Chroma	Post-Treatment Color Hue	Post-Treatment Color Value	Post-Treatment Color Chroma	DCB Extractable Iron†
		------ cm	------							g kg^{-1}
OW3 Low	CA	6	14	9.6 YR	4.4	1.7	1.5 Y	4.7	1.2	bdl
	Cg1	14	23	0.2 Y	5.0	1.6	1.9 Y	4.7	0.9	bdl
	Cg2	23	103	1.3 Y	5.1	0.9	1.8 Y	4.8	0.6	bdl
	Cg3	103	138	2.7 Y	4.7	1.0	3.0 Y	4.4	0.6	bdl
	Cg4	138	174							
	Ab	174	238							
OW3 Mid	A1	0	1.5	8.0 YR	2.7	0.8	9.0 YR	2.6	1.0	0.68
	A2	1.5	6	8.8 YR	3.6	1.6	0.2 Y	3.9	1.5	0.23
	CA	6	15	9.0 YR	4.1	2.2	0.5 Y	4.8	1.6	0.13
	Cg1	15	31	0.7 Y	4.4	1.5	1.3 Y	4.7	1.2	0.15
	Cg2	31	77	1.6 Y	4.9	1.1	1.5 Y	4.8	0.7	bdl
	Cg3	77	114	1.6 Y	4.5	1.0	1.9 Y	4.6	0.6	bdl
	Cse1	114	139							
	Cse2	139	154							
	Cse3	154	174							
	Aseb	174	199							
	C'se	199	226							
	C'g	226	250							
OW3 High	AC	0	3	9.1 YR	4.0	1.6	9.7 YR	4.6	1.3	0.17
	Bw1	3	11.5	9.2 YR	4.3	2.0	0.2 Y	4.9	1.1	0.21
	Bw2	11.5	36	9.4 YR	4.6	2.4	0.8 Y	5.1	1.0	0.25
	Bw3	36	54	0.3 Y	4.7	2.2	0.9 Y	5.1	1.0	0.21
	Bw4	54	74	0.2 Y	5.1	2.3	1.4 Y	5.3	1.0	0.21
	2Bw5	74	80	9.7 YR	4.8	2.2	0.9 Y	5.2	1.1	0.22
	2Cg	80	123	0.5 Y	5.0	1.9	1.2 Y	5.1	1.0	0.20

Site	Horizon	Upper Depth	Lower Depth	Pre-Treatment Color			Post-Treatment Color			DCB Extractable Iron†
				Hue	Value	Chroma	Hue	Value	Chroma	
		------ cm ------								g kg^{-1}
OW3 High	2Cg/Ab	123	158	1.2 Y	4.8	1.1	1.2 Y	4.9	0.8	bdl
	2C'g1	158	184							
	2C'g2	184	198							
OW4 Low	A1	0	1.5	7.7 YR	2.4	0.9	7.8 YR	2.3	0.9	0.90
	A2	1.5	3.5	8.6 YR	3.9	1.5	9.4 YR	4.0	1.6	0.20
	AC	3.5	6	8.9 YR	4.6	1.7	0.1 Y	4.5	1.4	bdl
	C	6	11	8.9 YR	4.8	1.7	10.0 YR	4.8	1.3	bdl
	Cg1	11	23	9.4 YR	5.2	1.5	0.8 Y	5.1	1.0	bdl
	Cg2	23	28	9.4 YR	4.7	1.3	1.2 Y	4.8	0.9	0.10
	Ab	28	29.5	9.4 YR	3.1	1.4	0.6 Y	3.4	1.2	0.24
	C'g	29.5	32	9.8 YR	3.8	1.3	1.4 Y	4.2	1.0	0.09
	A'b	32	35	8.8 YR	2.9	1.3	9.3 YR	2.9	1.2	0.48
	C"g	35	42	9.6 YR	4.2	1.4	0.7 Y	4.7	1.1	bdl
	Cse1	42	44	1.0 Y	4.4	1.0	1.7 Y	4.6	0.7	0.15
	Cse2	44	78	1.5 Y	4.2	1.0	2.1 Y	4.6	0.7	0.17
	C'"g	78	164	1.7 Y	4.6	0.9	1.6 Y	4.8	0.7	bdl
	A"b	164	183							
	C""g	183	205							
OW4 Mid	A	0	2	8.7 YR	2.6	0.9	8.9 YR	2.7	0.9	0.35
	C1	2	25	9.1 YR	4.6	1.7	9.6 YR	4.6	1.3	bdl
	C2	25	32	9.4 YR	5.2	1.6	0.5 Y	5.1	1.0	bdl
	Cg	32	34	9.2 YR	4.6	1.5	10.0 YR	4.8	1.2	bdl
	Ab	34	36	9.0 YR	3.4	1.2	9.4 YR	3.4	1.2	0.27
	C'g	36	39	9.6 YR	4.3	1.1	1.0 Y	4.5	0.9	0.10
	A'b	39	42	9.4 YR	3.4	1.1	9.9 YR	3.5	1.2	0.20

Site	Horizon	Upper Depth	Lower Depth	Pre-Treatment Color Hue	Pre-Treatment Color Value	Pre-Treatment Color Chroma	Post-Treatment Color Hue	Post-Treatment Color Value	Post-Treatment Color Chroma	DCB Extractable Iron†
		------ cm	------							g kg^{-1}
OW4 Mid	Cse	42	52	0.1 Y	4.3	1.3	0.8 Y	4.8	1.0	0.11
	C"g1	52	147	1.1 Y	4.8	1.0	1.1 Y	4.9	0.7	bdl
	C"g2	147	200							
	C"g3	200	220							
OW4 High	C	0	24	0.8 Y	5.0	1.6	0.8 Y	5.0	0.9	0.11
	Ab1	24	25	9.2 YR	2.9	0.9	9.1 YR	2.6	0.8	0.52
	Ab2	25	29	9.4 YR	4.1	1.6	10.0 YR	4.5	1.2	0.17
	Cg1	29	38	9.4 YR	4.4	1.8	1.3 Y	4.8	1.1	0.13
	Cg2	38	49	9.4 YR	4.3	1.5	0.3 Y	5.0	1.1	bdl
	Cg3	49	68	9.7 YR	4.5	1.2	0.9 Y	4.9	0.8	bdl
	Aseb	68	73	9.4 YR	2.8	1.0	9.5 YR	3.1	1.0	0.40
	Cse1	73	90	0.8 Y	4.4	1.2	1.7 Y	5.0	0.8	0.25
	Cse2	90	113	0.8 Y	4.5	1.4	0.8 Y	5.0	0.9	0.30
	C'g1	113	137							
	C'g2	137	165							
	C'g3	165	198							

APPENDIX F: pH FOLLOWING MOIST INCUBATION

Site	Horizon	Upper Depth	Lower Depth	Field pH	Final Oxidized pH	Time to reach final pH	Time for pH to drop below 4
		------ cm ------				-------- days --------	
BC1 Low	A	0	2				
	A/C	2	5				
	Cg	5	13	4.18	3.79	96	52
	Cse	13	73	5.76	3.80	79	79
	C'g1	73	104	7.15	5.53	67	na
	C'g2	104	184	7.00	4.30	96	na
	C'g3	184	212	7.50	4.32	96	na
BC1 Mid	A	0	2.0				
	C	2	16				
	Cg	16	85	6.97	5.72	0	na
	Cse1	85	138	7.20	6.17	52	na
	Cse2	138	234	7.12	3.97	0	0
	Aseb	234	250	7.91	3.74	79	38
BC1 High	CA	0	16				
	C1	16	41				
	C2	41	60				
	C3	60	78				
	Cg1	78	131	6.50	5.99	67	na
	Cg2	131	161	7.09	4.07	79	na
	Cg3	161	187	6.96	5.85	67	na
	Cg4	187	213	7.20	6.26	38	na
BC2 Low	Oa	0	2.5				
	AC	2.5	4.5				
	Cg1	4.5	18	5.83[†]	6.10	0	na
	Cg2	18	25	6.42[†]	6.35	67	na
	Cg3	25	39	6.41[†]	6.34	0	na
	2CAb	39	56	5.85[†]	4.73	111	na
	2Cg	56	92	4.21[†]	3.86	79	79
	2Cse1	92	127	4.83[†]	3.83	79	79
	2Cse2	127	147	4.59[†]	3.85	79	79
	3Ab1	147	164	6.11[†]	4.15	96	na
	3Ab2	164	171	6.38[†]	4.28	111	na
	3Aseb1	171	183	5.66[†]	3.36	79	38
	3Aseb2	183	198	5.08[†]	3.08	79	24
BC2 Mid	Oa	0	1.5				
	A	1.5	8				
	Cg1	8	22	4.30	4.23	79	na
	Cg2	22	28	4.73	5.42	0	na
	Cg3	28	60	5.95	5.71	0	na

Site	Horizon	Upper Depth	Lower Depth	Field pH	Final Oxidized pH	Time to reach final pH	Time for pH to drop below 4
		------ cm ------				-------- days --------	
BC2 Mid	Ab	60	70	5.75	4.13	111	na
	Cse1	70	94	5.93	3.86	79	79
	2Cse2	94	106	6.96	3.55	79	52
	2Cse3	106	153	6.94	3.95	79	79
	2ACseb	153	165	6.98	3.52	79	52
	3Aseb1	165	174	6.88	4.43	111	na
	3Aseb2	174	186	7.03	3.91	111	111
	3Aseb3	186	197	6.89	4.00	111	111
	3Aseb4	197	212	7.13	3.21	111	52
BC2 High	CA	0	19				
	Bw1	19	29				
	Bw2	29	63				
	Cg	63	77	5.52	5.95	52	na
	2Cg/Ab	77	123	6.72	5.30	79	na
	2Cse1	123	159	6.96	3.62	79	67
	2Cse2	159	185	7.60	3.67	96	79
	2ACseb	185	198	7.00	3.82	79	79
	3Aseb	198	214	7.08	3.24	111	52
	3Oa	214	220				
BC3 Low	A	0	1.5				
	AC	1.5	6.5				
	Cg1	6.5	22				
	Cg2	22	32.5	6.55[†]	4.86	79	na
	Cg3	32.5	101	6.72[†]	4.61	96	na
	Cse1	101	115	5.97[†]	3.81	79	79
	Cse2	115	182	6.18[†]	3.82	79	79
	Cse3	182	224	4.26[†]	3.98	96	96
	2Aseb	224	238	4.50[†]	3.74	111	79
BC3 Mid	AC	0	8				
	C1	8	31				
	C2	31	48				
	Cg1	48	64	4.65	5.10	0	na
	Cg2	64	76	7.08	5.90	52	na
	Ab/Cg	76	87	7.00	5.30	0	na
	Cse1	87	105	6.96	4.74	0	na
	Cse2	105	235	7.22	4.10	0	na
	2Aseb	235	240	7.55	3.71	0	0
BC3 High	AC	0	6				
	CA	6	14				
	C1	14	26				
	C2	26	50				

Site	Horizon	Upper Depth	Lower Depth	Field pH	Final Oxidized pH	Time to reach final pH	Time for pH to drop below 4
		------ cm ------				-------- days --------	
BC3 High	Cg	50	59	6.14	6.17	79	na
	Cse1	59	73	7.52	6.21	52	na
	Cse2	73	112	7.69	6.38	38	na
	Cse3	112	135	7.58	5.65	111	na
	Cse4	135	238	7.63	3.75	79	79
	2Aseb	238	250	7.81	3.45	79	38
BC4 Low	Oa	0	5				
	A	5	9.5				
	CA	9.5	17				
	Cg	17	25				
	Ab	25	26				
	C'g	26	28				
	A'b	28	30				
	C'g	30	46				
	Cse1	46	67	6.59	3.48	8	0
	Cse2	67	89	6.60	3.20	8	0
	Cse3	89	130	7.38	3.88	8	8
	C'''g	130	180	7.60	8.01	28	na
BC4 Mid	A	0	10				
	CA	10	22				
	C	22	43				
	Cg	43	45				
	ACb	45	71	5.97	5.28	8	na
	Cse	71	120	6.45	3.80	28	8
	C'g1	120	177	7.86	7.92	28	na
	C'g2	177	212	7.88	7.96	28	na
BC4 High	A	0	2.5				
	CA	2.5	10				
	C1	10	21				
	C2	21	32				
	Ab	32	38				
	ACb	38	43				
	C'	43	52				
	Cg1	52	70				
	Cg2	70	76	5.96	5.62	8	na
	Cg3	76	113	6.43	6.29	28	na
	Cg4	113	136	6.35	6.44	0	na
	AC'b	136	156	6.23	5.33	0	na
	C'g1	156	182	6.75	5.91	8	na
	C'g2	182	198	8.29	8.25	43	na
BC5 Low	Oe	0	13				

Site	Horizon	Upper Depth	Lower Depth	Field pH	Final Oxidized pH	Time to reach final pH	Time for pH to drop below 4
		------ cm ------				-------- days --------	
BC5 Low	A	13	20				
	Cg1	20	30	5.02	5.37	28	na
	Cg2	30	56	6.00	6.08	28	na
	Cg3	56	82	6.35	4.04	28	na
	2Ab1	82	99	6.62	5.50	28	na
	2Ab2	99	109	6.48	5.28	28	na
	3Cg	109	157	6.84	6.19	8	na
	3Cse1	157	177	6.87	3.10	8	0
	3Cse2	177	198	6.84	3.31	8	0
BC5 Mid	Oe	0	13				
	A	13	24				
	C1	24	51				
	C2	51	65				
	C3	65	92				
	Cse	92	119	6.12	4.02	28	na
	2Ab1	119	131	6.59	4.83	28	na
	2Ab2	131	136	6.54	4.47	28	na
	3Ab3	136	152	6.64	4.11	76	na
	3ACb	152	170	6.80	5.66	28	na
	3Cg	170	196	6.54	4.60	28	na
BC5 High	Oi	0	2.5				
	Oe	2.5	6				
	AE	6	19				
	A	19	30				
	Bw1	30	77				
	Bw2	77	98				
	Bw3	98	145				
	C	145	171				
	Cse	171	198	5.41	3.39	0	0
	2Ab1	198	216	6.38	5.69	76	na
	3Ab2	216	232	6.35	4.54	76	na
	3Cg	232	268	6.83	4.26	76	na
BC6 Low	Oe	0	2				
	Oa	2	5				
	A1	5	7				
	A2	7	9.5				
	2Cg1	9.5	20				
	2Cg2	20	33				
	2Cg3	33	78	4.39	4.07	28	na
	2Cg4	78	93	6.46	4.34	76	na
	3Ab	93	110	6.50	5.69	76	na

Site	Horizon	Upper Depth	Lower Depth	Field pH	Final Oxidized pH	Time to reach final pH	Time for pH to drop below 4
		------ cm ------				-------- days --------	
BC6 Low	3Oa	110	117	5.76	4.53	76	na
	3A'b1	117	128	5.76	4.86	76	na
	3A'b2	128	142	5.51	4.35	76	na
	3Aseb	142	168	4.69	3.09	28	0
	4Cse	168	210	4.17	3.78	28	8
BC6 Mid	Oi	0	5				
	Oe	5	10				
	A1	10	12				
	2A2	12	16				
	2Cg	16	56	6.88	6.92	0	na
	2Cse	56	117	7.19	3.41	28	0
	3Aseb	117	134	7.01	3.24	28	0
	3Oase	134	146	6.88	2.48	8	0
	3A'seb1	146	156	6.94	3.49	8	0
	3A'seb2	156	171	7.00	3.18	28	0
	4Cse	171	207	7.13	2.99	28	0
BC6 High	Oe	0	3				
	A	3	10				
	Bw/Bhs	10	33				
	C	33	47				
	Cse1	47	66	6.30	5.00	28	na
	Cse2	66	138	6.57	3.25	8	0
	2Aseb	138	157	6.97	3.05	8	0
	2Oase	157	174	6.80	2.93	8	0
	2A'seb1	174	185	6.80	3.95	8	8
	2A'seb2	185	198	7.08	2.97	8	0
	3Cse	198	220	7.25	3.12	28	0
OW1 Low	A	0	1.5				
	CA	1.5	9				
	C	9	20				
	Cg	20	23				
	Ab	23	26				
	C'g	26	29	4.85	4.27	8	na
	Aseb	29	32	5.32	3.29	42	0
	Cse	32	71	6.05	3.74	42	21
	C"g1	71	131	8.21	7.45	128	na
	C"g2	131	164	7.77	7.71	0	na
	ACb	164	185	8.37	7.56	0	na
	C'"g	185	218	8.43	7.71	142	na
OW1 Mid	CA	0	16				
	C	16	39				

Site	Horizon	Upper Depth	Lower Depth	Field pH	Final Oxidized pH	Time to reach final pH	Time for pH to drop below 4
		------ cm ------				-------- days --------	
OW1 Mid	Cg	39	53				
	Aseb	53	57	5.18	3.59	128	8
	Cse1	57	82	5.02	3.49	42	0
	Cse2	82	122	5.69	4.02	42	na
	C'g1	122	168	8.47	8.34	0	na
	C'g2	168	198	8.22	8.72	0	na
	C'g3	198	245	8.53	8.29	0	na
	2ACb	245	250	8.58	6.59	91	na
OW1 High	CA	0	5				
	C1	5	31				
	C2	31	44				
	Cg	44	58				
	Ab	58	62				
	C'g1	62	83	5.99	4.20	69	na
	C'g2	83	144	6.56	4.10	69	na
	C'g3	144	161	8.17	8.58	91	na
	C'g4	161	183	8.41	8.82	114	na
	C'g5	183	198	8.28	8.80	114	na
OW2 Low	Oa	0	2.5				
	CA	2.5	7				
	Cg	7	18				
	Cse1	18	31	7.10†	4.21	186	na
	Cse2	31	79	7.16†	3.96	194	194
	Cse3	79	129	8.24†	3.84	194	194
	C'g	129	175	8.57†	6.30	114	na
	Ab	175	198	7.34†	6.14	114	na
OW2 Mid	Oa	0	2.5				
	CA	2.5	7				
	C	7	13				
	Cg1	13	27				
	Cg2	27	60	6.25	4.76	29	na
	Cg3	60	101	7.37	4.14	21	na
	Cg4	101	147	7.62	4.16	8	na
	Cg5	147	192	7.61	6.02	114	na
	Aseb	192	228	7.72	3.43	194	103
OW2 High	CA	0	16				
	C1	16	33				
	2C2	33	43				
	2C3	43	52				
	2Cg	52	107				
	2Cse1	107	151	7.11	4.02	142	0

Site	Horizon	Upper Depth	Lower Depth	Field pH	Final Oxidized pH	Time to reach final pH	Time for pH to drop below 4
		------ cm ------				-------- days --------	
OW2 High	2Cse2	151	185	7.22	3.92	103	103
	2C'g	185	218	7.71	6.46	114	0
OW3 Low	Oa1	0	3				
	Oa2	3	6				
	CA	6	14				
	Cg1	14	23	7.93	7.56	0	na
	Cg2	23	103	7.54	7.86	0	na
	Cg3	103	138	7.98	7.47	0	na
	Cg4	138	174	8.45	7.41	114	na
	Ab	174	238	8.27	7.24	142	na
OW3 Mid	A1	0	1.5				
	A2	1.5	6				
	CA	6	15				
	Cg1	15	31				
	Cg2	31	77	7.78	8.70	8	na
	Cg3	77	114	8.11	8.39	91	na
	Cse1	114	139	7.98	8.21	91	na
	Cse2	139	154	8.07	8.22	0	na
	Cse3	154	174	8.27	6.96	128	na
	Aseb	174	199	8.21	2.98	103	42
	C'se	199	226	8.21	2.96	103	0
	C'g	226	250	8.40	5.33	142	na
OW3 High	AC	0	3				
	Bw1	3	11.5				
	Bw2	11.5	36				
	Bw3	36	54				
	Bw4	54	74				
	2Bw5	74	80				
	2Cg	80	123	7.17	6.64	114	na
	2Cg/Ab	123	158	7.88	8.54	0	na
	2C'g1	158	184	7.81	7.84	8	na
	2C'g2	184	198	7.97	7.74	114	na
OW4 Low	A1	0	1.5				
	A2	1.5	3.5				
	AC	3.5	6				
	C	6	11				
	Cg1	11	23				
	Cg2	23	28				
	Ab	28	29.5				
	C'g	29.5	32	6.78	5.01	103	na
	A'b	32	35	6.68	4.88	128	na

Site	Horizon	Upper Depth	Lower Depth	Field pH	Final Oxidized pH	Time to reach final pH	Time for pH to drop below 4
		------ cm ------				-------- days --------	
OW4 Low	C"g	35	42	6.67	4.16	128	na
	Cse1	42	44	6.63	3.71	128	8
	Cse2	44	78	6.54	3.45	103	0
	C"'g	78	164	7.56	4.51	142	na
	A"b	164	183	7.37	5.13	128	na
	C""g	183	205	7.84	6.11	114	na
OW4 Mid	A	0	2				
	C1	2	25				
	C2	25	32				
	Cg	32	34				
	Ab	34	36				
	C'g	36	39				
	A'b	39	42				
	Cse	42	52	6.71	3.95	42	29
	C"g1	52	147	7.44	4.39	128	na
	C"g2	147	200	7.75	6.54	142	na
	C"g3	200	220	7.62	6.27	142	na
OW4 High	C	0	24				
	Ab1	24	25				
	Ab2	25	29				
	Cg1	29	38				
	Cg2	38	49				
	Cg3	49	68				
	Aseb	68	73	6.95	3.54	128	21
	Cse1	73	90	7.08	3.67	29	0
	Cse2	90	113	6.54	3.50	0	0
	C'g1	113	137	7.19	4.50	91	na
	C'g2	137	165	7.56	5.85	142	na
	C'g3	165	198	7.45	5.57	114	na

[†] pH was measured on air dried soil (not field moist samples)

APPENDIX G: CARBON AND NITROGEN STOCKS

		Soil Organic Carbon†			Soil Total Nitrogen†		
Site	Rep	Total	Mineral Horizons	Organic Horizons	Total	Mineral Horizons	Organic Horizons
		---------- kg C m^{-2} ----------			---------- kg N m^{-2} ----------		
BC1 Low	1	1.536	1.536	0.000	0.084	0.084	0.000
	2	1.374	1.374	0.000	0.079	0.079	0.000
	3	1.206	1.206	0.000	0.068	0.068	0.000
BC1 Mid	1	1.393	1.393	0.000	0.047	0.047	0.000
	2	1.258	0.819	0.439	0.043	0.028	0.015
	3	1.093	0.731	0.362	0.045	0.033	0.012
BC1 High	1	0.170	0.170	0.000	0.000	0.000	0.000
	2	0.303	0.303	0.000	0.000	0.000	0.000
	3	0.487	0.487	0.000	0.000	0.000	0.000
BC2 Low	1‡	1.811	1.014	0.796	0.077	0.031	0.047
	2‡	2.627	0.991	1.636	0.109	0.033	0.076
	3‡	2.121	0.810	1.312	0.080	0.017	0.063
BC2 Mid	1	2.200	0.772	1.428	0.065	0.011	0.053
	2	2.591	0.635	1.955	0.100	0.016	0.084
	3	1.441	0.651	0.790	0.054	0.016	0.038
BC2 High	1	0.521	0.521	0.000	0.007	0.007	0.000
	2	0.320	0.320	0.000	0.002	0.002	0.000
	3	0.589	0.589	0.000	0.000	0.000	0.000
BC3 Low	1	2.450	0.653	1.797	0.141	0.041	0.100
	2	1.643	1.035	0.608	0.102	0.072	0.030
	3	2.428	2.428	0.000	0.130	0.130	0.000
BC3 Mid	1	0.872	0.872	0.000	0.041	0.041	0.000
	2	1.182	1.182	0.000	0.061	0.061	0.000
	3	0.755	0.755	0.000	0.021	0.021	0.000
BC3 High	1	0.871	0.871	0.000	0.032	0.032	0.000
	2	1.013	1.013	0.000	0.016	0.016	0.000
	3	1.004	1.004	0.000	0.048	0.048	0.000
BC4 Low	1‡	6.993	4.494	2.498	0.428	0.264	0.164
	2‡	6.070	6.070	0.000	0.357	0.357	0.000
	3‡	5.175	5.175	0.000	0.303	0.303	0.000
BC4 Mid	1‡	2.488	2.488	0.000	0.139	0.139	0.000
	2‡	3.020	3.020	0.000	0.155	0.155	0.000
	3‡	2.785	2.785	0.000	0.120	0.120	0.000
BC4 High	1‡	1.583	1.583	0.000	0.061	0.061	0.000
	2‡	1.540	1.540	0.000	0.046	0.046	0.000
	3‡	1.221	1.221	0.000	0.048	0.048	0.000
BC5 Low	1	9.902	1.373	8.529	0.421	0.068	0.353
	2	8.014	1.228	6.785	0.369	0.059	0.310
	3	8.263	1.610	6.653	0.356	0.070	0.286

		Soil Organic Carbon[†]			Soil Total Nitrogen[†]		
Site	Rep	Total	Mineral Horizons	Organic Horizons	Total	Mineral Horizons	Organic Horizons
		---------- kg C m^{-2} ----------			---------- kg N m^{-2} ----------		
BC5 Mid	1	9.962	2.226	7.736	0.281	0.064	0.218
	2	11.436	2.547	8.889	0.329	0.081	0.248
	3	9.362	1.935	7.427	0.285	0.067	0.218
BC5 High	1	2.739	1.574	1.165	0.165	0.136	0.029
	2	3.331	1.980	1.351	0.113	0.080	0.032
	3	2.121	2.121	0.000	0.063	0.063	0.000
BC6 Low	1	4.863	2.351	2.512	0.308	0.157	0.151
	2	4.752	2.159	2.593	0.318	0.146	0.172
	3	5.444	3.493	1.951	0.337	0.219	0.118
BC6 Mid	1	7.086	1.895	5.191	0.296	0.094	0.202
	2	8.307	2.243	6.064	0.363	0.131	0.232
	3	7.662	2.281	5.381	0.333	0.124	0.209
BC6 High	1	3.723	3.190	0.533	0.136	0.122	0.015
	2	3.685	2.531	1.154	0.127	0.099	0.028
	3	5.037	3.116	1.921	0.195	0.132	0.064
OW1 Low	1[‡]	1.788	1.788	0.000	0.072	0.072	0.000
	2[‡]	1.862	1.862	0.000	0.093	0.093	0.000
	3[‡]	2.034	2.034	0.000	0.107	0.107	0.000
OW1 Mid	1[‡]	1.106	1.106	0.000	0.023	0.023	0.000
	2[‡]	0.998	0.998	0.000	0.032	0.032	0.000
	3[‡]	0.961	0.961	0.000	0.027	0.027	0.000
OW1 High	1	0.550	0.550	0.000	0.010	0.010	0.000
	2	0.554	0.554	0.000	0.008	0.008	0.000
	3	0.430	0.430	0.000	0.006	0.006	0.000
OW2 Low	1	2.259	0.742	1.517	0.103	0.027	0.076
	2	2.876	0.800	2.076	0.145	0.032	0.113
	3	2.176	0.888	1.288	0.135	0.046	0.089
OW2 Mid	1	2.199	1.443	0.756	0.116	0.083	0.032
	2	2.553	1.693	0.860	0.146	0.105	0.041
	3	2.208	1.345	0.864	0.121	0.085	0.036
OW2 High	1	0.444	0.444	0.000	0.013	0.013	0.000
	2	0.398	0.398	0.000	0.008	0.008	0.000
	3	0.323	0.323	0.000	0.006	0.006	0.000
OW3 Low	1	2.554	1.437	1.117	0.137	0.014	0.123
	2	2.320	0.573	1.747	0.145	0.027	0.118
	3	2.834	0.638	2.196	0.136	0.018	0.118
OW3 Mid	1	1.307	1.307	0.000	0.088	0.088	0.000
	2	0.867	0.867	0.000	0.051	0.051	0.000
	3	1.533	1.533	0.000	0.085	0.085	0.000
OW3 High	1	0.393	0.393	0.000	0.018	0.018	0.000
	2	0.289	0.289	0.000	0.020	0.020	0.000

		Soil Organic Carbon[†]			Soil Total Nitrogen[†]		
Site	Rep	Total	Mineral Horizons	Organic Horizons	Total	Mineral Horizons	Organic Horizons
		---------- kg C m^{-2} ----------			---------- kg N m^{-2} ----------		
OW3 High	3	0.421	0.421	0.000	0.018	0.018	0.000
OW4 Low	1[‡]	1.494	1.494	0.000	0.054	0.054	0.000
	2[‡]	1.502	1.502	0.000	0.068	0.068	0.000
	3[‡]	1.743	1.743	0.000	0.059	0.059	0.000
OW4 Mid	1[‡]	2.550	2.550	0.000	0.100	0.100	0.000
	2[‡]	1.952	1.952	0.000	0.073	0.073	0.000
	3[‡]	2.020	2.020	0.000	0.090	0.090	0.000
OW4 High	1[‡]	1.041	1.041	0.000	0.043	0.043	0.000
	2[‡]	1.506	1.506	0.000	0.063	0.063	0.000
	3[‡]	0.991	0.991	0.000	0.055	0.055	0.000

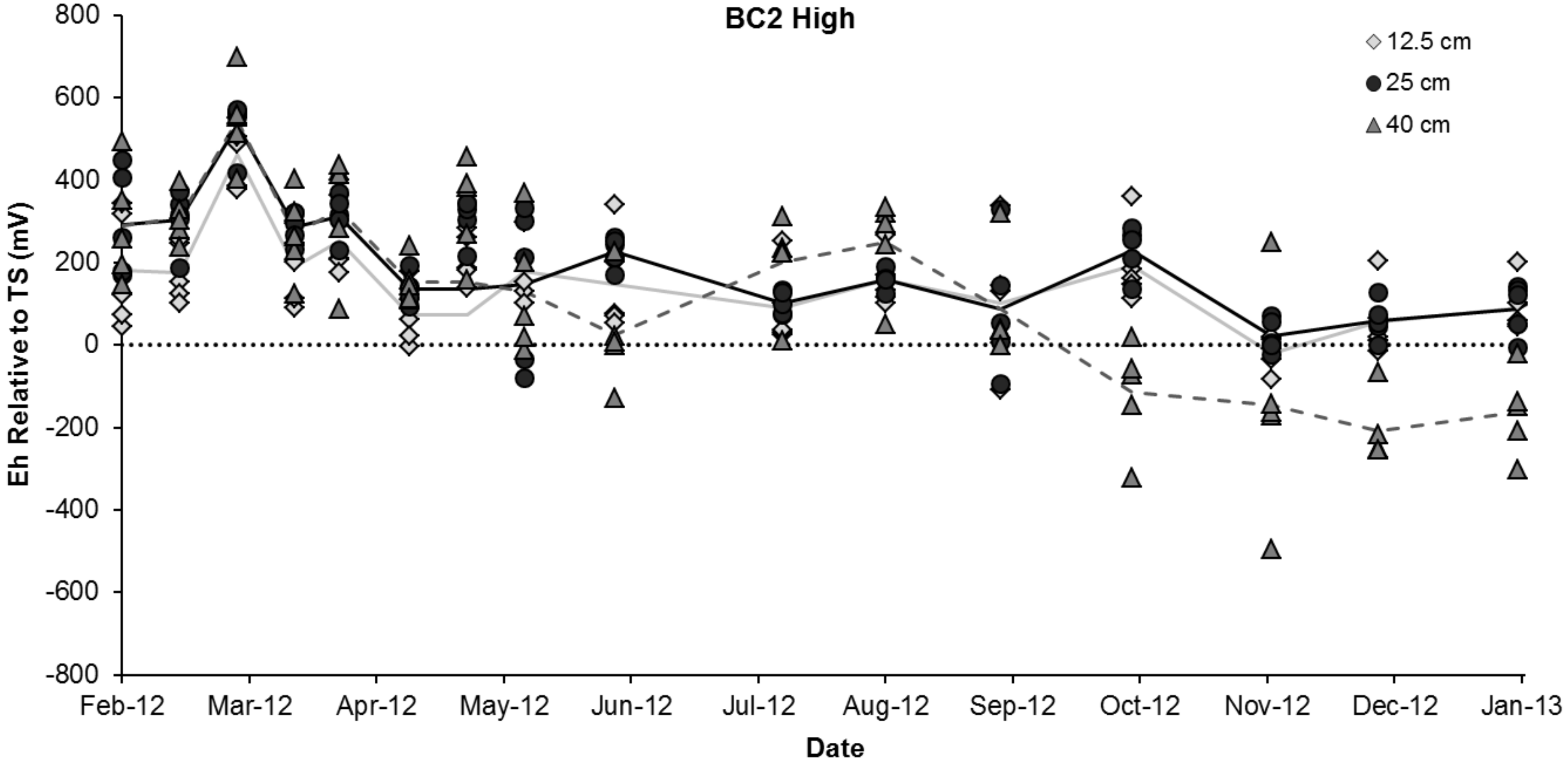
[†] Carbon and nitrogen stocks were measured to a depth of 50 cm on three replicate cores at each transect position.

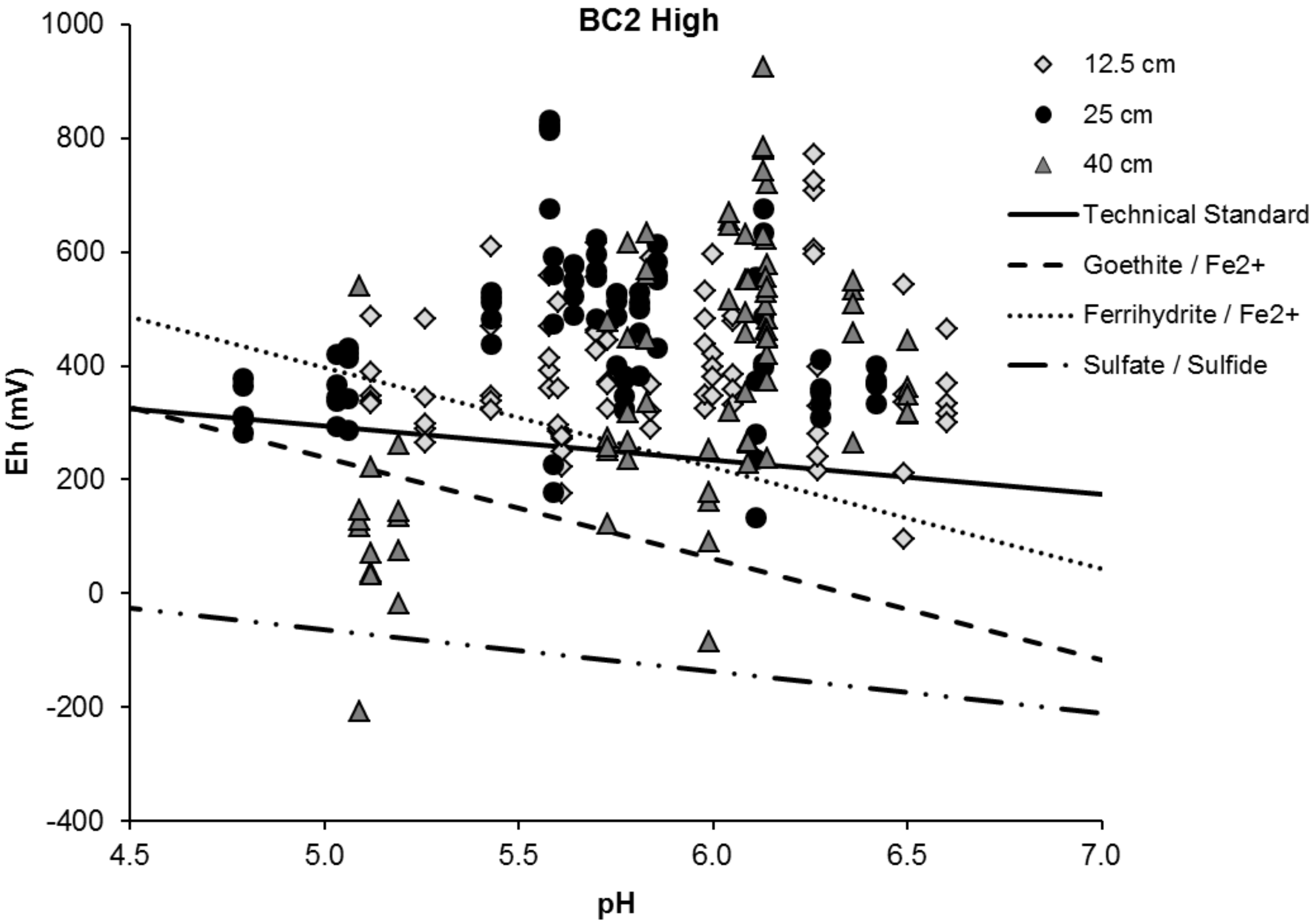
[‡] Buried A horizon occurs within 50 cm of the soil surface and is included in calculations of carbon and nitrogen stocks.

APPENDIX H: REDOX POTENTIAL MEASUREMENTS

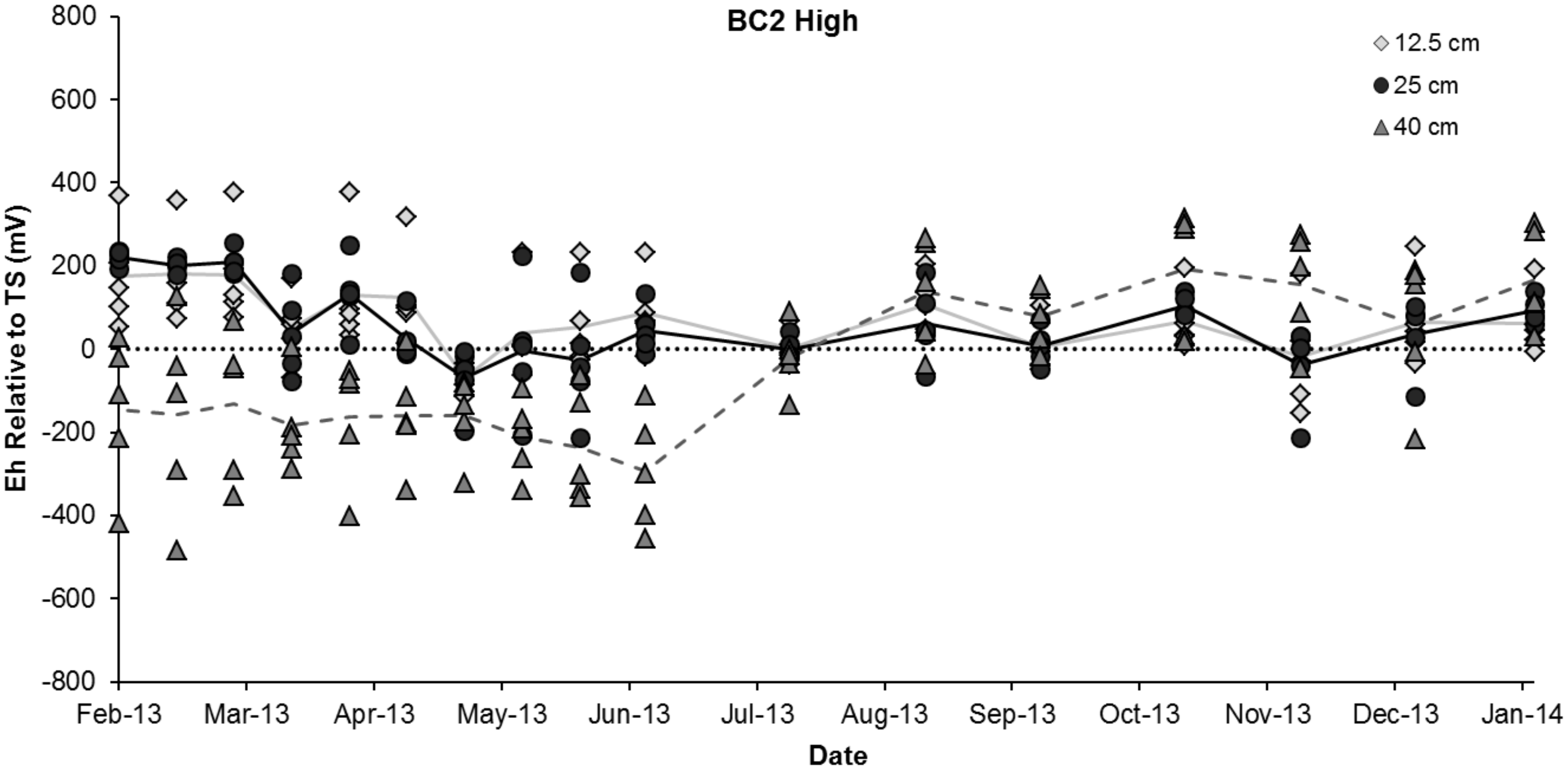
Redox potential (Eh) and pH were measured twice monthly (February through May) and once a month the remainder of the year. Measurements were made at depths of 12.5, 25, and 40 cm. Five replicate Eh measurements were made at each depth and are indicated by symbols; average Eh is indicated by the line.

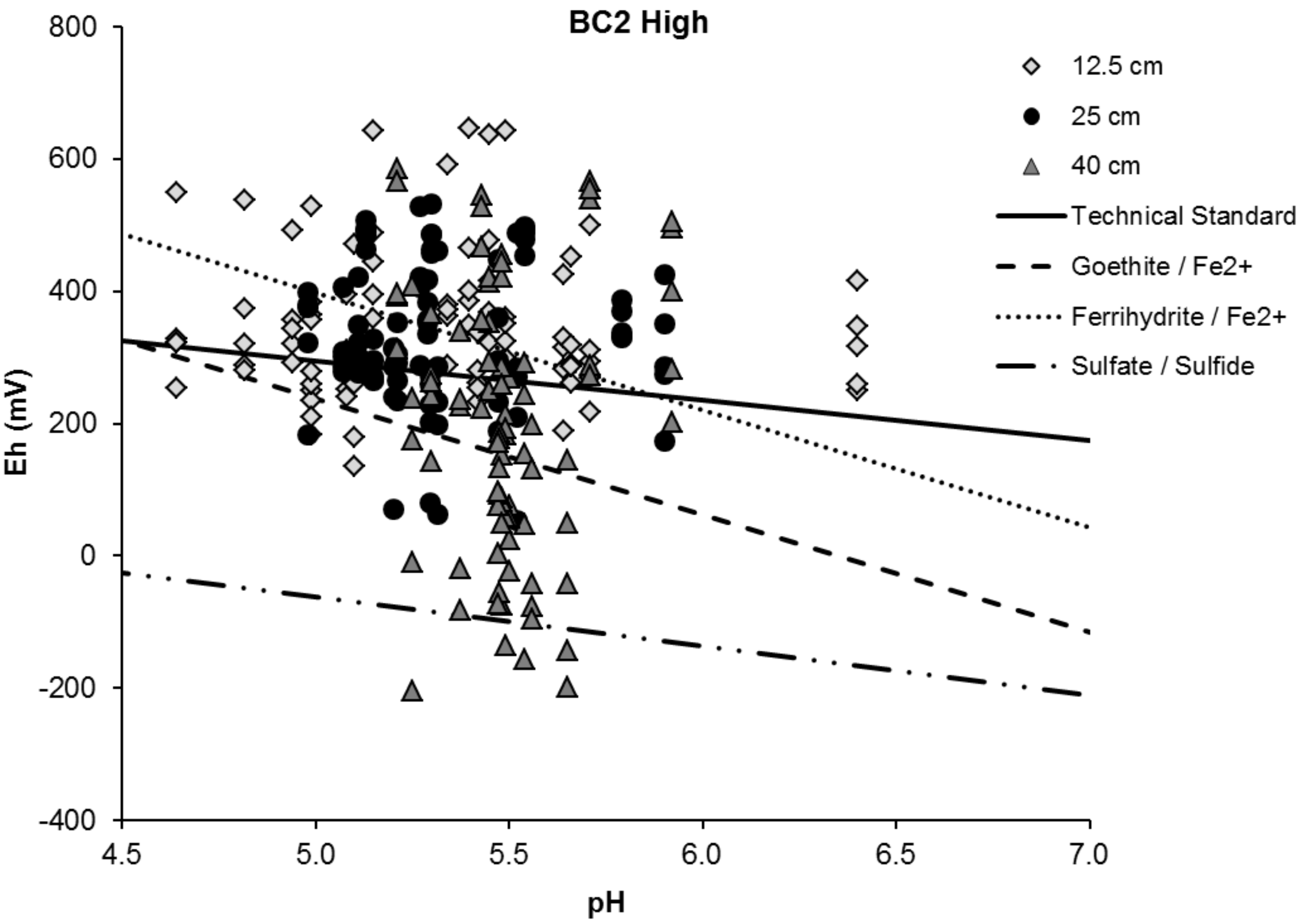
BC2 High: 2/9/2012 – 1/14/2013



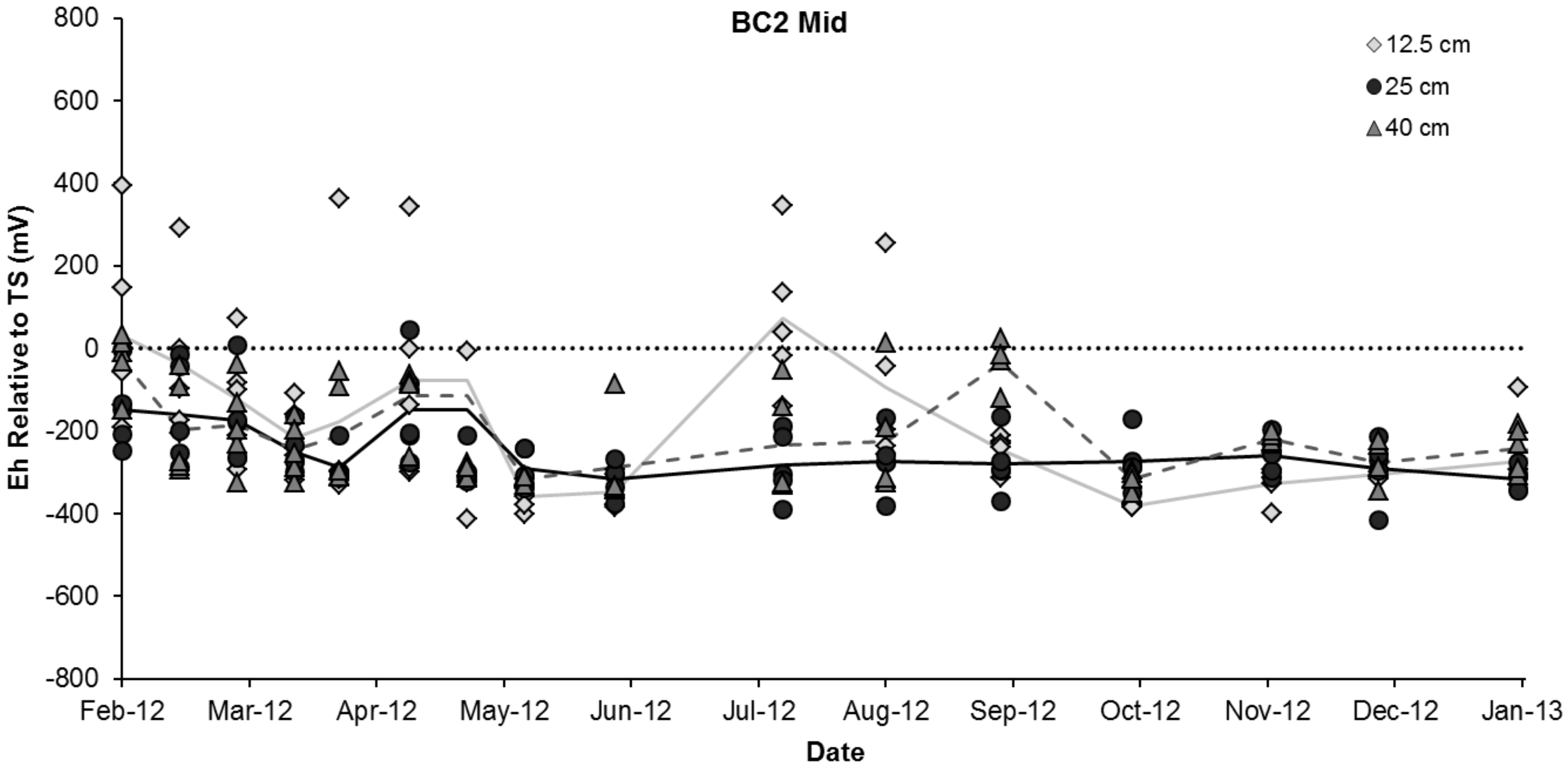

BC2 High
Eh (mV)
pH
1000
800
600
400
200
0
-200
-400
4.5
5.0
5.5
6.0
6.5
7.0
12.5 cm
25 cm
40 cm
Technical Standard
Goethite / Fe2+
Ferrihydrite / Fe2+
Sulfate / Sulfide

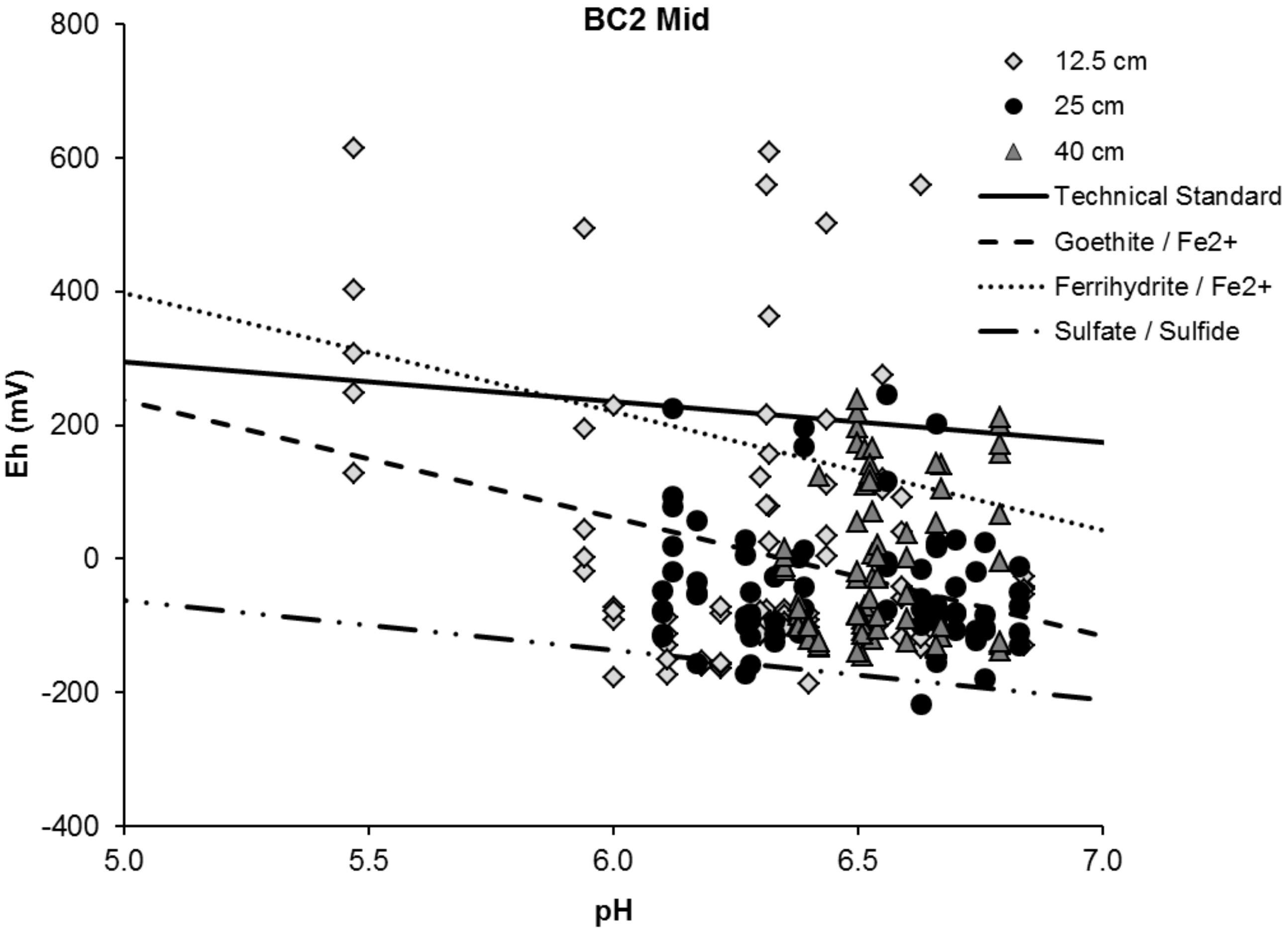
BC2 High: 2/5/2013 – 1/15/2014



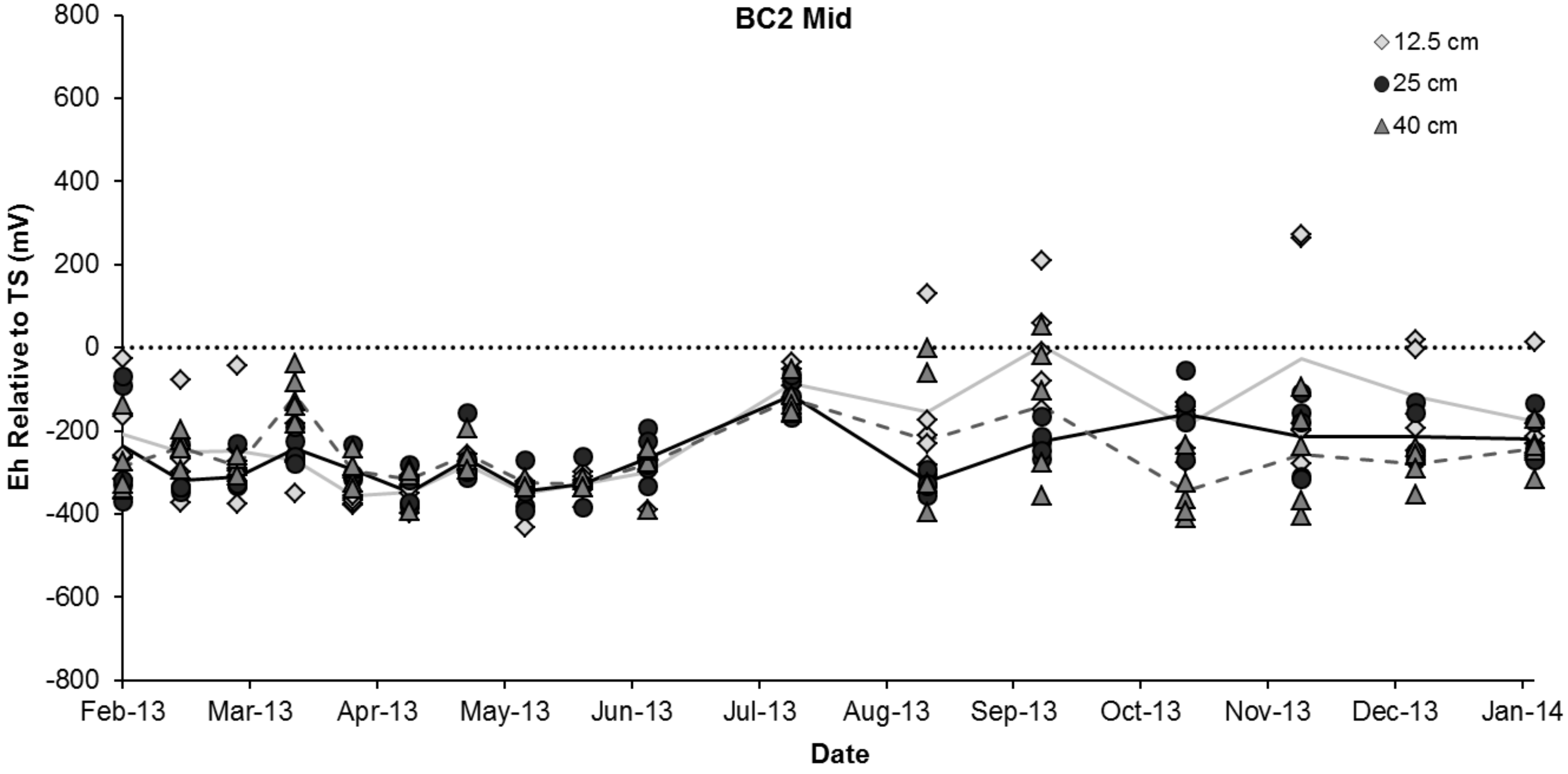

BC2 High
Eh (mV)
800
600
400
200
0
-200
-400
pH
4.5
5.0
5.5
6.0
6.5
7.0
12.5 cm
25 cm
40 cm
Technical Standard
Goethite / Fe2+
Ferrihydrite / Fe2+
Sulfate / Sulfide

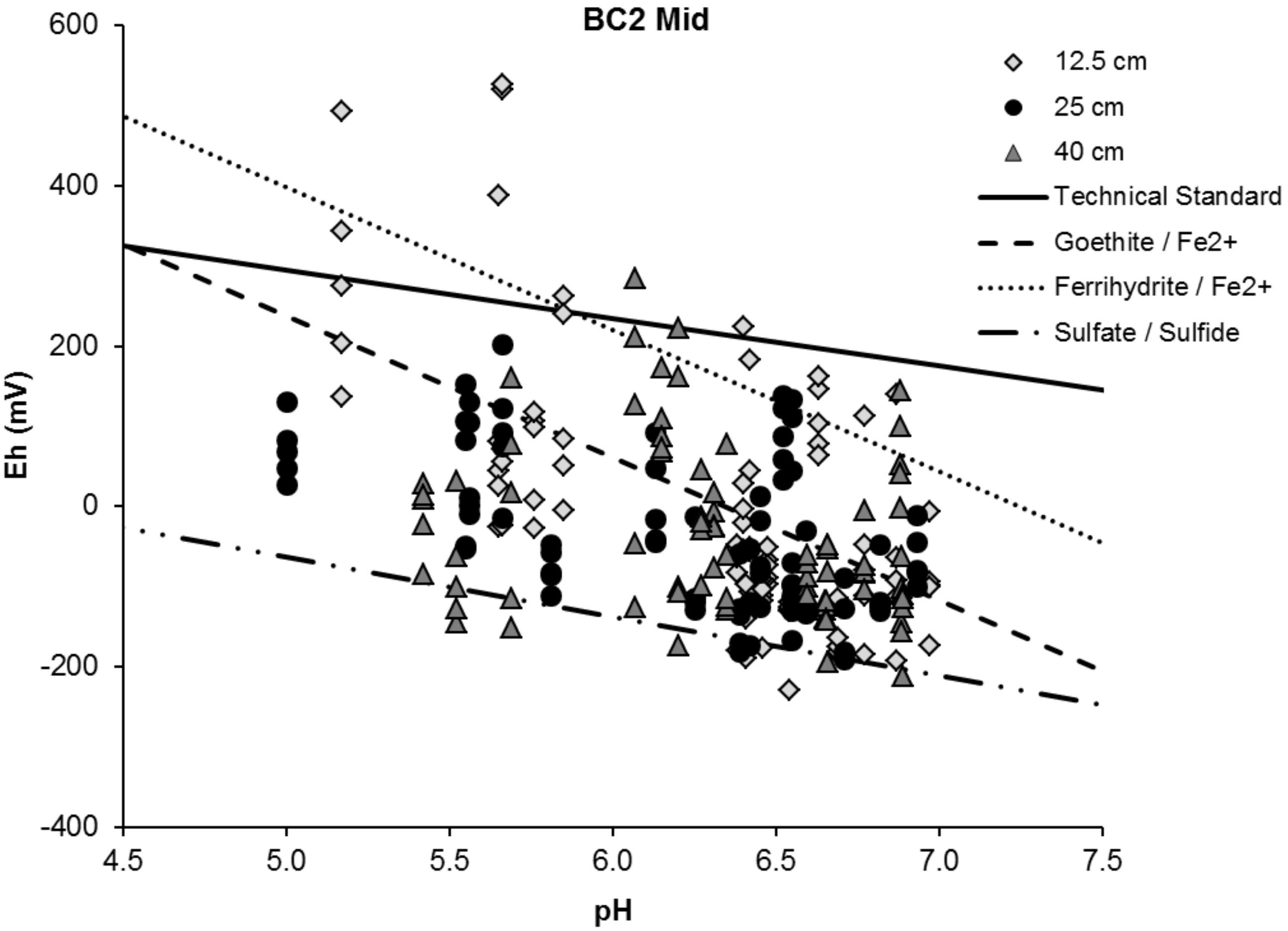
BC2 Mid: 2/9/2012 – 1/14/2013



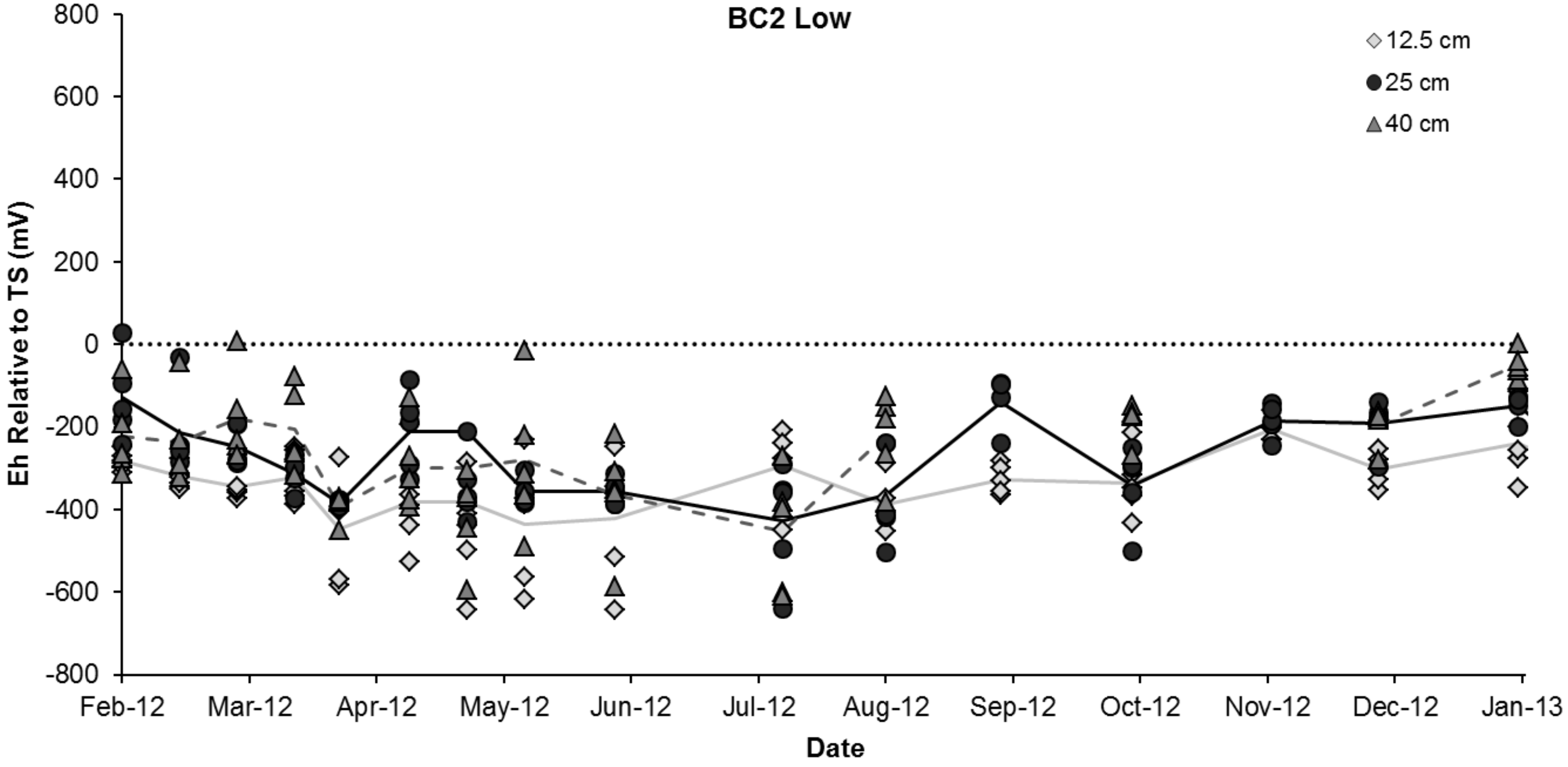

BC2 Mid
Eh (mV)
800
600
400
200
0
-200
-400
pH
5.0
5.5
6.0
6.5
7.0
◇ 12.5 cm
● 25 cm
▲ 40 cm
Technical Standard
Goethite / Fe2+
Ferrihydrite / Fe2+
Sulfate / Sulfide

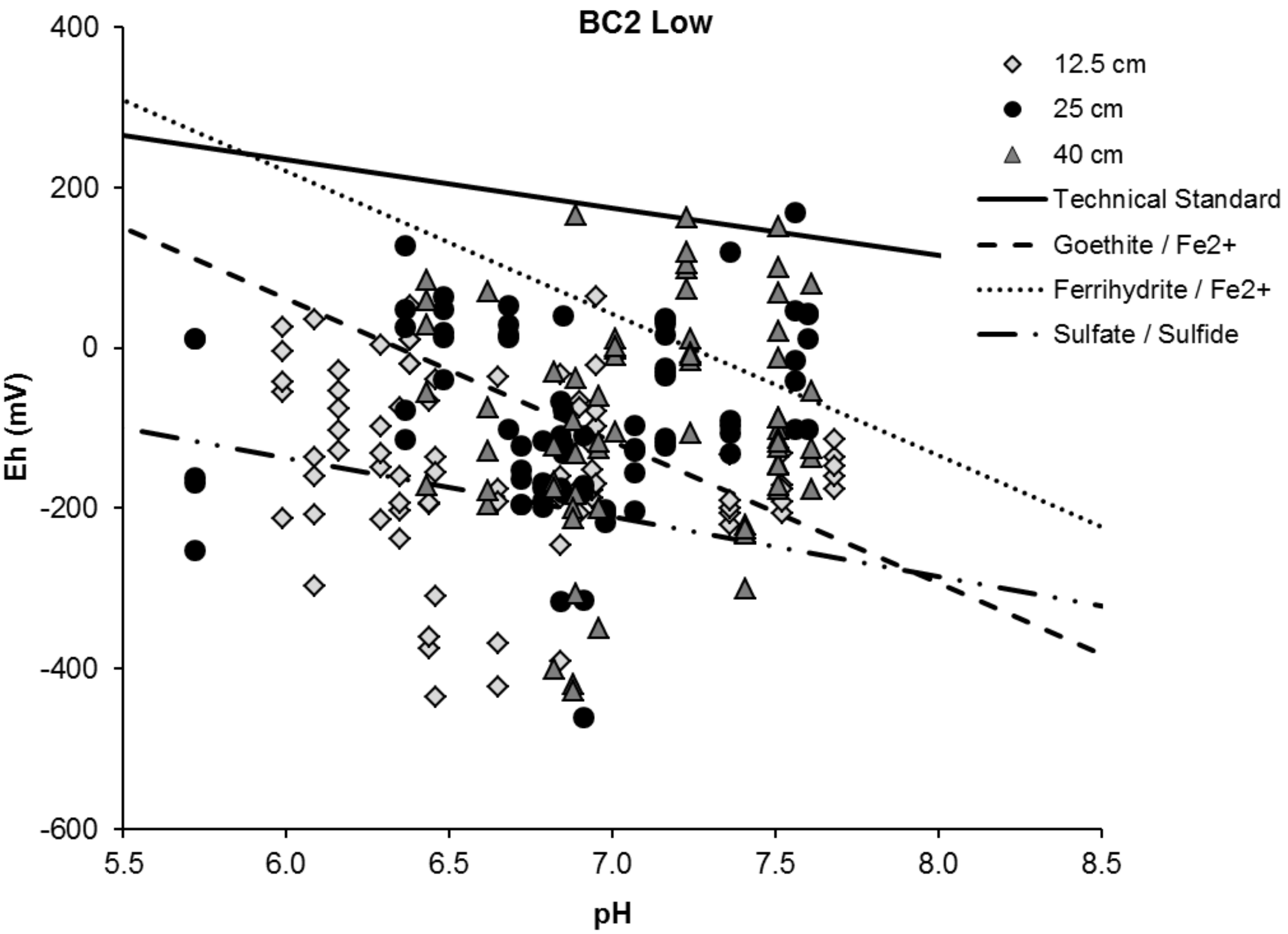
BC2 Mid: 2/5/2013 – 1/15/2014



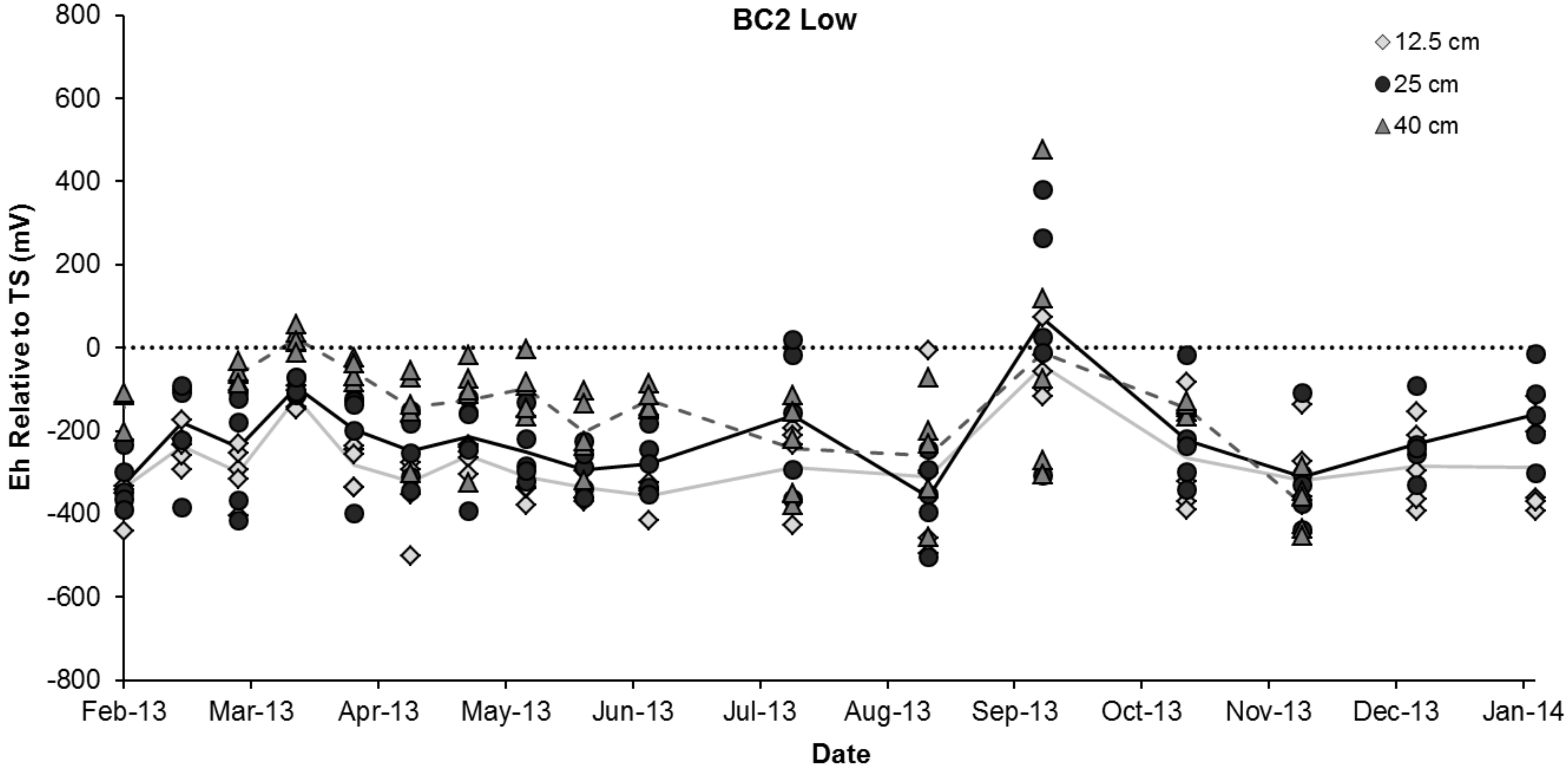

BC2 Mid
600
400
200
0
-200
-400
Eh (mV)
4.5
5.0
5.5
6.0
6.5
7.0
7.5
pH
◇ 12.5 cm
● 25 cm
▲ 40 cm
Technical Standard
Goethite / Fe2+
Ferrihydrite / Fe2+
Sulfate / Sulfide

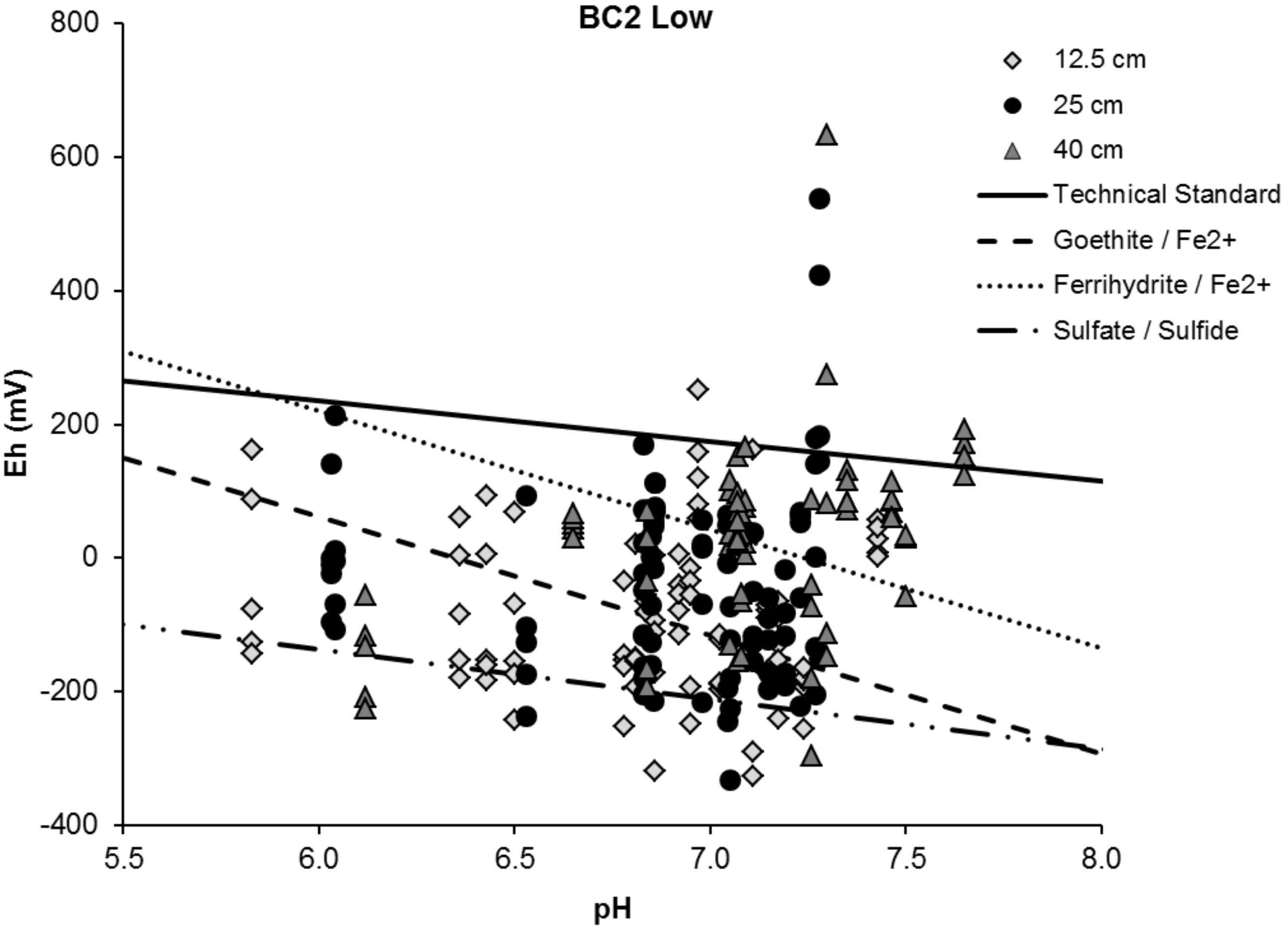
BC2 Low: 2/9/2012 – 1/14/2013



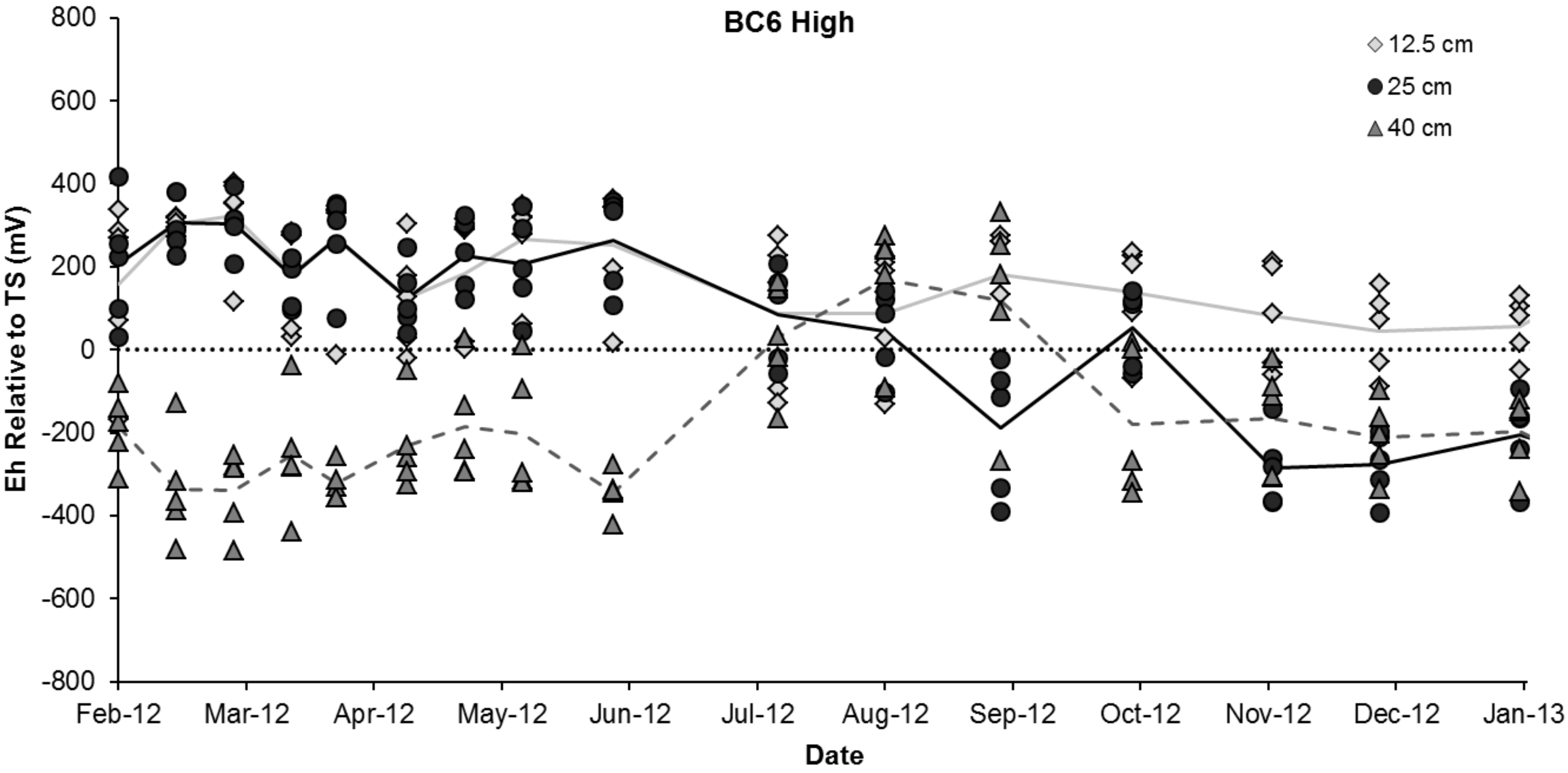

BC2 Low
400
200
0
-200
-400
-600
Eh (mV)
5.5
6.0
6.5
7.0
7.5
8.0
8.5
pH
◇ 12.5 cm
● 25 cm
▲ 40 cm
Technical Standard
Goethite / Fe2+
Ferrihydrite / Fe2+
Sulfate / Sulfide

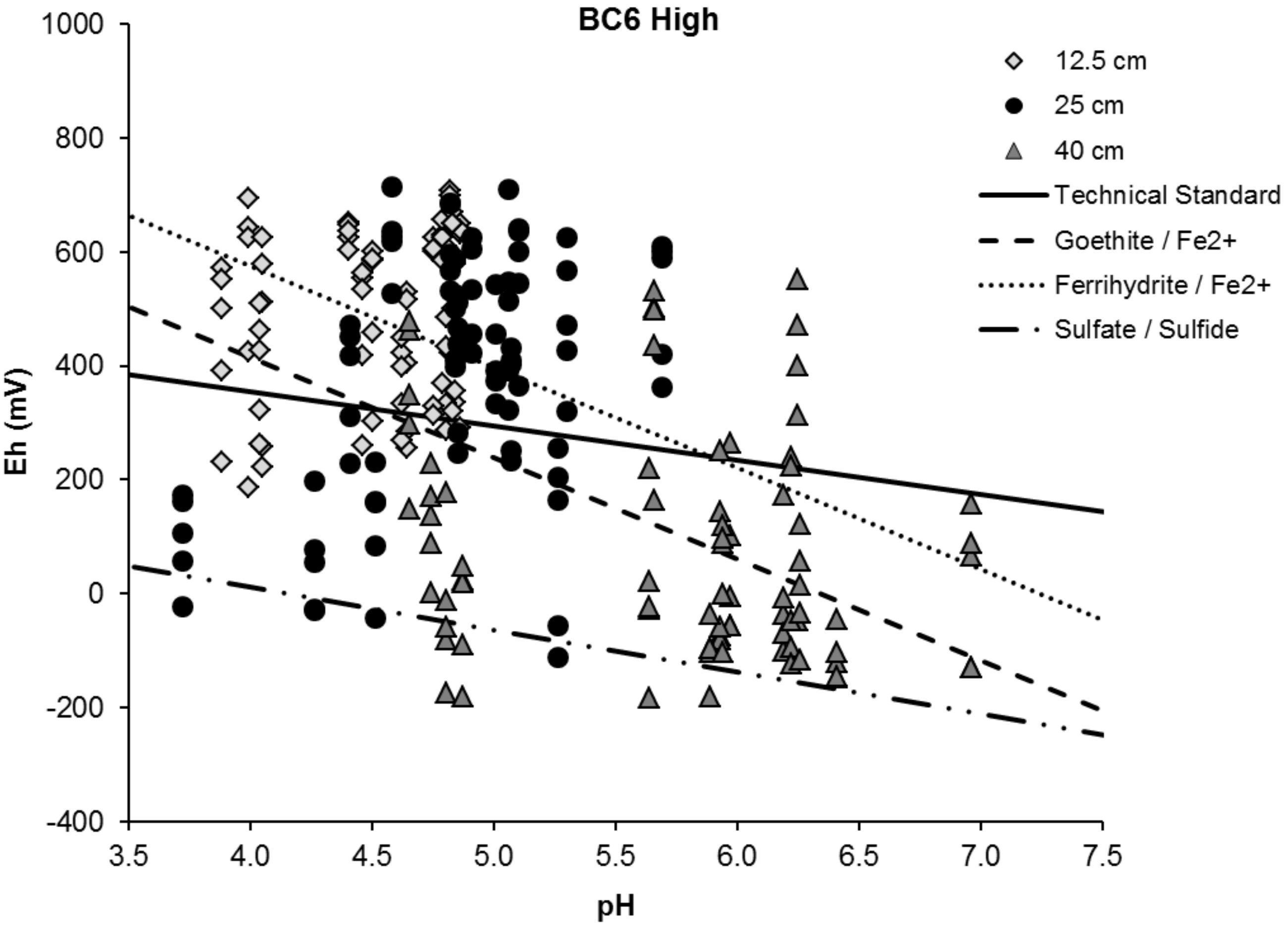
BC2 Low: 2/5/2013 – 1/15/2014



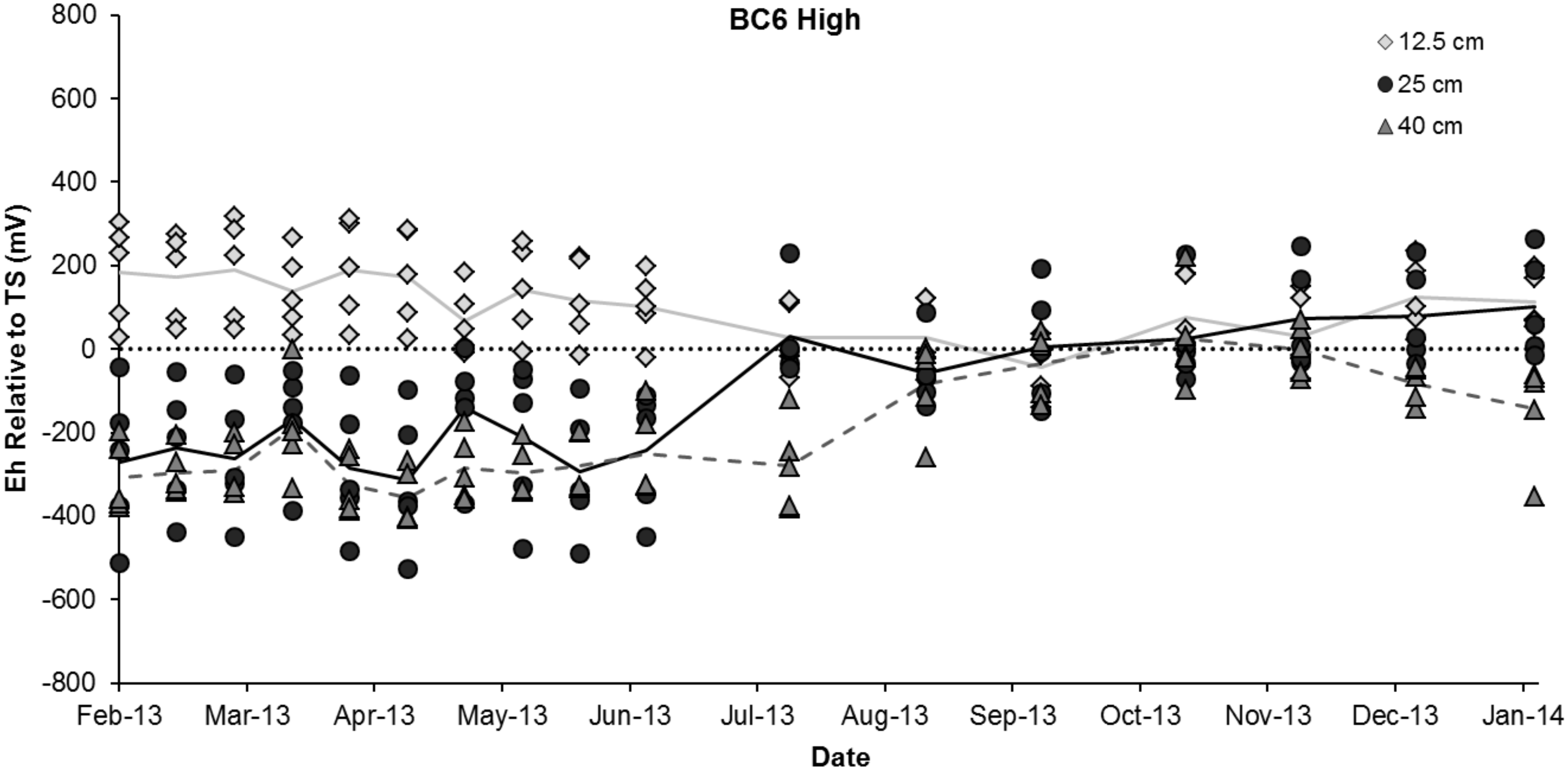

BC2 Low
800
600
400
200
0
-200
-400
Eh (mV)
5.5
6.0
6.5
7.0
7.5
8.0
pH
◇ 12.5 cm
● 25 cm
▲ 40 cm
Technical Standard
Goethite / Fe2+
Ferrihydrite / Fe2+
Sulfate / Sulfide

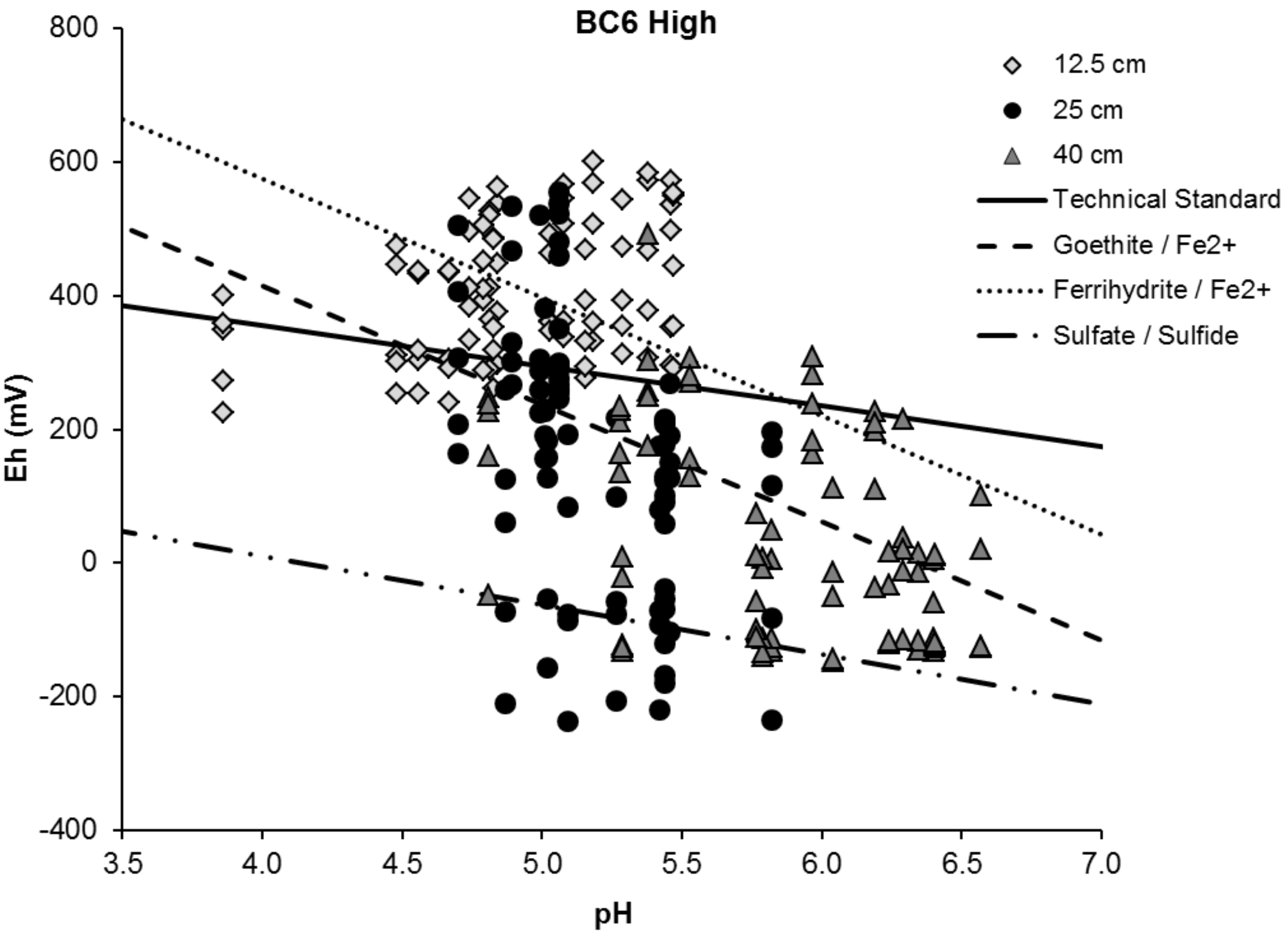
BC6 High: 2/9/2012 – 1/14/2013



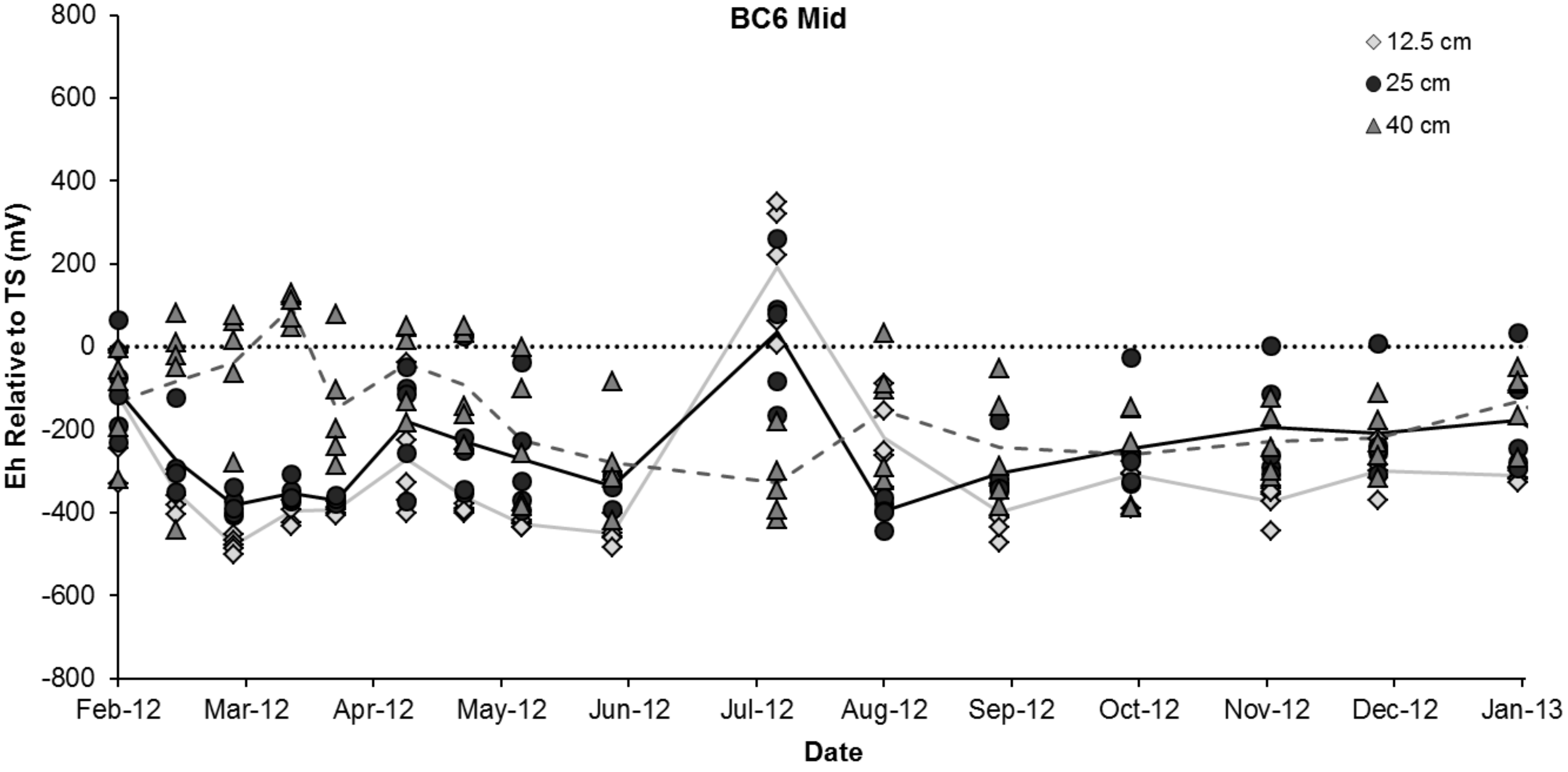

BC6 High
Eh (mV)
1000
800
600
400
200
0
-200
-400
pH
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
7.5
◇ 12.5 cm
● 25 cm
▲ 40 cm
Technical Standard
Goethite / Fe2+
Ferrihydrite / Fe2+
Sulfate / Sulfide

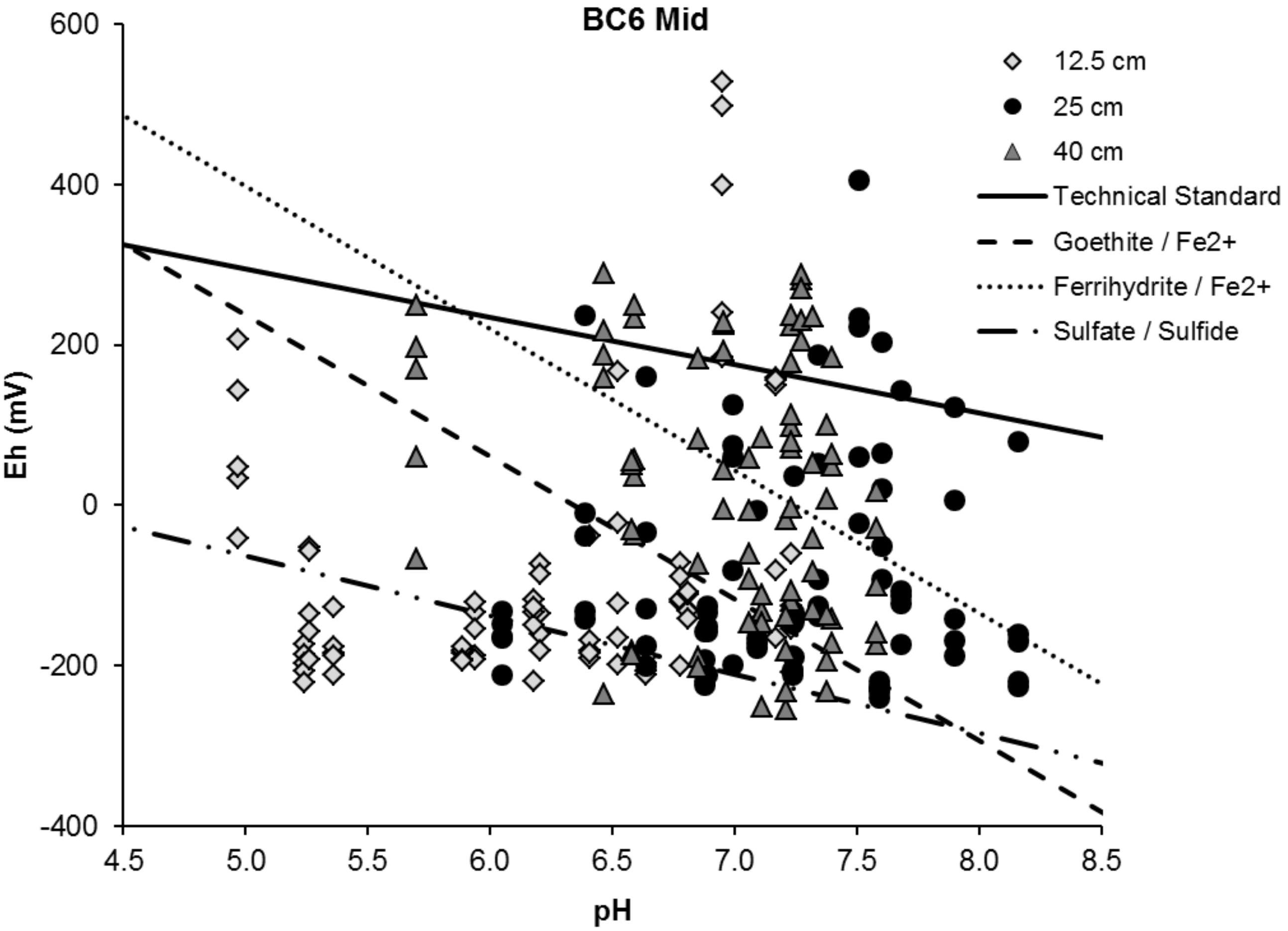
BC6 High: 2/5/2013 – 1/15/2014



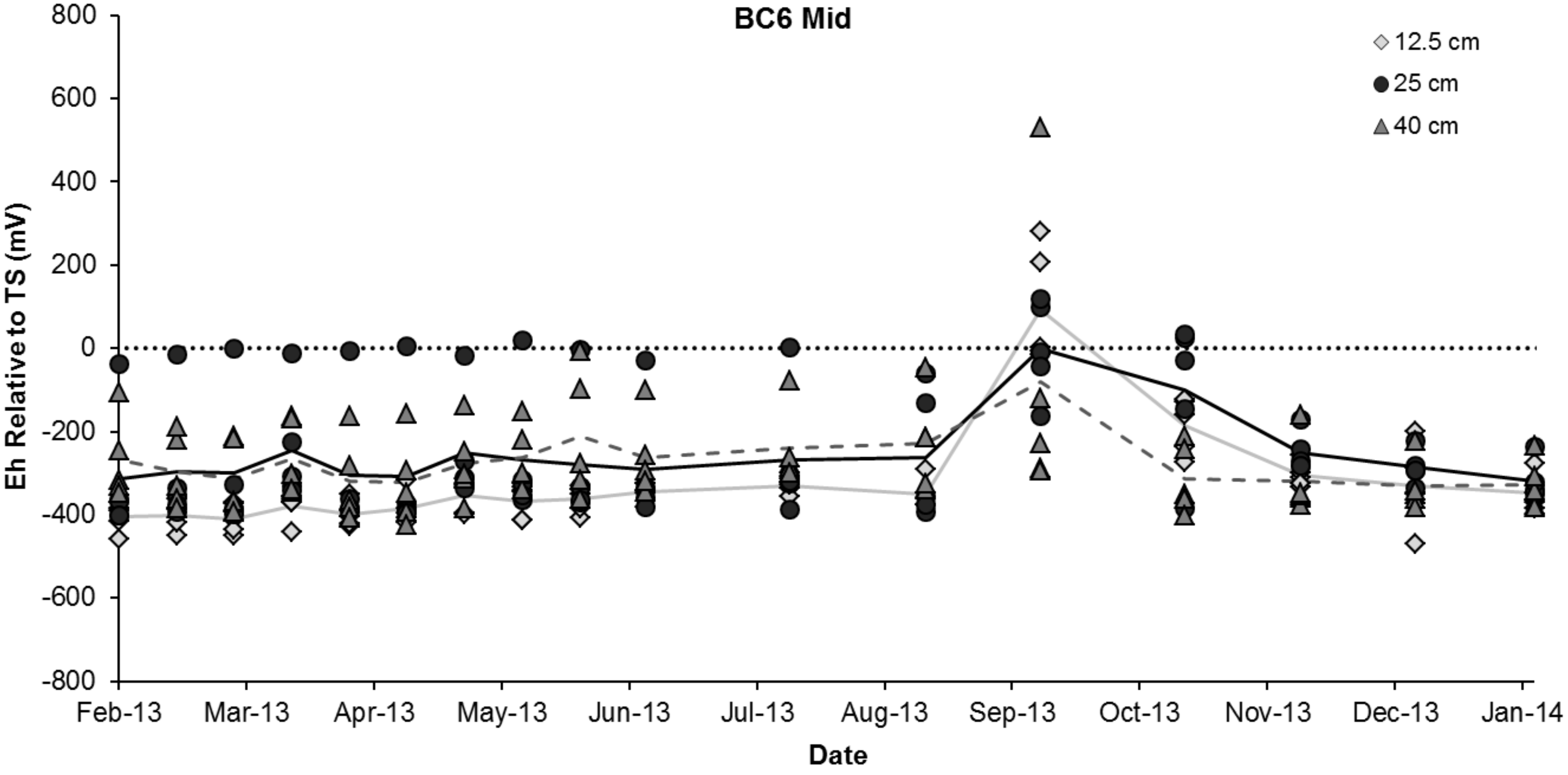

BC6 High
Eh (mV)
800
600
400
200
0
-200
-400
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
pH
12.5 cm
25 cm
40 cm
Technical Standard
Goethite / Fe2+
Ferrihydrite / Fe2+
Sulfate / Sulfide

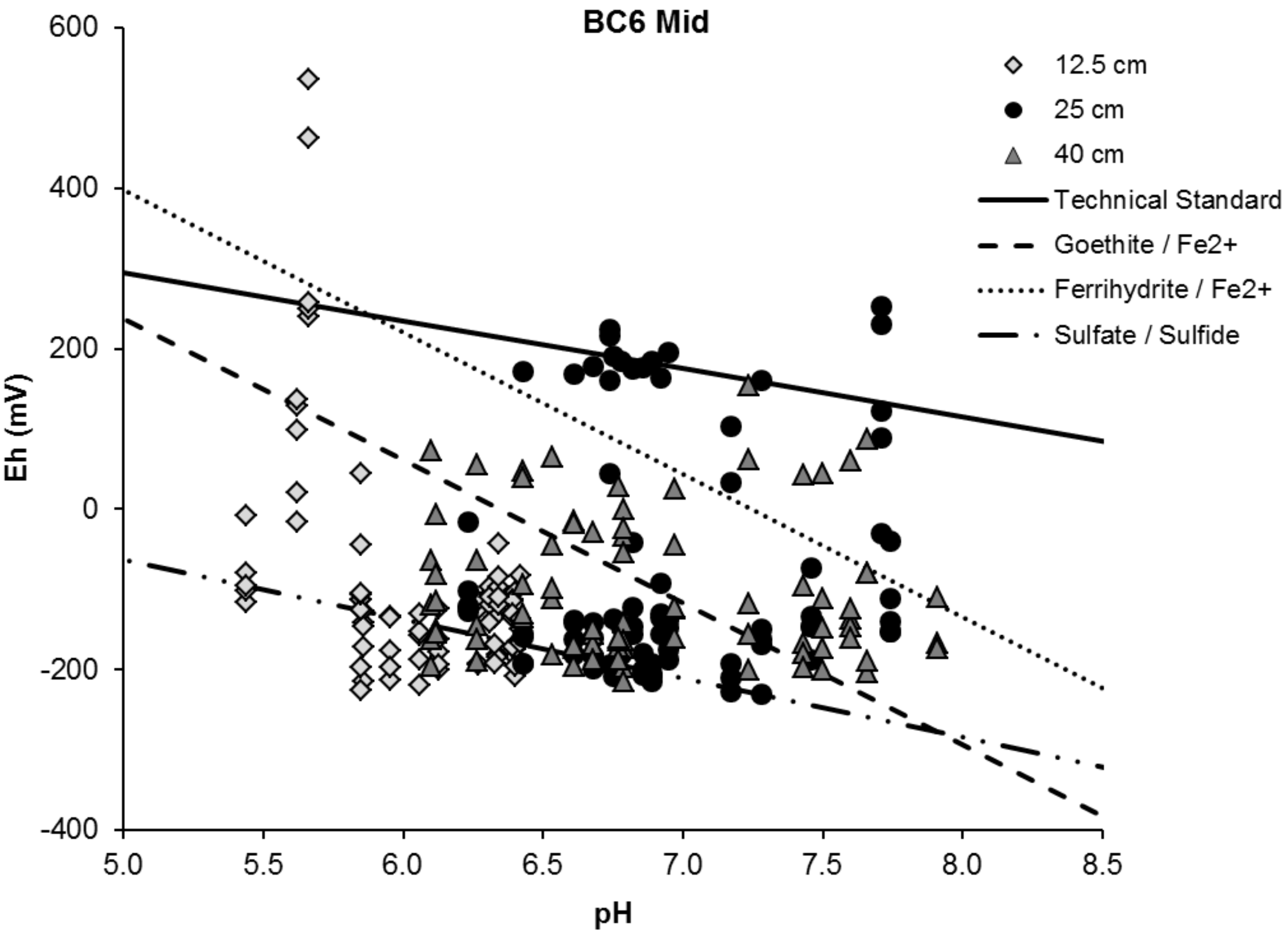
BC6 Mid: 2/9/2012 – 1/14/2013



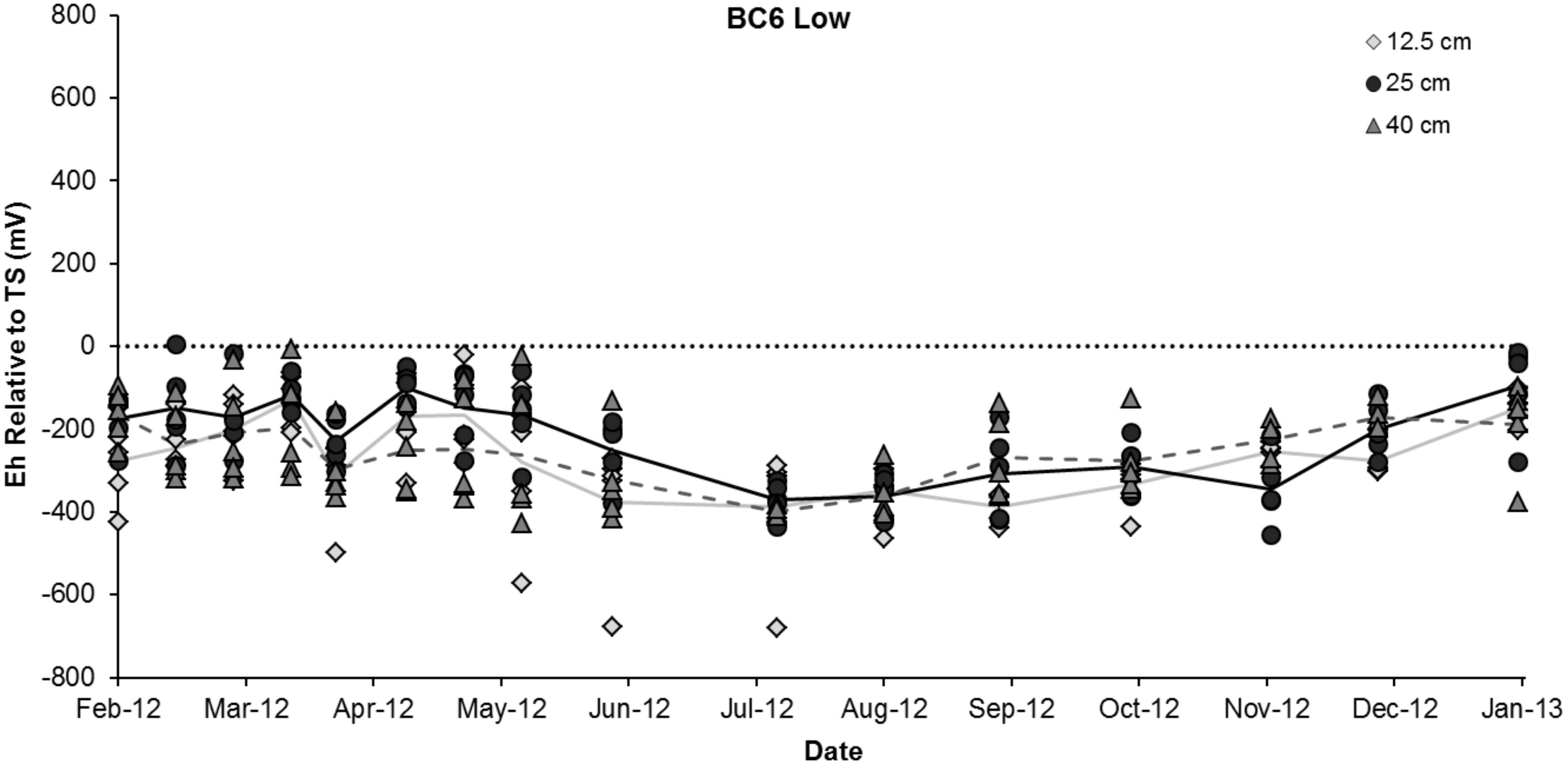

BC6 Mid
Eh (mV)
600
400
200
0
-200
-400
pH
4.5
5.0
5.5
6.0
6.5
7.0
7.5
8.0
8.5
12.5 cm
25 cm
40 cm
Technical Standard
Goethite / Fe2+
Ferrihydrite / Fe2+
Sulfate / Sulfide

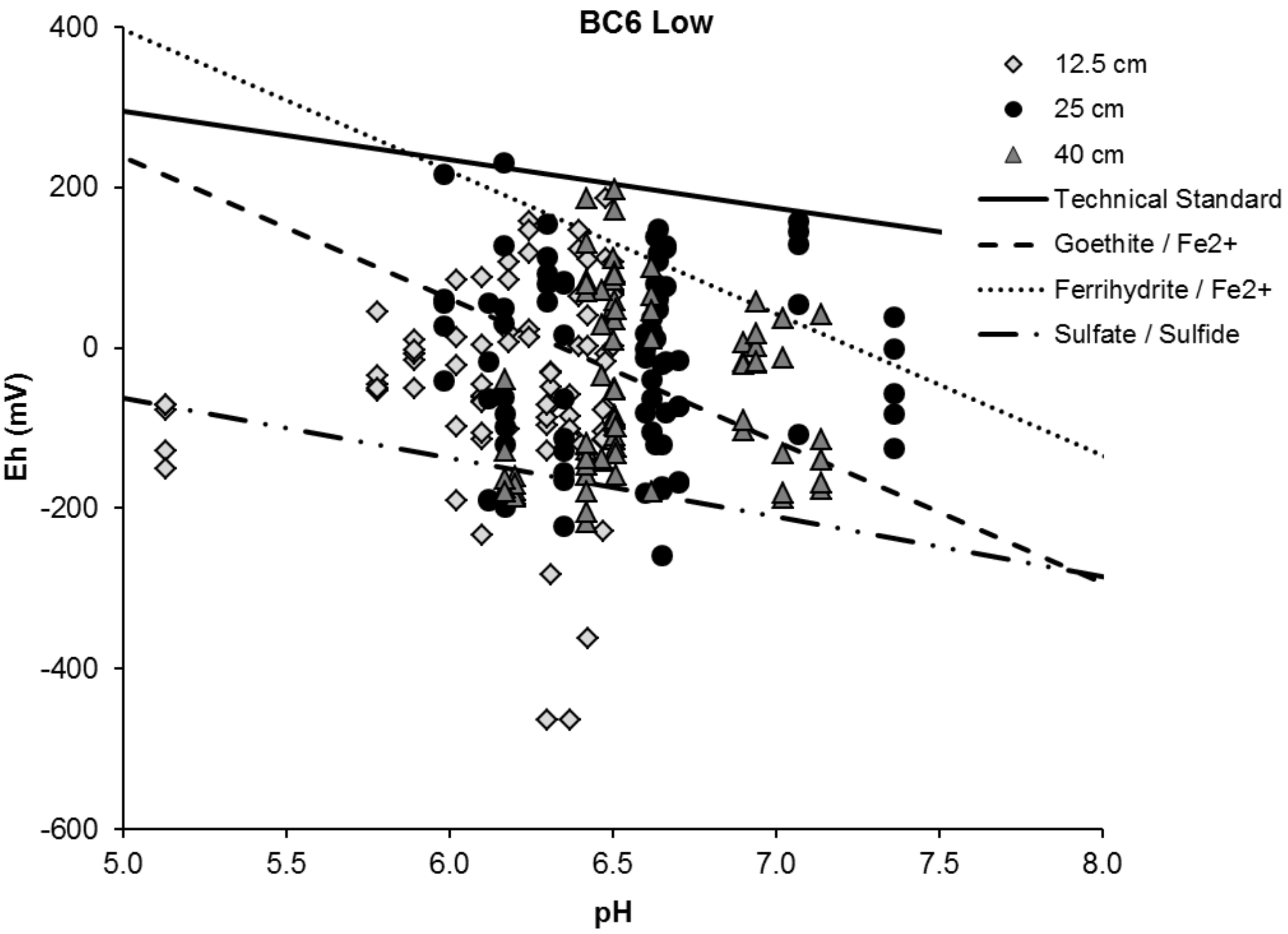
BC6 Mid: 2/5/2013 – 1/15/2014



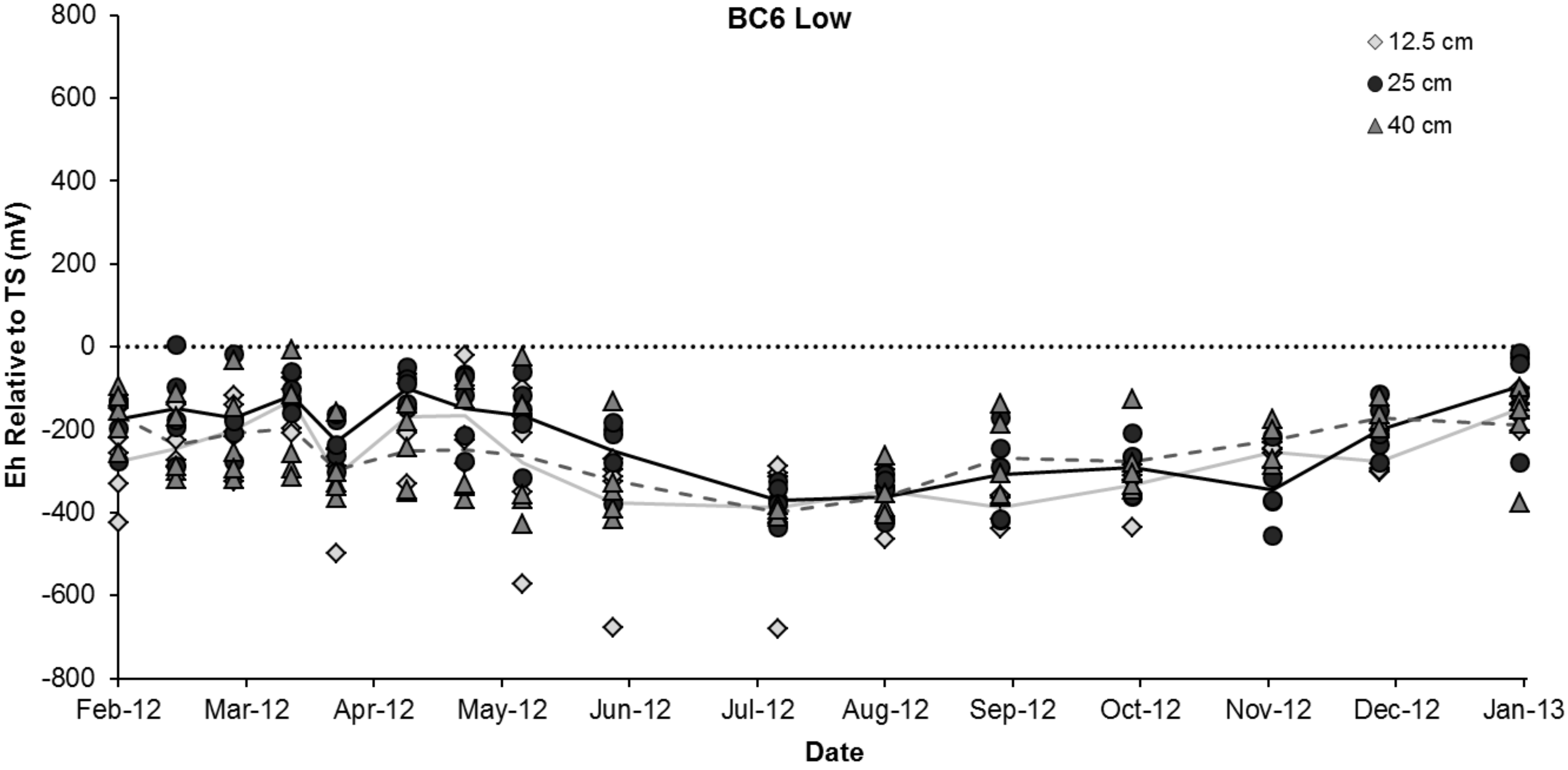

BC6 Mid
Eh (mV)
600
400
200
0
-200
-400
pH
5.0
5.5
6.0
6.5
7.0
7.5
8.0
8.5
12.5 cm
25 cm
40 cm
Technical Standard
Goethite / Fe2+
Ferrihydrite / Fe2+
Sulfate / Sulfide

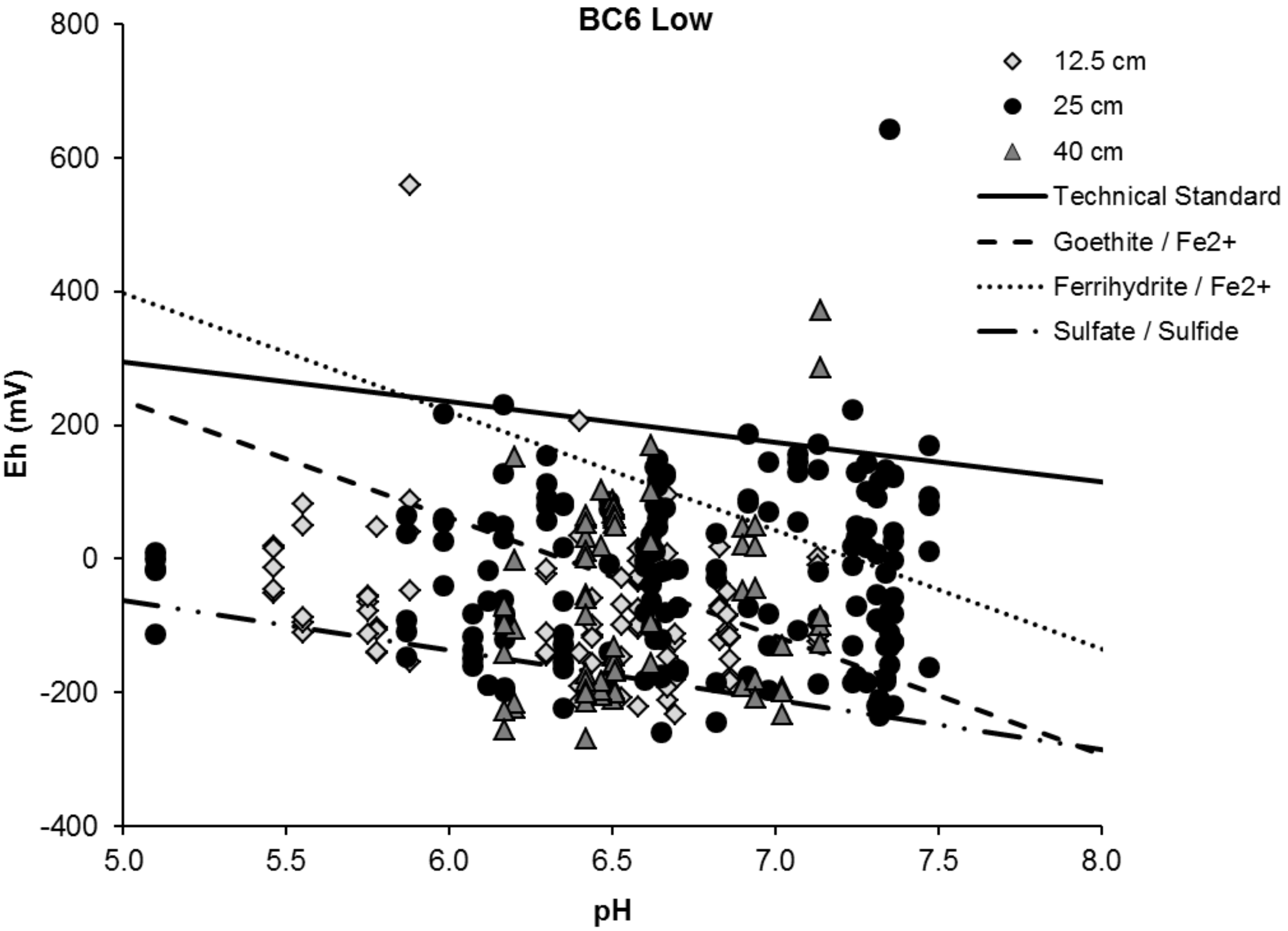
BC6 Low: 2/9/2012 – 1/14/2013



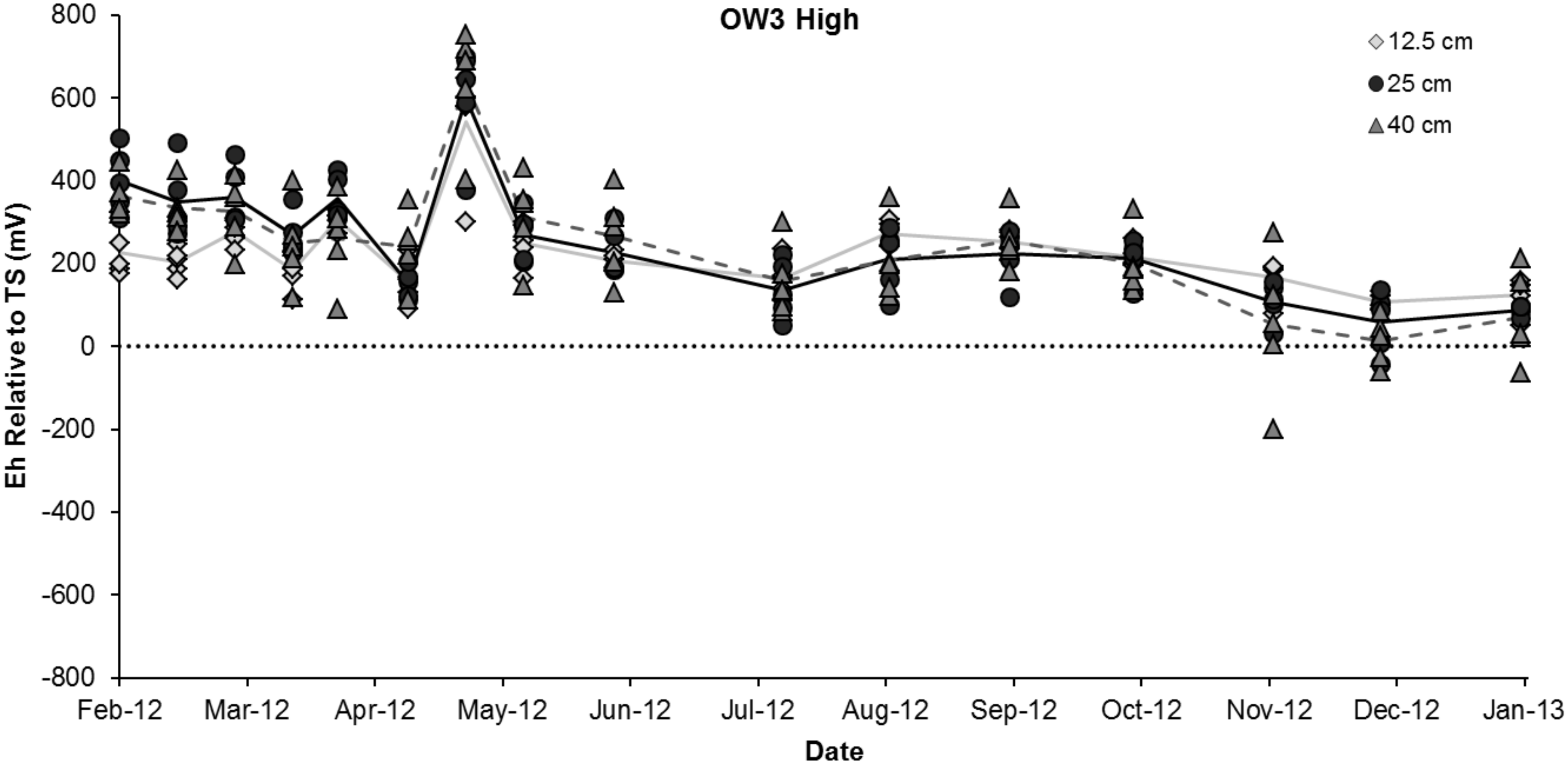

BC6 Low
Eh (mV)
pH
400
200
0
-200
-400
-600
5.0
5.5
6.0
6.5
7.0
7.5
8.0
◇ 12.5 cm
● 25 cm
▲ 40 cm
Technical Standard
Goethite / Fe2+
Ferrihydrite / Fe2+
Sulfate / Sulfide

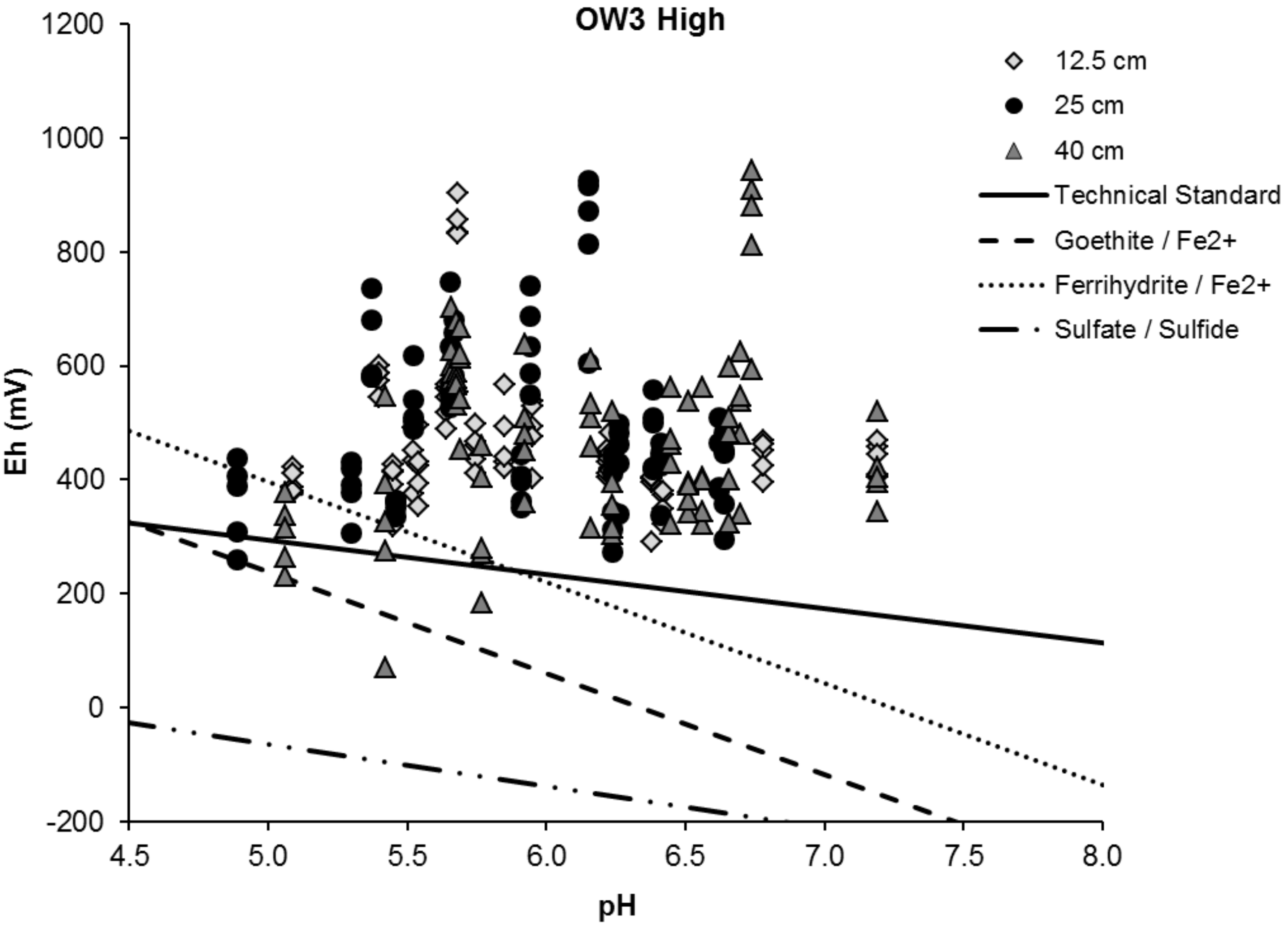
BC6 Low: 2/5/2013 – 1/15/2014



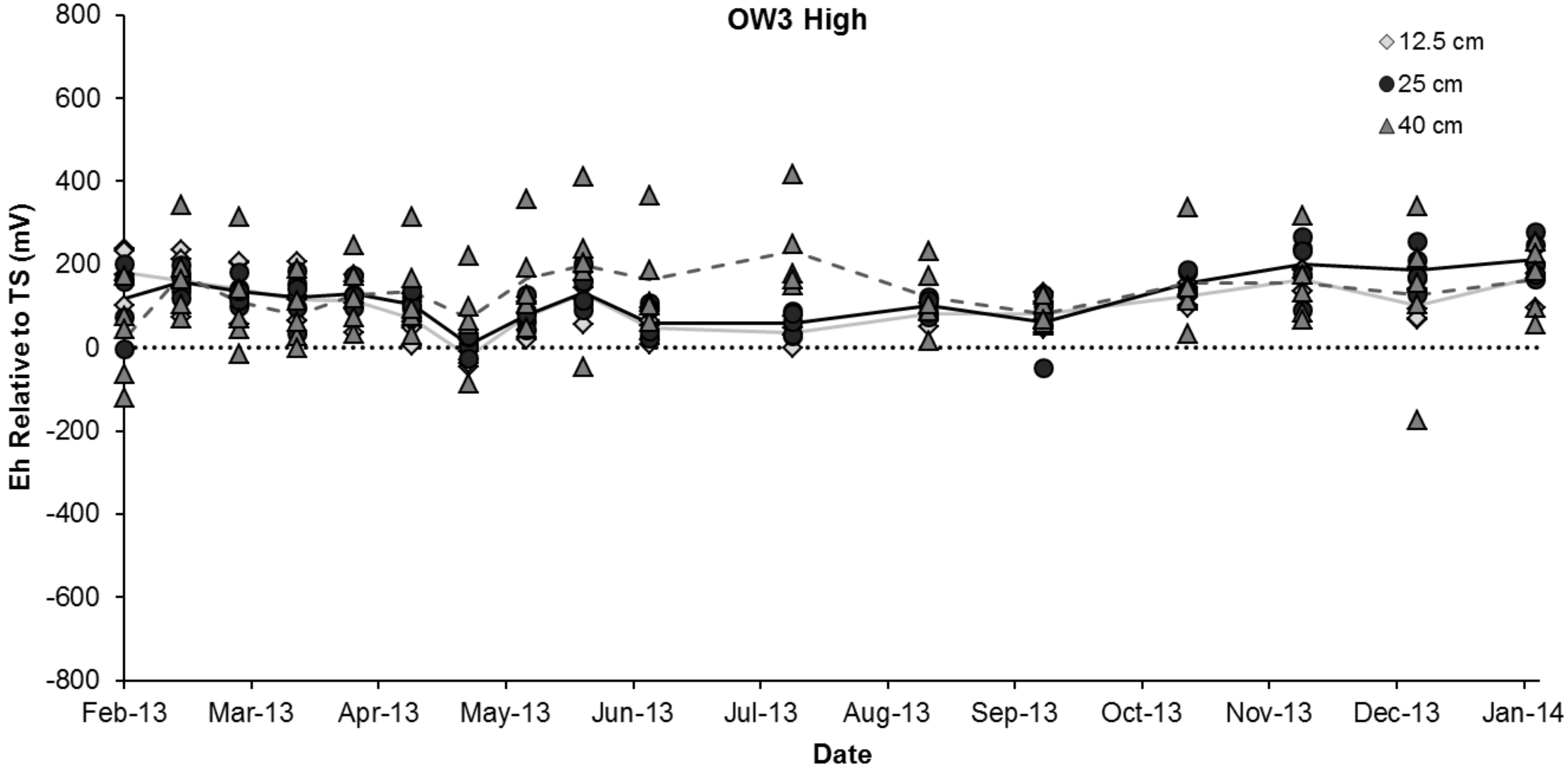

BC6 Low
Eh (mV)
800
600
400
200
0
-200
-400
pH
5.0
5.5
6.0
6.5
7.0
7.5
8.0
12.5 cm
25 cm
40 cm
Technical Standard
Goethite / Fe2+
Ferrihydrite / Fe2+
Sulfate / Sulfide

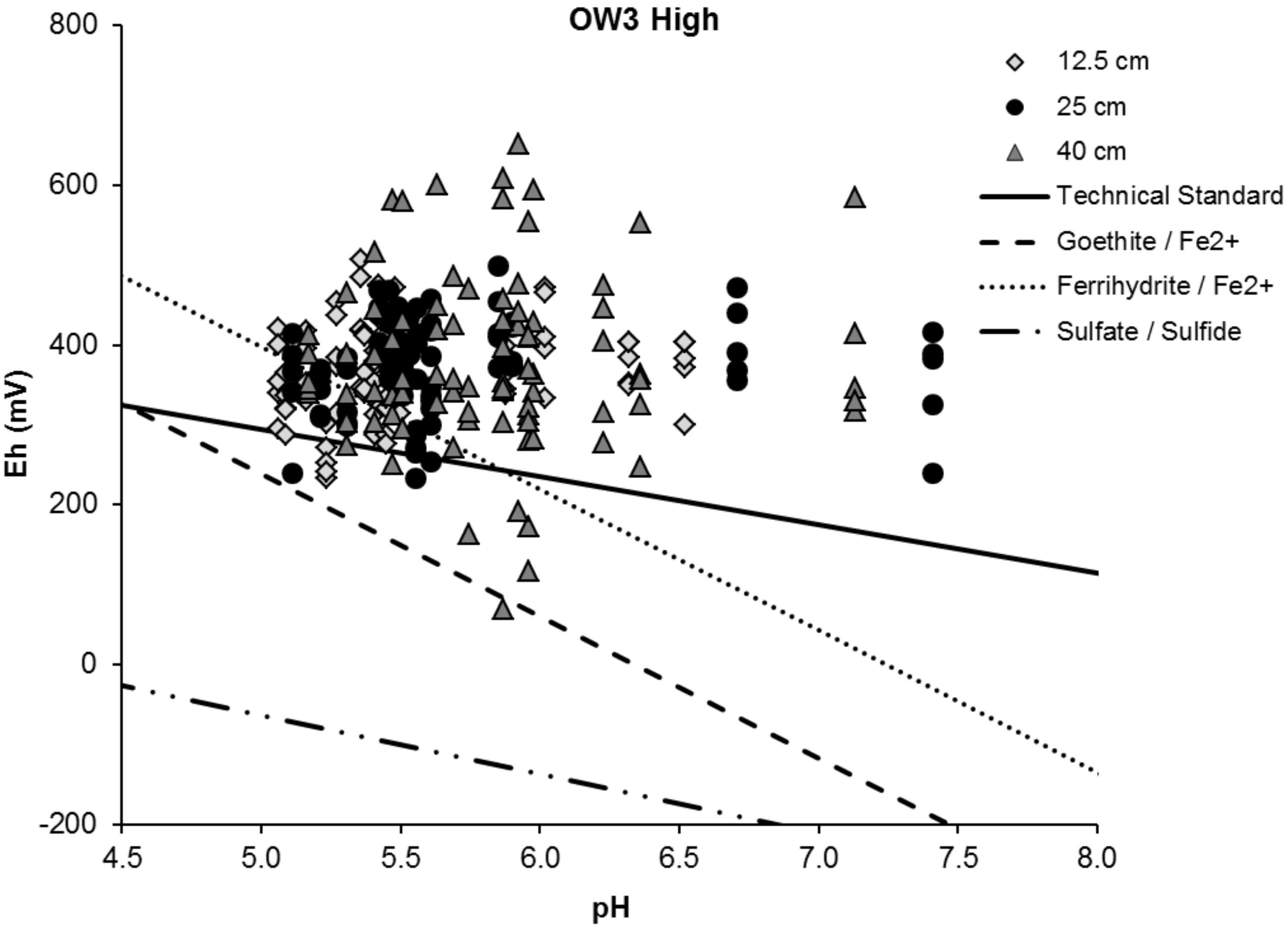
OW3 High: 2/9/2012 – 1/14/2013



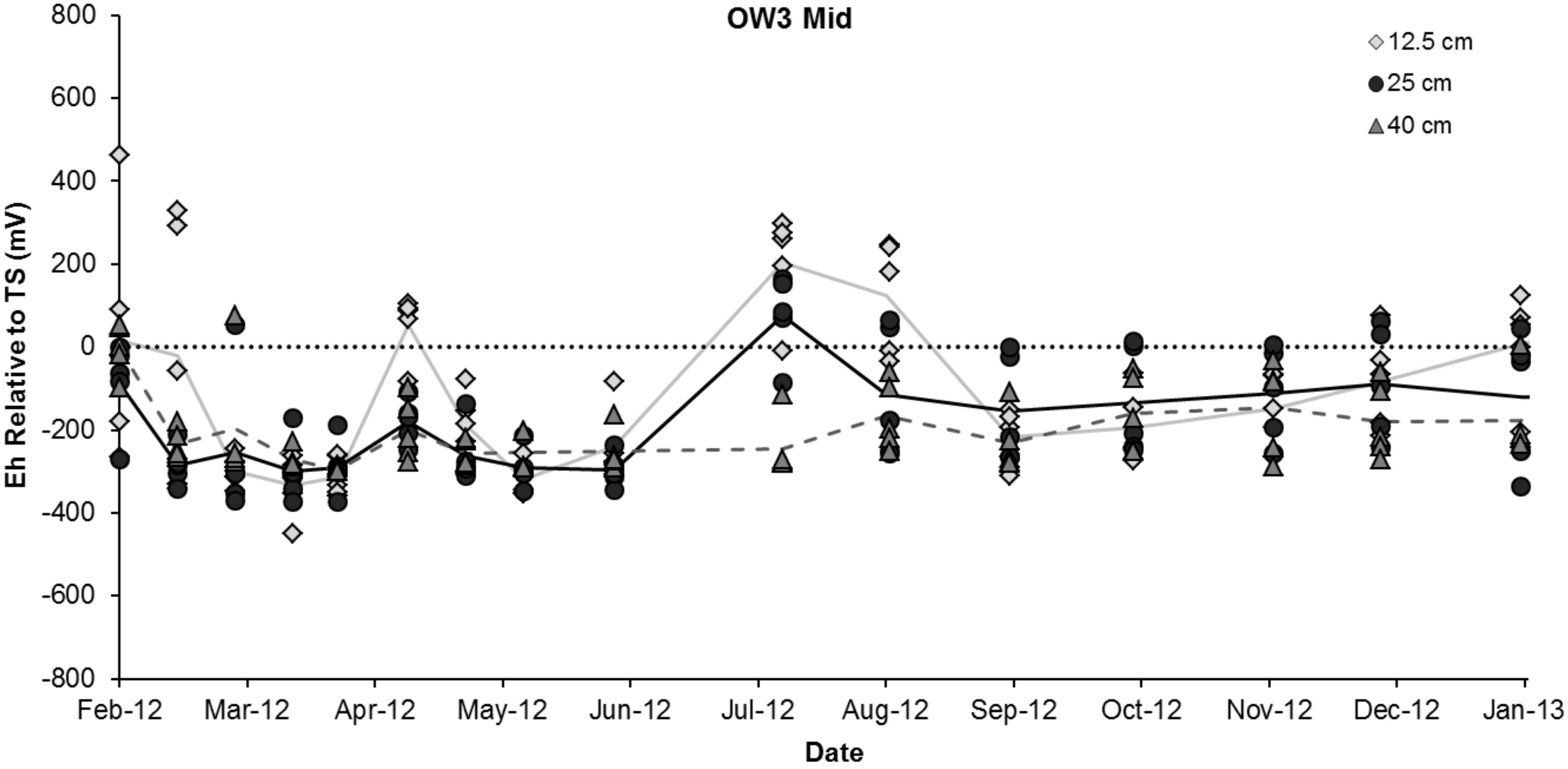

OW3 High
Eh (mV)
1200
1000
800
600
400
200
0
-200
pH
4.5
5.0
5.5
6.0
6.5
7.0
7.5
8.0
12.5 cm
25 cm
40 cm
Technical Standard
Goethite / Fe2+
Ferrihydrite / Fe2+
Sulfate / Sulfide

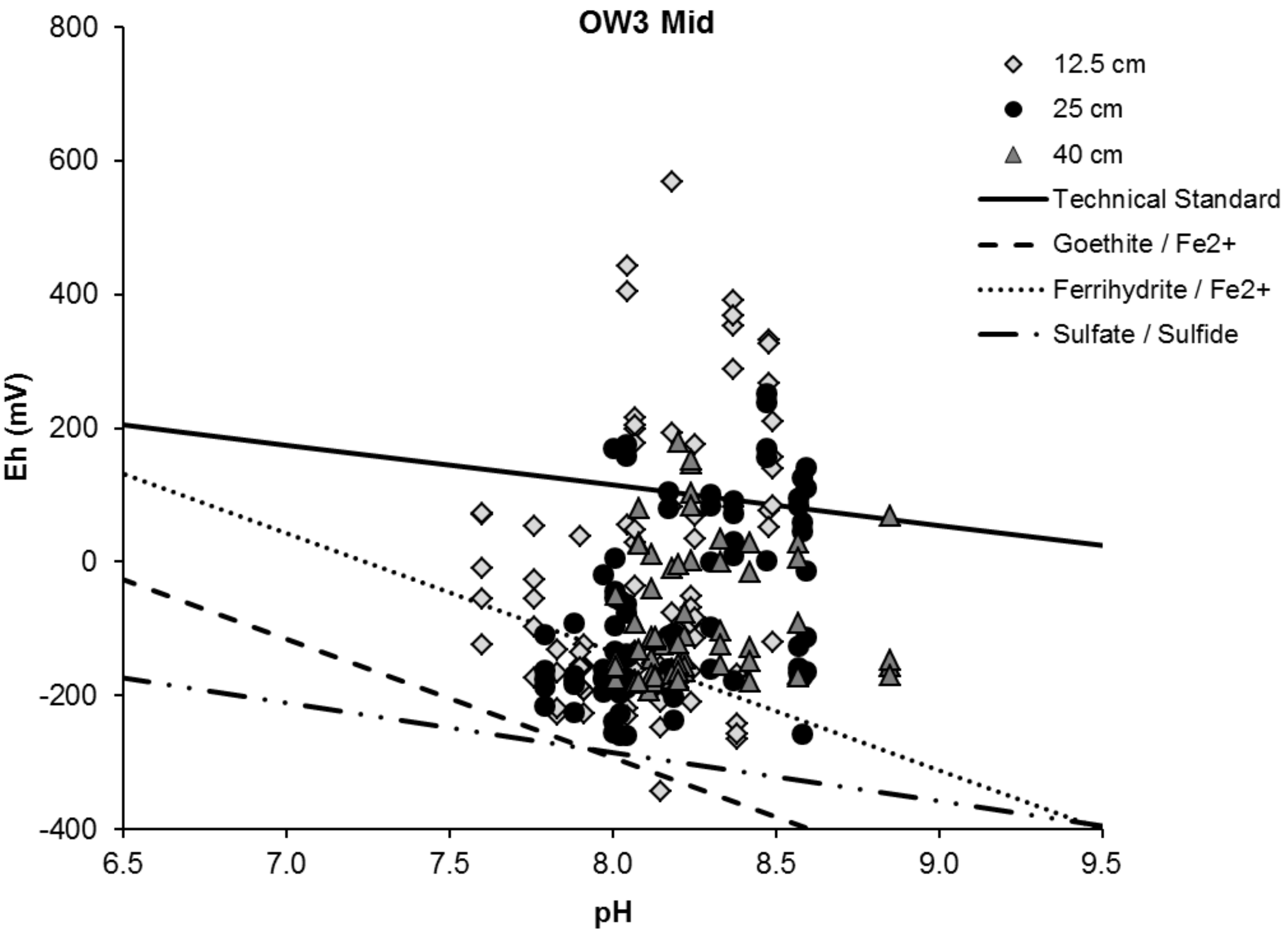
OW3 High: 2/5/2013 – 1/15/2014



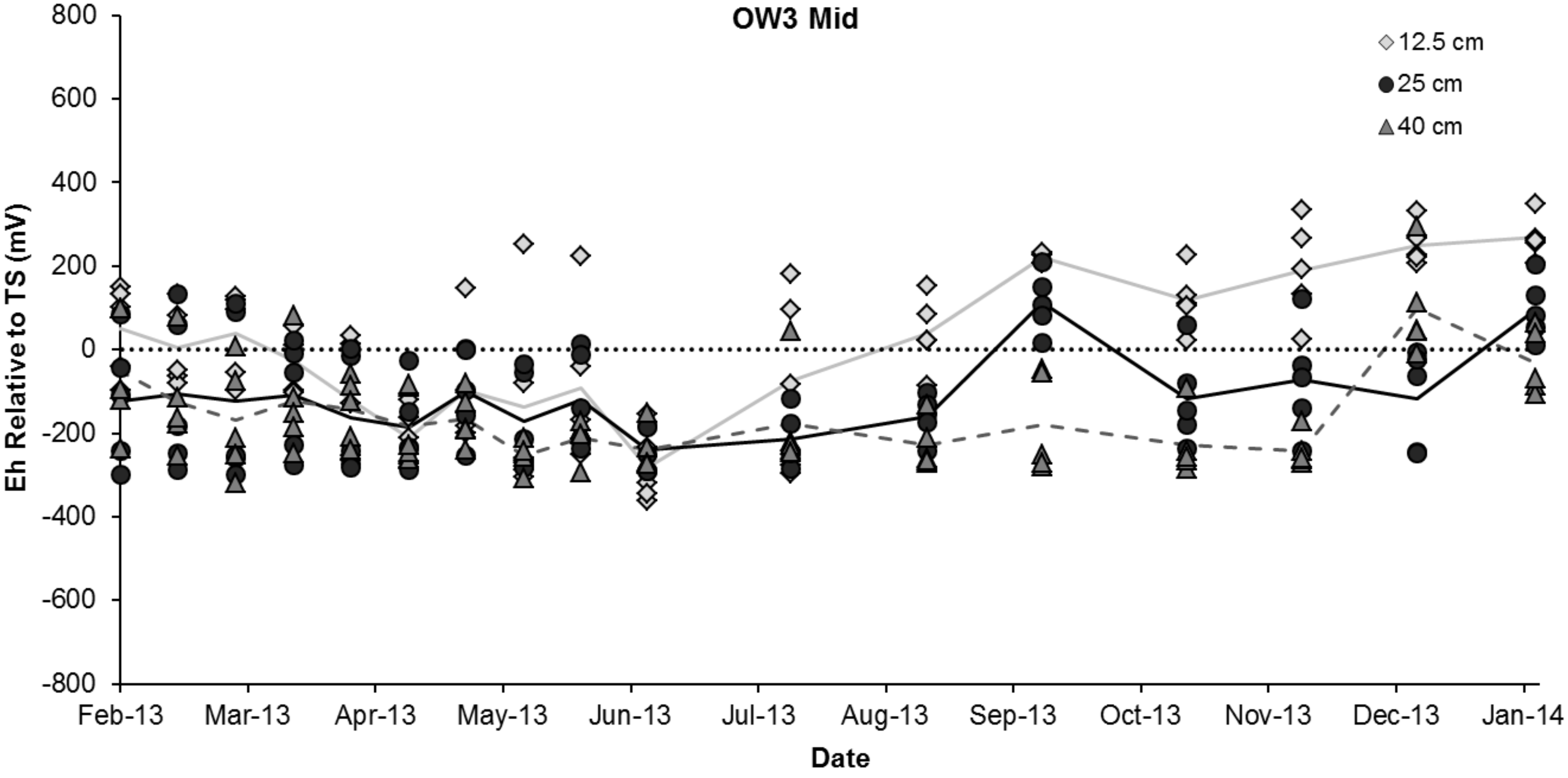

OW3 High
800
600
400
200
0
-200
Eh (mV)
4.5
5.0
5.5
6.0
6.5
7.0
7.5
8.0
pH
◇ 12.5 cm
● 25 cm
▲ 40 cm
Technical Standard
Goethite / Fe2+
Ferrihydrite / Fe2+
Sulfate / Sulfide

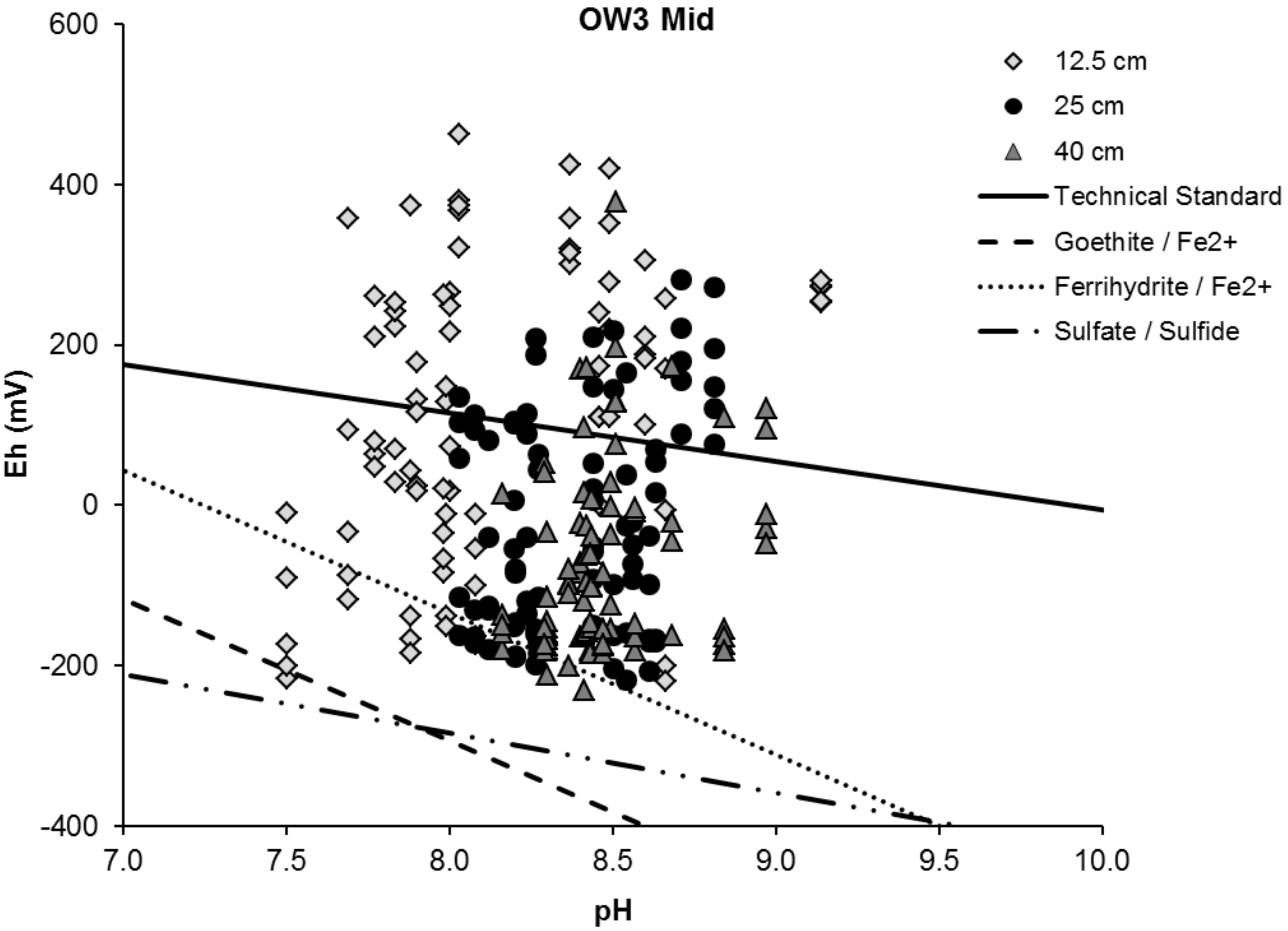
OW3 Mid: 2/9/2012 – 1/14/2013



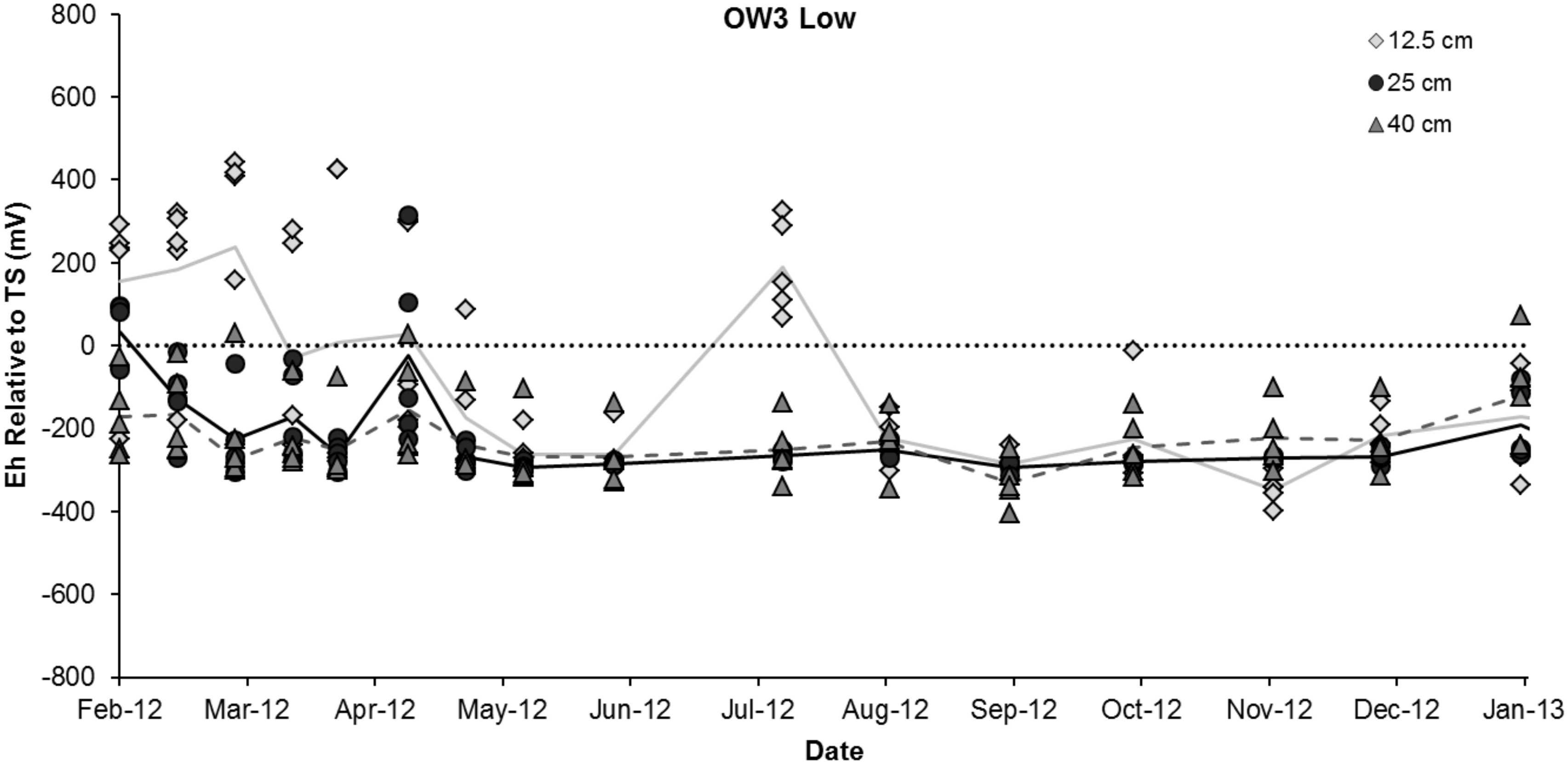

OW3 Mid
Eh (mV)
800
600
400
200
0
-200
-400
pH
6.5
7.0
7.5
8.0
8.5
9.0
9.5
◇ 12.5 cm
● 25 cm
▲ 40 cm
Technical Standard
Goethite / Fe2+
Ferrihydrite / Fe2+
Sulfate / Sulfide

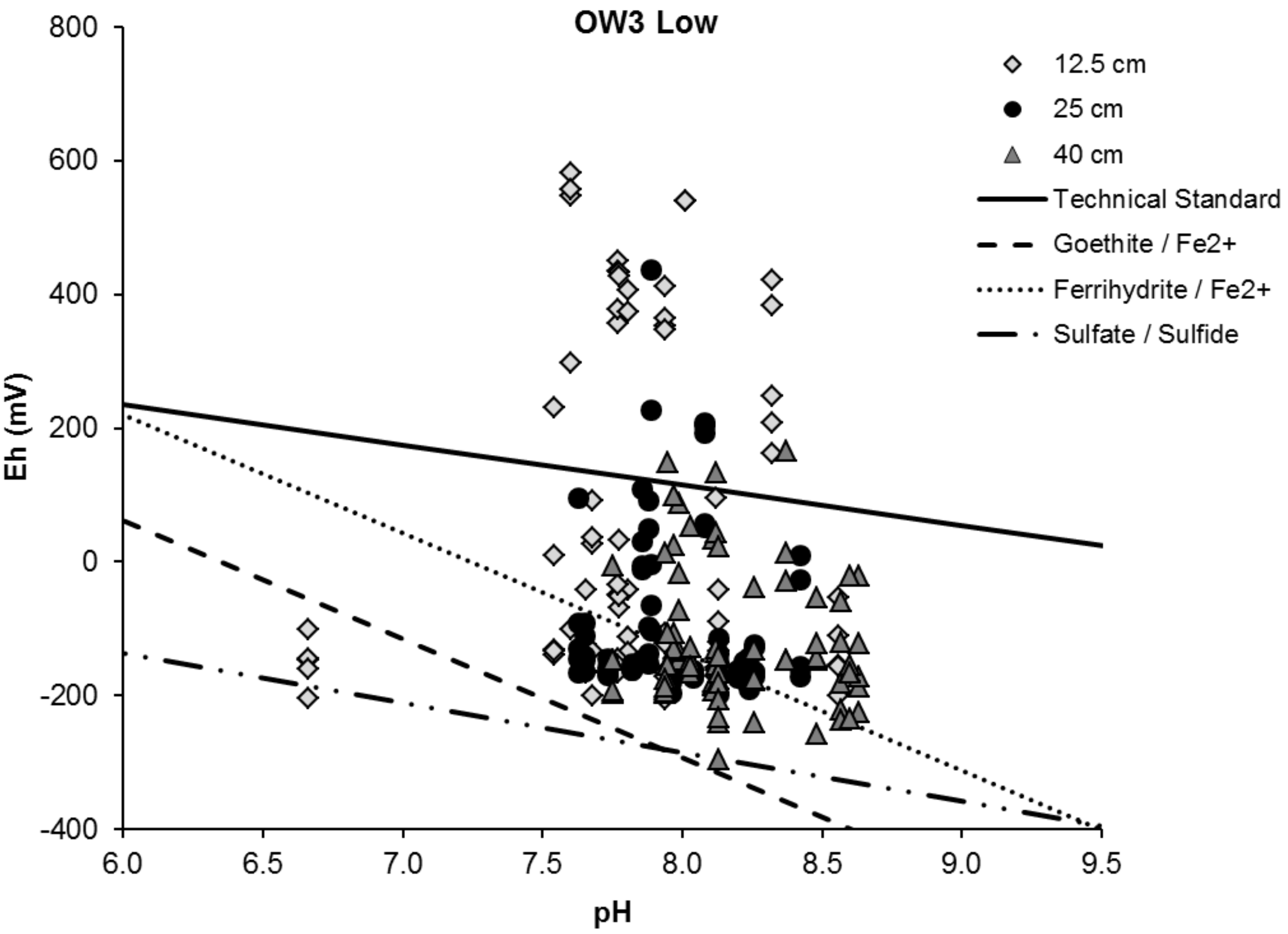
OW3 Mid: 2/5/2013 – 1/15/2014



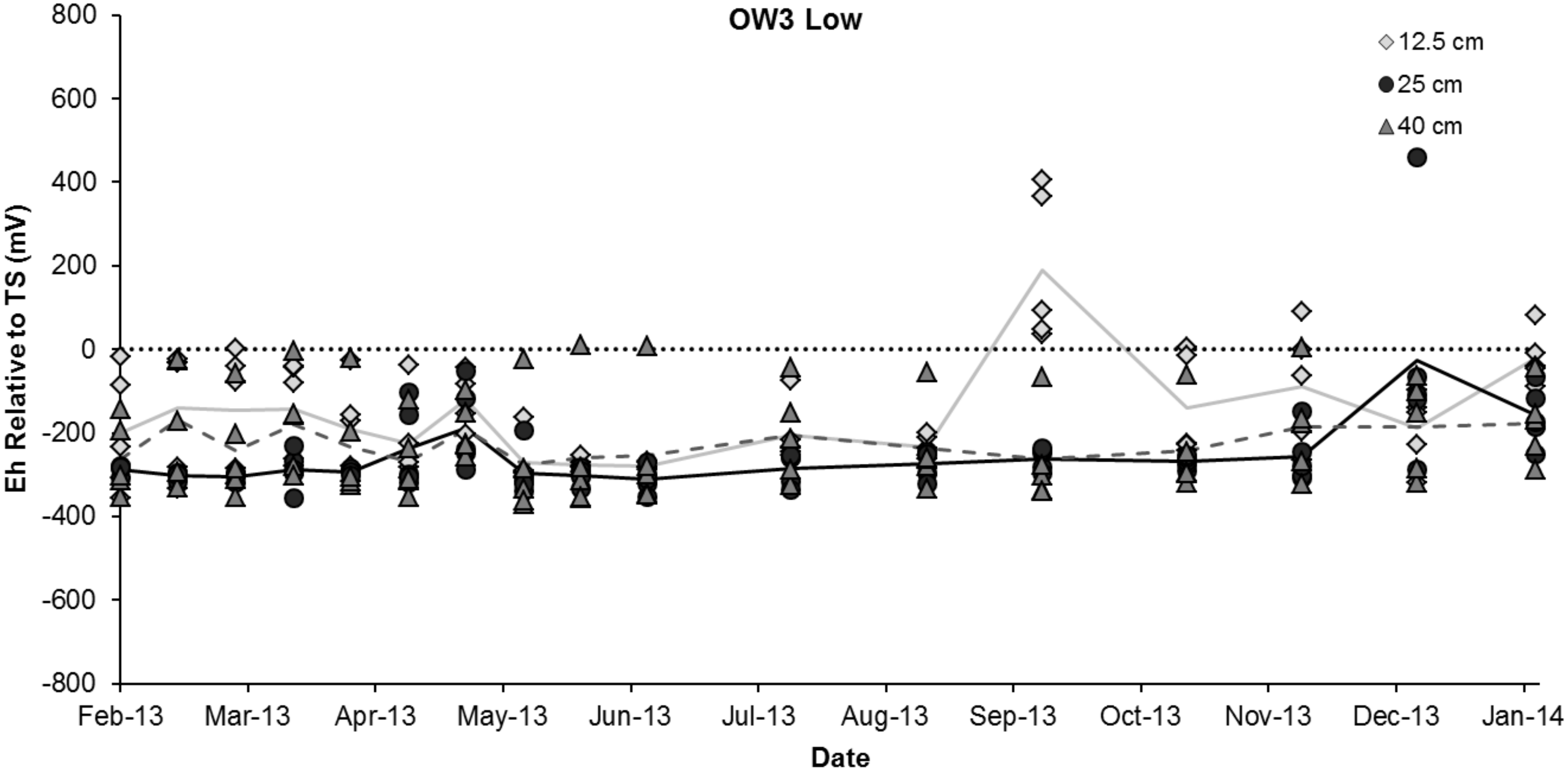

OW3 Mid
Eh (mV)
600
400
200
0
-200
-400
pH
7.0
7.5
8.0
8.5
9.0
9.5
10.0
12.5 cm
25 cm
40 cm
Technical Standard
Goethite / Fe2+
Ferrihydrite / Fe2+
Sulfate / Sulfide

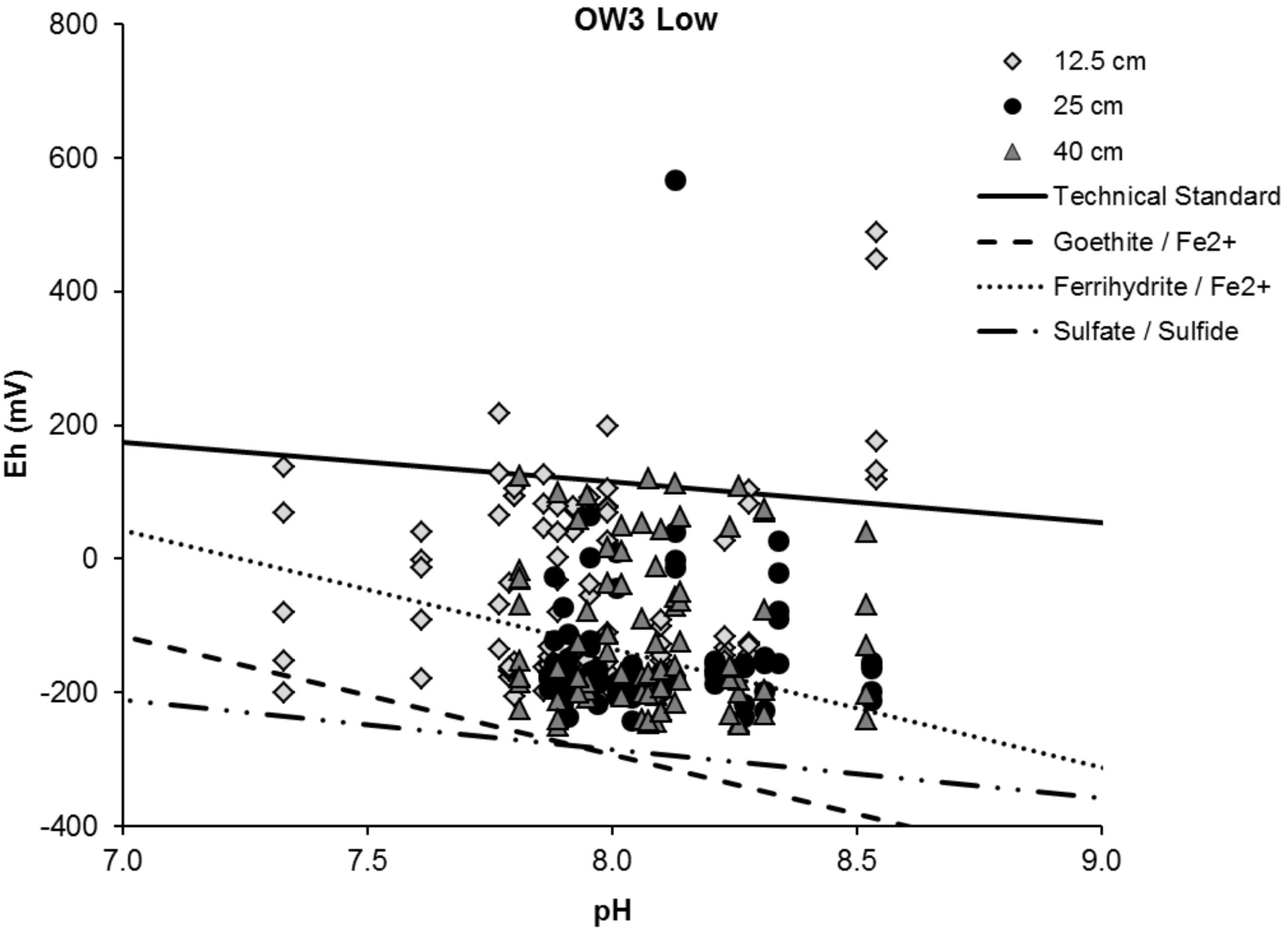
OW3 Low: 2/9/2012 – 1/14/2013




OW3 Low
800
600
400
200
0
-200
-400
Eh (mV)
6.0
6.5
7.0
7.5
8.0
8.5
9.0
9.5
pH
◇ 12.5 cm
● 25 cm
▲ 40 cm
Technical Standard
Goethite / Fe2+
Ferrihydrite / Fe2+
Sulfate / Sulfide

OW3 Low: 2/5/2013 – 1/15/2014




OW3 Low
Eh (mV)
800
600
400
200
0
-200
-400
7.0
7.5
8.0
8.5
9.0
pH
◇ 12.5 cm
● 25 cm
▲ 40 cm
Technical Standard
Goethite / Fe2+
Ferrihydrite / Fe2+
Sulfate / Sulfide

APPENDIX I: IRIS Tubes

					Shallowest Depth To[§]		
Transect	Position	Interval Dates	Tubes Meeting Technical Standard[†]	Maximum Paint Loss in 15 cm zone[‡]	Paint Removal	FeS	Evidence of FeS
				%	------------	cm	------------
BC1	Low	2/26/11-3/24/11	5	93	1	2	2
BC1	Low	3/24/11-4/21/11	5	100	0	0	0
BC1	Low	4/21/11-5/21/11	5	100	2	20	3
BC1	Low	2/16/12-3/15/12	5	100	4	4	3
BC1	Low	3/15/12-4/12/12	5	100	6	10	6
BC1	Low	4/12/12-5/12/12	5	100	3	18	12
BC1	Mid	2/26/11-3/24/11	0	2	16 (1)	na	na
BC1	Mid	3/24/11-4/21/11	0	9	21 (3)	na	na
BC1	Mid	4/21/11-5/21/11	2	27	26	38 (1)	na
BC1	Mid	2/16/12-3/15/12	5	66	19	19	19
BC1	Mid	3/15/12-4/12/12	5	100	14	18	18
BC1	Mid	4/12/12-5/12/12	5	95	16	na	na
BC1	High	2/26/11-3/24/11	0	0	na	na	na
BC1	High	3/24/11-4/21/11	0	0	na	na	na
BC1	High	2/16/12-3/15/12	0	0	na	na	na
BC1	High	3/15/12-4/12/12	0	0	na	na	na
BC1	High	4/12/12-5/12/12	0	0	na	na	na
BC2	Low	2/26/11-3/24/11	5	100	0	0	0
BC2	Low	3/24/11-4/21/11	5	100	2	3	3
BC2	Low	4/21/11-5/19/11	5	100	4	13	6
BC2	Low	2/16/12-3/15/12	5	100	0	1	1
BC2	Low	3/15/12-4/12/12	5	100	1	8	8
BC2	Low	4/12/12-5/12/12	5	100	0	3	2
BC2	Mid	2/26/11-3/24/11	5	100	1	9	9
BC2	Mid	3/24/11-4/21/11	5	100	8	11 (3)	9

Transect	Position	Interval Dates	Tubes Meeting Technical Standard[†]	Maximum Paint Loss in 15 cm zone[‡]	Shallowest Depth To[§] Paint Removal	FeS	Evidence of FeS
				%	------------ cm ------------		
BC2	Mid	4/21/11-5/19/11	5	98	5	22 (3)	18
BC2	Mid	2/16/12-3/15/12	5	0	45 (3)	na	na
BC2	Mid	3/15/12-4/12/12	5	100	8	na	na
BC2	Mid	4/12/12-5/12/12	5	100	7	na	na
BC2	High	2/26/11-3/24/11	0	0	na	na	na
BC2	High	3/24/11-4/21/11	0	0	46 (2)	48 (1)	48 (1)
BC2	High	2/16/12-3/15/12	0	0	na	na	na
BC2	High	3/15/12-4/12/12	0	0	na	na	na
BC2	High	4/12/12-5/12/12	0	0	na	na	na
BC3	Low	2/26/11-3/24/11	5	100	1	1	1
BC3	Low	3/24/11-4/21/11	5	100	4	5	5
BC3	Low	4/21/11-5/19/11	5	100	12	18 (4)	12
BC3	Low	2/16/12-3/15/12	5	100	6	9	9
BC3	Low	3/15/12-4/12/12	5	100	1	12	10
BC3	Low	4/12/12-5/12/12	5	100	0	8	8
BC3	Mid	2/26/11-3/24/11	0	0	33	33	33
BC3	Mid	3/24/11-4/21/11	0	0	34	34	34
BC3	Mid	4/21/11-5/19/11	0	0	43	44 (3)	43
BC3	Mid	2/16/12-3/15/12	0	0	45 (4)	na	45 (3)
BC3	Mid	3/15/12-4/12/12	0	0	42	43	43
BC3	Mid	4/12/12-5/12/12	0	0	43	42 (1)	44 (2)
BC3	High	2/26/11-3/24/11	0	0	na	na	na
BC3	High	3/24/11-4/21/11	0	0	na	na	na
BC3	High	2/16/12-3/15/12	0	0	na	na	na
BC3	High	3/15/12-4/12/12	0	0	na	na	na
BC3	High	4/12/12-5/12/12	0	0	na	na	na
BC4	Low	2/27/11-3/24/11	5	100	12	24 (4)	24 (4)
BC4	Low	3/24/11-4/21/11	5	100	11	18 (3)	15

Transect	Position	Interval Dates	Tubes Meeting Technical Standard[†]	Maximum Paint Loss in 15 cm zone[‡]	Shallowest Depth To[§] Paint Removal	FeS	Evidence of FeS
				%	------------ cm ------------		
BC4	Low	4/21/11-5/19/11	5	100	14	19	15
BC4	Low	2/16/12-3/15/12	5	97	14	25 (2)	20
BC4	Low	3/15/12-4/12/12	5	97	15	22 (3)	15
BC4	Low	4/12/12-5/12/12	5	97	15	na	na
BC4	Mid	2/27/11-3/24/11	0	0	35 (3)	na	na
BC4	Mid	3/24/11-4/21/11	0	0	36 (4)	37 (1)	37 (3)
BC4	Mid	4/21/11-5/19/11	0	0	40	40 (2)	40 (2)
BC4	Mid	2/16/12-3/15/12	4	36	23	26	26
BC4	Mid	3/15/12-4/12/12	0	0	34	35	35
BC4	Mid	4/12/12-5/12/12	0	0	na	na	na
BC4	High	2/27/11-3/24/11	0	0	na	na	na
BC4	High	3/24/11-4/21/11	0	0	na	na	na
BC4	High	2/16/12-3/15/12	0	0	na	na	na
BC4	High	3/15/12-4/12/12	0	0	na	na	na
BC4	High	4/12/12-5/12/12	0	0	na	na	na
BC5	Low	2/26/11-3/24/11	5	54	21	33 (3)	32
BC5	Low	3/24/11-4/21/11	5	69	17	29 (2)	25
BC5	Low	4/21/11-5/19/11	5	69	20	28 (2)	26 (3)
BC5	Low	2/16/12-3/15/12	0	0	41 (4)	na	na
BC5	Low	3/15/12-4/12/12	5	90	9	na	28 (1)
BC5	Low	4/12/12-5/12/12	4	48	21	24 (1)	24 (1)
BC5	Mid	2/26/11-3/24/11	0	0	na	na	na
BC5	Mid	3/24/11-4/21/11	0	0	42 (4)	45 (1)	45 (1)
BC5	Mid	4/21/11-5/19/11	0	0	46	na	na
BC5	Mid	2/16/12-3/15/12	2	19	28	39 (2)	36 (3)
BC5	Mid	3/15/12-4/12/12	0	0	34	40 (2)	34 (3)
BC5	Mid	4/12/12-5/12/12	0	0	35	44 (2)	38 (3)

					Shallowest Depth To[§]		
Transect	Position	Interval Dates	Tubes Meeting Technical Standard[†]	Maximum Paint Loss in 15 cm zone[‡]	Paint Removal	FeS	Evidence of FeS
				%	------------ cm ------------		
BC5	High	2/26/11-3/24/11	0	0	na	na	na
BC5	High	3/24/11-4/21/11	0	0	na	na	na
BC5	High	2/16/12-3/15/12	0	0	na	na	na
BC5	High	3/15/12-4/12/12	0	0	na	na	na
BC5	High	4/12/12-5/12/12	0	0	na	na	na
BC6	Low	2/26/11-3/24/11	5	100	1	1	1
BC6	Low	3/24/11-4/21/11	5	100	0	0	0
BC6	Low	4/21/11-5/19/11	5	100	0	3	1
BC6	Low	2/16/12-3/15/12	5	100	0	0	0
BC6	Low	3/15/12-4/12/12	5	100	0	1	1
BC6	Low	4/12/12-5/12/12	5	100	0	2	2
BC6	Mid	2/26/11-3/24/11	2	28	12	39 (3)	39 (3)
BC6	Mid	3/24/11-4/21/11	5	99	13	24	20
BC6	Mid	4/21/11-5/19/11	5	79	18	20	18
BC6	Mid	2/16/12-3/15/12	5	91	9	14	9
BC6	Mid	3/15/12-4/12/12	5	100	13	17	13
BC6	Mid	4/12/12-5/12/12	5	92	14	26	18
BC6	High	2/26/11-3/24/11	0	0	na	na	na
BC6	High	3/24/11-4/21/11	0	0	34 (1)	na	na
BC6	High	4/21/11-5/19/11	0	0	38	10 (1)	10 (1)
BC6	High	2/16/12-3/15/12	0	3	31	34 (1)	35
BC6	High	3/15/12-4/12/12	0	0	34	35 (4)	35
BC6	High	4/12/12-5/12/12	0	0	38	na	na
OW1	Low	2/26/11-3/25/11		100	13	15	15
OW1	Low	3/25/11-4/21/11	5	94	13	25 (1)	14 (4)
OW1	Low	4/21/11-5/19/11	5	80	16	17 (2)	17
OW1	Low	2/16/12-3/15/12	5	99	13	19 (4)	17

Transect	Position	Interval Dates	Tubes Meeting Technical Standard[†]	Maximum Paint Loss in 15 cm zone[‡]	Shallowest Depth To[§] Paint Removal	FeS	Evidence of FeS
				%	------------ cm	------------	
OW1	Low	3/15/12-4/12/12	5	91	15	25	17
OW1	Low	4/12/12-5/12/12	5	94	14	na	34
OW1	Mid	2/26/11-3/25/11	0	0	37	44 (2)	44 (2)
OW1	Mid	3/25/11-4/21/11	0	0	35	41 (4)	41 (4)
OW1	Mid	4/21/11-5/19/11	0	5	30	31 (3)	33
OW1	Mid	2/16/12-3/15/12	0	0	33	37 (4)	36
OW1	Mid	3/15/12-4/12/12	0	0	35	36	36
OW1	Mid	4/12/12-5/12/12	0	0	33	na	na
OW1	High	2/26/11-3/25/11	0	0	na	na	na
OW1	High	3/25/11-4/21/11	0	0	na	na	na
OW1	High	2/16/12-3/15/12	0	0	na	na	na
OW1	High	3/15/12-4/12/12	0	0	na	na	na
OW1	High	4/12/12-5/12/12	0	0	na	na	na
OW2	Low	2/27/11-3/25/11	5	100	0	0	0
OW2	Low	3/25/11-4/21/11	5	100	0	3	2
OW2	Low	4/21/11-5/19/11	5	100	2	9	9
OW2	Low	2/16/12-3/15/12	5	100	1	1	1
OW2	Low	3/15/12-4/12/12	5	100	1	9	2
OW2	Low	4/12/12-5/12/12	5	100	1	12	12
OW2	Mid	3/25/11-4/21/11	0	5	na	na	na
OW2	Mid	4/21/11-5/19/11	4	34	24	31 (1)	31 (1)
OW2	Mid	2/16/12-3/15/12	5	100	13	14	13
OW2	Mid	3/15/12-4/12/12	5	74	19	24 (4)	22
OW2	Mid	4/12/12-5/12/12	5	55	21	28 (1)	28 (1)
OW2	High	2/27/11-3/25/11	0	0	na	na	na
OW2	High	3/25/11-4/21/11	0	0	na	na	na
OW2	High	2/16/12-3/15/12	0	0	na	na	na
OW2	High	3/15/12-4/12/12	0	0	na	na	na

Transect	Position	Interval Dates	Tubes Meeting Technical Standard[†]	Maximum Paint Loss in 15 cm zone[‡]	Shallowest Depth To[§] Paint Removal	FeS	Evidence of FeS
				%	------------ cm ------------		
OW2	High	4/12/12-5/12/12	0	0	na	na	na
OW3	Low	2/26/11-3/25/11	5	100	0	0	0
OW3	Low	3/25/11-4/21/11	5	100	1	1	1
OW3	Low	4/21/11-5/19/11	5	100	2	17 (4)	9
OW3	Low	2/16/12-3/15/12	5	79	1	3	1
OW3	Low	3/15/12-4/12/12	5	100	0	16	16
OW3	Low	4/12/12-5/12/12	5	97	0	23 (4)	21
OW3	Mid	2/26/11-3/25/11	4	57	12	26 (3)	25 (4)
OW3	Mid	3/25/11-4/21/11	5	86	7	18 (4)	20
OW3	Mid	4/21/11-5/19/11	5	94	12	17	17
OW3	Mid	2/16/12-3/15/12	5	85	8	13	11
OW3	Mid	3/15/12-4/12/12	5	100	11	21	21
OW3	Mid	4/12/12-5/12/12	5	97	12	25 (3)	26 (2)
OW3	High	2/26/11-3/25/11	0	0	na	na	na
OW3	High	3/25/11-4/21/11	0	0	na	na	na
OW3	High	2/16/12-3/15/12	0	0	na	na	na
OW3	High	3/15/12-4/12/12	0	0	na	na	na
OW3	High	4/12/12-5/12/12	0	0	na	na	na
OW4	Low	2/27/11-3/25/11	5	65	19	19	19
OW4	Low	3/25/11-4/21/11	5	98	14	19	19
OW4	Low	4/21/11-5/19/11	5	61	20	28	20
OW4	Low	2/16/12-3/15/12	5	100	13	15	15
OW4	Low	3/15/12-4/12/12	5	58	21	23	22
OW4	Low	4/12/12-5/12/12	5	67	20	24	24
OW4	Mid	2/27/11-3/25/11	0	6	28	30	30
OW4	Mid	3/25/11-4/21/11	4	34	25	28	27
OW4	Mid	4/21/11-5/19/11	2	21	27	32	31
OW4	Mid	2/16/12-3/15/12	0	0	32	33	32

Transect	Position	Interval Dates	Tubes Meeting Technical Standard[†]	Maximum Paint Loss in 15 cm zone[‡]	Shallowest Depth To[§] Paint Removal	FeS	Evidence of FeS
				%	------------ cm ------------		
OW4	Mid	3/15/12-4/12/12	0	0	32	33	33
OW4	Mid	4/12/12-5/12/12	1	17	27	39	39
OW4	High	2/27/11-3/25/11	0	0	37	na	na
OW4	High	3/25/11-4/21/11	0	0	32	39 (3)	38 (3)
OW4	High	4/21/11-5/19/11	0	0	33	37 (4)	34
OW4	High	2/16/12-3/15/12	0	0	na	na	na
OW4	High	3/15/12-4/12/12	0	0	na	na	na
OW4	High	4/12/12-5/12/12	0	0	na	na	na

[†] Number of tubes (out of five) having greater than 30% paint loss in a 15 cm zone starting within the upper 30 cm of the soil surface. To meet the Technical Standard for Hydric Soils, three out of five tubes inserted in the soil for four weeks must meet this criteria (National Technical Committee for Hydric Soils, 2007).

[‡] Maximum paint loss in a 15 cm zone starting within the upper 30 cm of the soil surface.

[§] Shallowest depth of paint removal, presence of FeS, or evidence of FeS (stripping) greater than 20% in a 5 cm zone. Value is the average of five tubes unless indicated (number in parenthesis), na = paint removal, FeS, and/or evidence of sulfides (stripping) was not present at any depth on any of the five tubes.

APPENDIX J: VEGETATION SURVEYS

Site	Cover Class[†]	Scientific Name	Common Name	Growth Habit	Wetland Indicator Status[‡]
BC1 Low	dead	*Ptilimnium capillaceum* (Michx.) Raf	herbwilliam, mock bishop's weed	Forb/herb	OBL
	70	*Schoenoplectus americanus* (Pers.) Volkart ex Schinz & R. Keller	chairmaker's bulrush, three square	Graminoid	OBL
	40	*Setaria parviflora* (Poir.) Kerguélen	marsh bristlegrass, knotroot bristlegrass	Graminoid	FACW
	20	*Pluchea odorata* (L.) Cass.	sweetscent, marsh fleabane	Subshrub, Forb/herb	FACW
	10	*Mikania scandens* (L.) Willd.	climbing hempweed, climbing hempvine	Vine, Forb/herb	FACW
	10	*Polygonum puncatum* Elliott	dotted smartweed	Forb/herb	n/a
	3	*Lythrum lineare* L.	wand lythrum, loosestrife, saltmarsh loosestrife	Forb/herb	OBL
	3	*Phragmites australis* (Cav.) Trin. Ex Steud.	common reed	subshrub, shrub, graminoid	FACW
	3	*Solidago sempervirens* L.	seaside goldenrod	Forb/herb	FACW
	0.5	*Eupatorium capillifolium* (Lam.)	dogfennel	Forb/herb	FACU
	0.5	*Panicum amarum* Elliott	bitter panicgrass, colonial beachgrass	Graminoid	FAC
BC1 Mid	60	*Morella cerifera* (L.) Small	wax myrtle	Tree, Subshrub, Shrub	FAC
	50	*Hydrocotyle umbellata* L.	manyflower marshpennywort, water pennywort	Forb/herb	OBL
	20	*Vaccinium corymbosum* L.	highbush blueberry	Shrub	FACW

Site	Cover Class[†]	Scientific Name	Common Name	Growth Habit	Wetland Indicator Status[‡]
BC1 Mid	10	*Dichanthelium acuminatum* (Sw.) Gould & C.A. Clark var. *acuminatum*	tapered rosette grass, bushy panicgrass	Graminoid	FAC
	10	*Lythrum lineare* L.	wand lythrum, loosestrife, saltmarsh loosestrife	Forb/herb	OBL
	10	*Morella pensylvanica* (Mirb.) Kartesz	northern bayberry	Tree, Shrub	FAC
	10	*Pinus taeda* L.	loblolly pine	Tree	FAC
	3	*Andropogon virginicus* L.	broomsedge bluestem	Graminoid	FAC
	3	*Baccharis halimifolia* L.	groundsel, eastern baccharis	Tree, Shrub	FAC
	3	*Eragrostis spectabilis* (Pursh) Steud.	purple lovegrass	Graminoid	FACU
	3	*Erechtites hieraciifolia* (L.) Raf. ex DC.	fireweed, American burnweed	Forb/herb	FAC
	3	*Eupatorium capillifolium* (Lam.)	dogfennel	Forb/herb	FACU
	3	*Juncus scirpoides* Lam.	needlepod rush, rush	Graminoid	FACW
	3	*Mikania scandens* (L.) Willd.	climbing hempweed, climbing hempvine	Vine, Forb/herb	FACW
	3	*Panicum amarum* Elliott	bitter panicgrass, colonial beachgrass	Graminoid	FAC
	3	*Solidago sempervirens* L.	seaside goldenrod	Forb/herb	FACW
	3	*Toxicodendron radicans* (L.) Kuntze	eastern poison ivy	Shrub, Forb/herb, Subshrub, Vine	FAC
	0.5	*Diodia teres* Walter	poorjoe	Forb/herb	FACU
	0.5	*Euthamia caroliniana* (L.) Green ex Porter & Britton	slender goldentop, flat-topped goldenrod	Forb/herb	FAC
	0.5	*Juncus dichotomus* Elliott	forked rush	Graminoid	FACW
	0.5	*Pluchea foetida* (L.) DC.	marsh fleabane, stinking camphorweed	Forb/herb	OBL
	0.5	*Polygonum puncatum* Elliott	dotted smartweed	Forb/herb	n/a

Site	Cover Class[†]	Scientific Name	Common Name	Growth Habit	Wetland Indicator Status[‡]
BC1 Mid	0.5	*Schoenoplectus americanus* (Pers.) Volkart ex Schinz & R. Keller	chairmaker's bulrush, three square	Graminoid	OBL
	0.5	*Solidago fistulosa* Mill.	pine barren goldenrod	Forb/herb	FAC
	0	*Fimbristylis castanea* (Michx.) Vahl	coastal fimbry, marsh fimbry	Graminoid	OBL
	0	*Hypericum gentianoides* (L.) Britton, Sterns & Poggenb.	orangegrass, pinweed	Forb/herb	FACU
	0	*Scleria verticillata* Muhl. Ex Willd.	whorled nutrush, low nutrush	Graminoid	OBL
BC1 High	10	*Morella pensylvanica* (Mirb.) Kartesz	northern bayberry	Tree, Shrub	FAC
	3	*Hudsonia tomentosa* Nutt.	Beach heath, false Heather, woolly hudsonia, woolly beachheather	Subshrub, Shrub	n/a
	3	*Pinus taeda* L.	loblolly pine	Tree	FAC
	3	*Schizachyrium scoparium* (Michx.) Nash	little bluestem	Graminoid	FACU
	0.5	*Hypericum gentianoides* (L.) Britton, Sterns & Poggenb.	orangegrass, pinweed	Forb/herb	FACU
	0.5	*Panicum amarum* Elliott	bitter panicgrass, colonial beachgrass	Graminoid	FAC
	0.5	*Salicornia depressa* Standl.	Virginia glasswort	Forb/herb, subshrub	n/a
	0	*Aristida tuberculosa* Nutt.	seaside threeawn	Graminoid	n/a
	0	*Cyperus grayi* Torr.	Gray's cyperus, Gray's flatsedge	Graminoid	n/a
	0	*Dichanthelium acuminatum* (Sw.) Gould & C.A. Clark var. *acuminatum*	tapered rosette grass, bushy panicgrass	Graminoid	FAC
	0	*Diodia teres* Walter	poorjoe	Forb/herb	FACU
	0	*Solidago sempervirens* L.	seaside goldenrod	Forb/herb	FACW

Site	Cover Class[†]	Scientific Name	Common Name	Growth Habit	Wetland Indicator Status[‡]
BC2 Low	60	*Schoenoplectus americanus* (Pers.) Volkart ex Schinz & R. Keller	chairmaker's bulrush, three square	Graminoid	OBL
	50	*Polygonum puncatum* Elliott	dotted smartweed	Forb/herb	n/a
	10	*Mikania scandens* (L.) Willd.	climbing hempweed, climbing hempvine	Vine, Forb/herb	FACW
	10	*Ptilimnium capillaceum* (Michx.) Raf	herbwilliam, mock bishop's weed	Forb/herb	OBL
	3	*Andropogon virginicus* L.	broomsedge bluestem	Graminoid	FAC
	3	*Echinochloa walteri* (Pursh) A. Heller	coast cockspur grass, long-awn cock's spur grass	Graminoid	OBL
	3	*Pluchea odorata* (L.) Cass.	sweetscent, marsh fleabane	Subshrub, Forb/herb	FACW
	0.5	*Dichanthelium scabriusculum* (Elliott) Gould & C.A. Clark	woolly rosette grass	Graminoid	OBL
	0	*Dichanthelium dichotomum* (L.) Gould var. *dichotomum*	cypress panicgrass	Graminoid	FAC
	0	*Pluchea foetida* (L.) DC.	marsh fleabane, stinking camphorweed	Forb/herb	OBL
BC2 Mid	dead (60)	*Ptilimnium capillaceum* (Michx.) Raf	herbwilliam, mock bishop's weed	Forb/herb	OBL
	40	*Schoenoplectus americanus* (Pers.) Volkart ex Schinz & R. Keller	chairmaker's bulrush, three square	Graminoid	OBL
	30	*Polygonum puncatum* Elliott	dotted smartweed	Forb/herb	n/a
	10	*Baccharis halimifolia* L.	groundsel, eastern baccharis	Tree, Shrub	FAC
	10	*Dichanthelium scabriusculum* (Elliott) Gould &	woolly rosette grass	Graminoid	OBL

Site	Cover Class[†]	Scientific Name	Common Name	Growth Habit	Wetland Indicator Status[‡]
BC2 Mid	3	*Andropogon virginicus* L.	broomsedge bluestem	Graminoid	FAC
	3	*Juncus scirpoides* Lam.	needlepod rush, rush	Graminoid	FACW
	3	*Mikania scandens* (L.) Willd.	climbing hempweed, climbing hempvine	Vine, Forb/herb	FACW
	3	*Panicum amarum* Elliott	bitter panicgrass, colonial beachgrass	Graminoid	FAC
	3	*Panicum virgatum* L.	switchgrass	Graminoid	FAC
	3	*Spartina patens* (Aiton) Muhl.	saltmeadow cordgrass	Graminoid	FACW
	0.5	*Dichanthelium acuminatum* (Sw.) Gould & C.A. Clark var. *acuminatum*	tapered rosette grass, bushy panicgrass	Graminoid	FAC
	0	*Cenchrus tribuloides* L.	sanddune sandbur	Graminoid	FACU
	0	*Echinochloa walteri* (Pursh) A. Heller	coast cockspur grass, long-awn cock's spur grass	Graminoid	OBL
	0	*Eragrostis spectabilis* (Pursh) Steud.	purple lovegrass	Graminoid	FACU
	0	*Eupatorium capillifolium* (Lam.)	dogfennel	Forb/herb	FACU
	0	*Fimbristylis caroliniana* (Lam.) Fernald	Carolina fimbry	Graminoid	OBL
	0	*Hydrocotyle verticillata* Thunb.	whorled water-pennywort, whorled marshpennywort	Forb/herb	OBL
	0	*Morella cerifera* (L.) Small	wax myrtle	Tree, Subshrub, Shrub	FAC
	0	*Pluchea odorata* (L.) Cass.	sweetscent, marsh fleabane	Subshrub, Forb/herb	FACW
	0	*Setaria parviflora* (Poir.) Kerguélen	marsh bristlegrass, knotroot bristlegrass	Graminoid	FACW
	0	*Solidago sempervirens* L.	seaside goldenrod	Forb/herb	FACW

Site	Cover Class[†]	Scientific Name	Common Name	Growth Habit	Wetland Indicator Status[‡]
BC2 High	10	*Pinus taeda* L.	loblolly pine	Tree	FAC
	3	*Andropogon virginicus* L.	broomsedge bluestem	Graminoid	FAC
	3	*Juncus dichotomus* Elliott	forked rush	Graminoid	FACW
	3	*Juncus scirpoides* Lam.	needlepod rush, rush	Graminoid	FACW
	3	*Panicum virgatum* L.	switchgrass	Graminoid	FAC
	3	*Schizachyrium scoparium* (Michx.) Nash	little bluestem	Graminoid	FACU
	0.5	*Cyperus grayi* Torr.	Gray's cyperus, Gray's flatsedge	Graminoid	n/a
	0.5	*Dichanthelium acuminatum* (Sw.) Gould & C.A. Clark var. *acuminatum*	tapered rosette grass, bushy panicgrass	Graminoid	FAC
	0.5	*Salicornia depressa* Standl.	Virginia glasswort	Forb/herb, subshrub	n/a
	0	*Juncus gerardii* Loisel.	saltmeadow rush, blackgrass	Graminoid	OBL
BC3 Low	60	*Spartina patens* (Aiton) Muhl.	saltmeadow cordgrass	Graminoid	FACW
	40	*Echinochloa walteri* (Pursh) A. Heller	coast cockspur grass, long-awn cock's spur grass	Graminoid	OBL
	3	*Schoenoplectus americanus* (Pers.) Volkart ex Schinz & R. Keller	chairmaker's bulrush, three square	Graminoid	OBL
	3	*Setaria parviflora* (Poir.) Kerguélen	marsh bristlegrass, knotroot bristlegrass	Graminoid	FACW
	0.5	*Mikania scandens* (L.) Willd.	climbing hempweed, climbing hempvine	Vine, Forb/herb	FACW
	0.5	*Pluchea odorata* (L.) Cass.	sweetscent, marsh fleabane	Subshrub, Forb/herb	FACW
	0	*Cyperus esculentus* L.	yellow nutsedge	Graminoid	FAC

Site	Cover Class[†]	Scientific Name	Common Name	Growth Habit	Wetland Indicator Status[‡]
BC3 Mid	80	*Spartina patens* (Aiton) Muhl.	saltmeadow cordgrass	Graminoid	FACW
	3	*Juncus dichotomus* Elliott	forked rush	Graminoid	FACW
	0.5	*Euthamia caroliniana* (L.) Green ex Porter & Britton	slender goldentop, flat-topped goldenrod	Forb/herb	FAC
	0.5	*Hypericum gentianoides* (L.) Britton, Sterns & Poggenb.	orangegrass, pinweed	Forb/herb	FACU
	0.5	*Schizachyrium scoparium* (Michx.) Nash	little bluestem	Graminoid	FACU
	0	*Dichanthelium acuminatum* (Sw.) Gould & C.A. Clark var. *acuminatum*	tapered rosette grass, bushy panicgrass	Graminoid	FAC
	0	*Eupatorium capillifolium* (Lam.)	dogfennel	Forb/herb	FACU
	0	*Lactuca canadensis* L.	wild lettuce, Canada lettuce	Forb/herb	FACU
	0	*Opuntia humifusa* (Raf.) Raf.	prickly-pear cactus, devil's tongue	Shrub	n/a
BC3 High	70	*Spartina patens* (Aiton) Muhl.	saltmeadow cordgrass	Graminoid	FACW
	10	*Morella pensylvanica* (Mirb.) Kartesz	northern bayberry	Tree, Shrub	FAC
	3	*Diospyros virginiana* L.	common persimmon	Tree	FAC
	3	*Euthamia caroliniana* (L.) Green ex Porter & Britton	slender goldentop, flat-topped goldenrod	Forb/herb	FAC
	3	*Schizachyrium scoparium* (Michx.) Nash	little bluestem	Graminoid	FACU
	3	*Vaccinium corymbosum* L.	highbush blueberry	Shrub	FACW
	3	*Vitis rotundifolia* Michx.	muscadine, muscadine grape, round-leaved grape	Vine	FAC
	0.5	*Dichanthelium acuminatum* (Sw.) Gould & C.A. Clark var. *acuminatum*	tapered rosette grass, bushy panicgrass	Graminoid	FAC
	0.5	*Eragrostis spectabilis* (Pursh) Steud.	purple lovegrass	Graminoid	FACU

Site	Cover Class[†]	Scientific Name	Common Name	Growth Habit	Wetland Indicator Status[‡]
BC3 High	0.5	*Eupatorium hyssopifolium* L.	hyssopleaf thoroughwort, hyssop-leaved eupatorium	Forb/herb	n/a
	0.5	*Juncus dichotomus* Elliott	forked rush	Graminoid	FACW
	0.5	*Rumex acetosella* L.	common sheep sorrel, red sorrel	Forb/herb	FACU
	0	*Opuntia humifusa* (Raf.) Raf.	prickly-pear cactus, devil's tongue	Shrub	n/a
BC4 Low	60	*Andropogon virginicus* L.	broomsedge bluestem	Graminoid	FAC
	40	*Dichanthelium acuminatum* (Sw.) Gould & C.A. Clark var. *acuminatum*	tapered rosette grass, bushy panicgrass	Graminoid	FAC
	30	*Dichanthelium scabriusculum* (Elliott) Gould &	woolly rosette grass	Graminoid	OBL
	20	*Morella cerifera* (L.) Small	wax myrtle	Tree, Subshrub, Shrub	FAC
	10	*Chasmanthium laxum* (L.) Yates	slender woodoats, spikegrass	Graminoid	FACW
	3	*Baccharis halimifolia* L.	groundsel, eastern baccharis	Tree, Shrub	FAC
	3	*Juncus dichotomus* Elliott	forked rush	Graminoid	FACW
	3	*Juncus scirpoides* Lam.	needlepod rush, rush	Graminoid	FACW
	3	*Leersia virginica* Willd.	whitegrass	Graminoid	FACW
	3	*Mikania scandens* (L.) Willd.	climbing hempweed, climbing hempvine	Vine, Forb/herb	FACW
	3	*Panicum virgatum* L.	switchgrass	Graminoid	FAC
	3	*Phytolacca americana* L.	American pokeweed	Forb/herb	FACU
	0.5	*Erechtites hieraciifolia* (L.) Raf. ex DC.	fireweed, American burnweed	Forb/herb	FAC
	0.5	*Solidago fistulosa* Mill.	pine barren goldenrod	Forb/herb	FAC
	0	*Carex hormathodes* Fernald	marsh straw sedge	Graminoid	OBL

Site	Cover Class[†]	Scientific Name	Common Name	Growth Habit	Wetland Indicator Status[‡]
BC4 Mid	0	*Pluchea odorata* (L.) Cass.	sweetscent, marsh fleabane	Subshrub, Forb/herb	FACW
	0	*Schoenoplectus americanus* (Pers.) Volkart ex Schinz & R. Keller	chairmaker's bulrush, three square	Graminoid	OBL
	70	*Andropogon virginicus* L.	broomsedge bluestem	Graminoid	FAC
	60	*Dichanthelium scabriusculum* (Elliott) Gould &	woolly rosette grass	Graminoid	OBL
	40	*Dichanthelium acuminatum* (Sw.) Gould & C.A. Clark var. *acuminatum*	tapered rosette grass, bushy panicgrass	Graminoid	FAC
	20	*Pinus taeda* L.	loblolly pine	Tree	FAC
	10	*Baccharis halimifolia* L.	groundsel, eastern baccharis	Tree, Shrub	FAC
	10	*Chasmanthium laxum* (L.) Yates	slender woodoats, spikegrass	Graminoid	FACW
	10	*Morella cerifera* (L.) Small	wax myrtle	Tree, Subshrub, Shrub	FAC
	10	*Smilax rotundafolia* L.	roundleaf greenbrier	Shrub, Vine	FAC
	3	*Juncus dichotomus* Elliott	forked rush	Graminoid	FACW
	3	*Panicum virgatum* L.	switchgrass	Graminoid	FAC
	3	*Rubus* L.	blackberry	Subshrub	FAC, FACU, UPL
	3	*Vitis rotundifolia* Michx.	muscadine, muscadine grape, round-leaved grape	Vine	FAC
	0	*Eupatorium hyssopifolium* L.	hyssopleaf thoroughwort, hyssop-leaved eupatorium	Forb/herb	n/a
	0	*Lonicera japonica* Thunb.	Japanese honeysuckle	Vine	FAC

Site	Cover Class[†]	Scientific Name	Common Name	Growth Habit	Wetland Indicator Status[‡]
	0	*Parthenocissus quinquefolia* (L.) Planch.	Virginia creeper	Vine	FACU
	0	*Vaccinium corymbosum* L.	highbush blueberry	Shrub	FACW
BC4 High	60	*Triplasis purpurea* (Walter) Chapm.	purple sandgrass	Graminoid	n/a
	3	*Andropogon virginicus* L.	broomsedge bluestem	Graminoid	FAC
	3	*Dichanthelium acuminatum* (Sw.) Gould & C.A. Clark var. *acuminatum*	tapered rosette grass, bushy panicgrass	Graminoid	FAC
	3	*Eupatorium hyssopifolium* L.	hyssopleaf thoroughwort, hyssop-leaved eupatorium	Forb/herb	n/a
	3	*Opuntia humifusa* (Raf.) Raf.	prickly-pear cactus, devil's tongue	Shrub	n/a
	3	*Panicum amarum* Elliott	bitter panicgrass, colonial beachgrass	Graminoid	FAC
	3	*Panicum virgatum* L.	switchgrass	Graminoid	FAC
	3	*Rubus* L.	blackberry	Subshrub	FAC, FACU, UPL
	3	*Rumex acetosella* L.	common sheep sorrel, red sorrel	Forb/herb	FACU
	3	*Schizachyrium scoparium* (Michx.) Nash	little bluestem	Graminoid	FACU
	0.5	*Dichanthelium scabriusculum* (Elliott) Gould &	woolly rosette grass	Graminoid	OBL
	0.5	*Spartina patens* (Aiton) Muhl.	saltmeadow cordgrass	Graminoid	FACW
	0	*Baccharis halimifolia* L.	groundsel, eastern baccharis	Tree, Shrub	FAC
	0	*Bulbostylis capillaris* (L.) Kunth ex C.B. Clarke	densetuft hairsedge	Graminoid	FAC
	0	*Hypochaeris radicata* L.	hairy cat's ear	Forb/herb	UPL

Site	Cover Class[†]	Scientific Name	Common Name	Growth Habit	Wetland Indicator Status[‡]
BC4 High	0	*Smilax glauca* Walter	cat greenbrier	Shrub, Vine	FAC
	0	*Solidago sempervirens* L.	seaside goldenrod	Forb/herb	FACW
	0	*Vitis rotundifolia* Michx.	muscadine, muscadine grape, round-leaved grape	Vine	FAC
BC5 Low	30	*Acer rubrum L.*	red maple	Tree	FAC
	20	*Morella cerifera* (L.) Small	wax myrtle	Tree, Subshrub, Shrub	FAC
	10	*Pinus taeda* L.	loblolly pine	Tree	FAC
	10	*Vaccinium corymbosum* L.	highbush blueberry	Shrub	FACW
	3	*Amelanchier canadensis* (L.) Medik.	serviceberry, Canadian serviceberry	Tree, Shrub	FAC
	3	*Ilex opaca* Aiton	American holly	Tree, Shrub	FAC
	0.5	*Smilax rotundafolia* L.	roundleaf greenbrier	Shrub, Vine	FAC
	0	*Toxicodendron radicans* (L.) Kuntze	eastern poison ivy	Shrub, Forb/herb, Subshrub, Vine	FAC
BC5 Mid	50	*Pinus taeda* L.	loblolly pine	Tree	FAC
	40	*Acer rubrum* L.	red maple	Tree	FAC
	20	*Smilax rotundafolia* L.	roundleaf greenbrier	Shrub, Vine	FAC
	10	*Diospyros virginiana* L.	common persimmon	Tree	FAC
	10	*Vaccinium corymbosum* L.	highbush blueberry	Shrub	FACW
	10	*Vitis rotundifolia* Michx.	muscadine, muscadine grape, round-leaved grape	Vine	FAC

Site	Cover Class[†]	Scientific Name	Common Name	Growth Habit	Wetland Indicator Status[‡]
BC5 Mid	3	*Amelanchier canadensis* (L.) Medik.	serviceberry, Canadian serviceberry	Tree, Shrub	FAC
	0	*Smilax glauca* Walter	cat greenbrier	Shrub, Vine	FAC
BC5 High	50	*Pinus taeda* L.	loblolly pine	Tree	FAC
	40	*Diospyros virginiana* L.	common persimmon	Tree	FAC
	10	*Vitis rotundifolia* Michx.	muscadine, muscadine grape, round-leaved grape	Vine	FAC
	3	*Chasmanthium laxum* (L.) Yates	slender woodoats, spikegrass	Graminoid	FACW
	3	*Smilax rotundafolia* L.	roundleaf greenbrier	Shrub, Vine	FAC
	0	*Amelanchier canadensis* (L.) Medik.	serviceberry, Canadian serviceberry	Tree, Shrub	FAC
	0	*Carex hormathodes* Fernald	marsh straw sedge	Graminoid	OBL
	0	*Smilax glauca* Walter	cat greenbrier	Shrub, Vine	FAC
BC6 Low	60	*Acer rubrum* L.	red maple	Tree	FAC
	60	*Morella cerifera* (L.) Small	wax myrtle	Tree, Subshrub, Shrub	FAC
	20	*Vaccinium corymbosum* L.	highbush blueberry	Shrub	FACW
	10	*Amelanchier canadensis* (L.) Medik.	serviceberry, Canadian serviceberry	Tree, Shrub	FAC
	3	*Echinochloa walteri* (Pursh) A. Heller	coast cockspur grass, long-awn cock's spur grass	Graminoid	OBL
	3	*Pinus taeda* L.	loblolly pine	Tree	FAC
	0	*Cyperus esculentus* L.	yellow nutsedge	Graminoid	FAC

Site	Cover Class[†]	Scientific Name	Common Name	Growth Habit	Wetland Indicator Status[‡]
BC6 Low	0	*Pluchea odorata* (L.) Cass.	sweetscent, marsh fleabane	Subshrub, Forb/herb	FACW
BC6 Mid	60	*Acer rubrum* L.	red maple	Tree	FAC
	30	*Vaccinium corymbosum* L.	highbush blueberry	Shrub	FACW
	3	*Pinus taeda* L.	loblolly pine	Tree	FAC
	3	*Smilax rotundafolia* L.	roundleaf greenbrier	Shrub, Vine	FAC
	0.5	*Ilex opaca* Aiton	American holly	Tree, Shrub	FAC
	0	*Chasmanthium laxum* (L.) Yates	slender woodoats, spikegrass	Graminoid	FACW
BC6 High	80	*Amelanchier canadensis* (L.) Medik.	serviceberry, Canadian serviceberry	Tree, Shrub	FAC
	40	*Vaccinium corymbosum* L.	highbush blueberry	Shrub	FACW
	10	*Ilex opaca* Aiton	American holly	Tree, Shrub	FAC
	10	*Morella cerifera* (L.) Small	wax myrtle	Tree, Subshrub, Shrub	FAC
	3	*Pinus taeda* L.	loblolly pine	Tree	FAC
	3	*Acer rubrum* L.	red maple	Tree	FAC
	0.5	*Vitis rotundifolia* Michx.	muscadine, muscadine grape, round-leaved grape	Vine	FAC
	0.5	*Chasmanthium laxum* (L.) Yates	slender woodoats, spikegrass	Graminoid	FACW
OW1 Low	70	*Andropogon virginicus* L.	broomsedge bluestem	Graminoid	FAC
	40	*Juncus scirpoides* Lam.	needlepod rush, rush	Graminoid	FACW
	30	*Juncus dichotomus* Elliott	forked rush	Graminoid	FACW
	30	*Solidago sempervirens* L.	seaside goldenrod	Forb/herb	FACW

Site	Cover Class[†]	Scientific Name	Common Name	Growth Habit	Wetland Indicator Status[‡]
OW1 Low	3	*Dichanthelium acuminatum* (Sw.) Gould & C.A. Clark var. *acuminatum*	tapered rosette grass, bushy panicgrass	Graminoid	FAC
	3	*Dichanthelium scabriusculum* (Elliott) Gould &	woolly rosette grass	Graminoid	OBL
	3	*Leersia virginica* Willd.	whitegrass	Graminoid	FACW
	3	*Phragmites australis* (Cav.) Trin. Ex Steud.	common reed	subshrub, shrub, graminoid	FACW
	3	*Pluchea odorata* (L.) Cass.	sweetscent, marsh fleabane	Subshrub, Forb/herb	FACW
	0.5	*Andropogon glomeratus* (Walter) Britton, Sterns, & Poggenb.	bushy bluestem, broom-sedge	Graminoid	FACW
	0.5	*Baccharis halimifolia* L.	groundsel, eastern baccharis	Tree, Shrub	FAC
	0.5	*Eupatorium capillifolium* (Lam.)	dogfennel	Forb/herb	FACU
	0.5	*Morella cerifera* (L.) Small	wax myrtle	Tree, Subshrub, Shrub	FAC
	0	*Eupatorium hyssopifolium* L.	hyssopleaf thoroughwort, hyssop-leaved eupatorium	Forb/herb	n/a
	0	*Hypericum gentianoides* (L.) Britton, Sterns & Poggenb.	orangegrass, pinweed	Forb/herb	FACU
	0	*Juniperus virginiana* L.	eastern redcedar	Tree	FACU
	0	*Mikania scandens* (L.) Willd.	climbing hempweed, climbing hempvine	Vine, Forb/herb	FACW
OW1 Mid	40	*Hypericum gentianoides* (L.) Britton, Sterns & Poggenb.	orangegrass, pinweed	Forb/herb	FACU

Site	Cover Class†	Scientific Name	Common Name	Growth Habit	Wetland Indicator Status‡
OW1 Mid	20	*Euthamia caroliniana* (L.) Green ex Porter & Britton	slender goldentop, flat-topped goldenrod	Forb/herb	FAC
	20	*Solidago sempervirens* L.	seaside goldenrod	Forb/herb	FACW
	10	*Juncus dichotomus* Elliott	forked rush	Graminoid	FACW
	3	*Andropogon virginicus* L.	broomsedge bluestem	Graminoid	FAC
	3	*Panicum virgatum* L.	switchgrass	Graminoid	FAC
	0.5	*Dichanthelium acuminatum* (Sw.) Gould & C.A. Clark var. *acuminatum*	tapered rosette grass, bushy panicgrass	Graminoid	FAC
	0.5	*Eupatorium capillifolium* (Lam.)	dogfennel	Forb/herb	FACU
	0.5	*Eupatorium hyssopifolium* L.	hyssopleaf thoroughwort, hyssop-leaved eupatorium	Forb/herb	n/a
	0.5	*Triplasis purpurea* (Walter) Chapm.	purple sandgrass	Graminoid	n/a
	0	*Ammophila breviligulata* Fernald	American beachgrass	Graminoid	UPL
	0	*Cenchrus tribuloides* L.	sanddune sandbur	Graminoid	FACU
	0	*Eragrostis spectabilis* (Pursh) Steud.	purple lovegrass	Graminoid	FACU
	0	*Juncus scirpoides* Lam.	needlepod rush, rush	Graminoid	FACW
	0	*Phragmites australis* (Cav.) Trin. Ex Steud.	common reed	subshrub, shrub, graminoid	FACW
	0	*Pseudognaphalium obtusifolium* (L.) Hilliard & B.L. Burtt ssp. *Obusifloium*	rabbit-tobacco, cudweed	Forb/herb	n/a
OW1 High	50	*Solidago sempervirens* L.	seaside goldenrod	Forb/herb	FACW
	10	*Euthamia caroliniana* (L.) Green ex Porter & Britton	slender goldentop, flat-topped goldenrod	Forb/herb	FAC
	10	*Triplasis purpurea* (Walter) Chapm.	purple sandgrass	Graminoid	n/a

Site	Cover Class[†]	Scientific Name	Common Name	Growth Habit	Wetland Indicator Status[‡]
OW1 High	3	*Panicum virgatum* L.	switchgrass	Graminoid	FAC
	0.5	*Baccharis halimifolia* L.	groundsel, eastern baccharis	Tree, Shrub	FAC
	0	*Eupatorium hyssopifolium* L.	hyssopleaf thoroughwort, hyssop-leaved eupatorium	Forb/herb	n/a
	0	*Spartina patens* (Aiton) Muhl.	saltmeadow cordgrass	Graminoid	FACW
OW2 Low	70	*Pluchea odorata* (L.) Cass.	sweetscent, marsh fleabane	Subshrub, Forb/herb	FACW
	70	*Schoenoplectus americanus* (Pers.) Volkart ex Schinz & R. Keller	chairmaker's bulrush, three square	Graminoid	OBL
	40	*Setaria parviflora* (Poir.) Kerguélen	marsh bristlegrass, knotroot bristlegrass	Graminoid	FACW
	30	*Agrostis gigantea* Roth	redtop	Graminoid	FACW
	20	*Iva frutescens* L.	Jesuit's bark	Subshrub, Forb/herb	FACW
	3	*Fimbristylis caroliniana* (Lam.) Fernald	Carolina fimbry	Graminoid	OBL
	3	*Fimbristylis castanea* (Michx.) Vahl	coastal fimbry, marsh fimbry	Graminoid	OBL
	3	*Mikania scandens* (L.) Willd.	climbing hempweed, climbing hempvine	Vine, Forb/herb	FACW
	0.5	*Distichlis spicata* (L.) Greene	saltgrass	Graminoid	OBL
	0.5	*Solidago sempervirens* L.	seaside goldenrod	Forb/herb	FACW
	0	*Phragmites australis* (Cav.) Trin. Ex Steud.	common reed	subshrub, shrub, graminoid	FACW
OW2 Mid	70	*Dichanthelium acuminatum* (Sw.) Gould & C.A. Clark var. *acuminatum*	tapered rosette grass, bushy panicgrass	Graminoid	FAC

Site	Cover Class†	Scientific Name	Common Name	Growth Habit	Wetland Indicator Status‡
OW2 Mid	60	*Panicum virgatum* L.	switchgrass	Graminoid	FAC
	40	*Toxicodendron radicans* (L.) Kuntze	eastern poison ivy	Shrub, Forb/herb, Subshrub, Vine	FAC
	20	*Rubus* L.	blackberry	Subshrub	FAC, FACU, UPL
	10	*Eupatorium capillifolium* (Lam.)	dogfennel	Forb/herb	FACU
	10	*Hypericum gentianoides* (L.) Britton, Sterns & Poggenb.	orangegrass, pinweed	Forb/herb	FACU
	3	*Andropogon virginicus* L.	broomsedge bluestem	Graminoid	FAC
	3	*Eupatorium hyssopifolium* L.	hyssopleaf thoroughwort, hyssop-leaved eupatorium	Forb/herb	n/a
	3	*Fimbristylis castanea* (Michx.) Vahl	coastal fimbry, marsh fimbry	Graminoid	OBL
	3	*Juncus dichotomus* Elliott	forked rush	Graminoid	FACW
	3	*Juncus scirpoides* Lam.	needlepod rush, rush	Graminoid	FACW
	3	*Setaria parviflora* (Poir.) Kerguélen	marsh bristlegrass, knotroot bristlegrass	Graminoid	FACW
	3	*Solidago sempervirens* L.	seaside goldenrod	Forb/herb	FACW
	0.5	*Baccharis halimifolia* L.	groundsel, eastern baccharis	Tree, Shrub	FAC
	0.5	*Eragrostis spectabilis* (Pursh) Steud.	purple lovegrass	Graminoid	FACU
	0.5	*Nuttallanthus canadensis* (L.) D.A. Sutton	Canada toadflax	Forb/herb	n/a
	0.5	*Schoenoplectus americanus* (Pers.) Volkart ex Schinz & R. Keller	chairmaker's bulrush, three square	Graminoid	OBL
	0.5	*Vitis rotundifolia* Michx.	muscadine, muscadine grape, round-leaved grape	Vine	FAC

Site	Cover Class[†]	Scientific Name	Common Name	Growth Habit	Wetland Indicator Status[‡]
OW2 Mid	0	*Cyperus retrorsus* Chapm.	pine barren flatsedge, umbrella-sedge	Graminoid	FACU
	0	*Euthamia caroliniana* (L.) Green ex Porter & Britton	slender goldentop, flat-topped goldenrod	Forb/herb	FAC
OW2 High	20	*Hudsonia tomentosa* Nutt.	Beach heath, false Heather, woolly hudsonia, woolly beachheather	Subshrub, Shrub	n/a
	20	*Rubus* L.	blackberry	Subshrub	FAC, FACU, UPL
	10	*Eupatorium hyssopifolium* L.	hyssopleaf thoroughwort, hyssop-leaved eupatorium	Forb/herb	n/a
	10	*Euthamia caroliniana* (L.) Green ex Porter & Britton	slender goldentop, flat-topped goldenrod	Forb/herb	FAC
	10	*Juncus scirpoides* Lam.	needlepod rush, rush	Graminoid	FACW
	10	*Panicum virgatum* L.	switchgrass	Graminoid	FAC
	3	*Ammophila breviligulata* Fernald	American beachgrass	Graminoid	UPL
	3	*Andropogon virginicus* L.	broomsedge bluestem	Graminoid	FAC
	3	*Dichanthelium acuminatum* (Sw.) Gould & C.A. Clark var. *acuminatum*	tapered rosette grass, bushy panicgrass	Graminoid	FAC
	3	*Fimbristylis castanea* (Michx.) Vahl	coastal fimbry, marsh fimbry	Graminoid	OBL
	3	*Hypericum gentianoides* (L.) Britton, Sterns & Poggenb.	orangegrass, pinweed	Forb/herb	FACU
	3	*Juncus dichotomus* Elliott	forked rush	Graminoid	FACW
	0.5	*Baccharis halimifolia* L.	groundsel, eastern baccharis	Tree, Shrub	FAC

Site	Cover Class[†]	Scientific Name	Common Name	Growth Habit	Wetland Indicator Status[‡]
OW2 High	0.5	*Cyperus retrorsus* Chapm.	pine barren flatsedge, umbrella-sedge	Graminoid	FACU
	0.5	*Lechea maritima* Leggett ex. Britton, Sterns & Poggenb. var. *virginica* Hodgdon	Virginia pinweed	Subshrub, Forb/herb	n/a
	0	*Eupatorium rotundifolium* L. var. *ovatum* (Bigelow) Torr.	roundleaf thoroughwort, oval-leaf eupatorium	Forb/herb	FAC
OW3 Low	80	*Spartina patens* (Aiton) Muhl.	saltmeadow cordgrass	Graminoid	FACW
	60	*Lythrum lineare* L.	wand lythrum, loosestrife, saltmarsh loosestrife	Forb/herb	OBL
	50	*Fimbristylis castanea* (Michx.) Vahl	coastal fimbry, marsh fimbry	Graminoid	OBL
	40	*Iva frutescens* L.	Jesuit's bark	Subshrub, Forb/herb	FACW
	30	*Pluchea odorata* (L.) Cass.	sweetscent, marsh fleabane	Subshrub, Forb/herb	FACW
	20	*Baccharis halimifolia* L.	groundsel, eastern baccharis	Tree, Shrub	FAC
	10	*Distichlis spicata* (L.) Greene	saltgrass	Graminoid	OBL
	10	*Schoenoplectus americanus* (Pers.) Volkart ex Schinz & R. Keller	chairmaker's bulrush, three square	Graminoid	OBL
	0.5	*Phragmites australis* (Cav.) Trin. Ex Steud.	common reed	subshrub, shrub, graminoid	FACW
	0.5	*Setaria parviflora* (Poir.) Kerguélen	marsh bristlegrass, knotroot bristlegrass	Graminoid	FACW
	0	*Mikania scandens* (L.) Willd.	climbing hempweed, climbing hempvine	Vine, Forb/herb	FACW

Site	Cover Class[†]	Scientific Name	Common Name	Growth Habit	Wetland Indicator Status[‡]
OW3 Low	0	*Solidago sempervirens* L.	seaside goldenrod	Forb/herb	FACW
OW3 Mid	40	*Eleocharis rostellata* (Torr.) Torr.	beaked spikerush, walking spikerush	Graminoid	OBL
	20	*Panicum virgatum* L.	switchgrass	Graminoid	FAC
	20	*Phragmites australis* (Cav.) Trin. Ex Steud.	common reed	subshrub, shrub, graminoid	FACW
	20	*Scleria verticillata* Muhl. Ex Willd.	whorled nutrush, low nutrush	Graminoid	OBL
	10	*Fimbristylis caroliniana* (Lam.) Fernald	Carolina fimbry	Graminoid	OBL
	10	*Fimbristylis castanea* (Michx.) Vahl	coastal fimbry, marsh fimbry	Graminoid	OBL
	3	*Andropogon glomeratus* (Walter) Britton, Sterns, & Poggenb.	bushy bluestem, broom-sedge	Graminoid	FACW
	3	*Baccharis halimifolia* L.	groundsel, eastern baccharis	Tree, Shrub	FAC
	3	*Dichanthelium acuminatum* (Sw.) Gould & C.A. Clark var. *acuminatum*	tapered rosette grass, bushy panicgrass	Graminoid	FAC
	3	*Eupatorium hyssopifolium* L.	hyssopleaf thoroughwort, hyssop-leaved eupatorium	Forb/herb	n/a
	3	*Euthamia caroliniana* (L.) Green ex Porter & Britton	slender goldentop, flat-topped goldenrod	Forb/herb	FAC
	3	*Juncus scirpoides* Lam.	needlepod rush, rush	Graminoid	FACW
	3	*Morella cerifera* (L.) Small	wax myrtle	Tree, Subshrub, Shrub	FAC
	3	*Setaria parviflora* (Poir.) Kerguélen	marsh bristlegrass, knotroot bristlegrass	Graminoid	FACW
	0.5	*Eragrostis spectabilis* (Pursh) Steud.	purple lovegrass	Graminoid	FACU

Site	Cover Class[†]	Scientific Name	Common Name	Growth Habit	Wetland Indicator Status[‡]
OW3 Mid	0.5	*Pluchea odorata* (L.) Cass.	sweetscent, marsh fleabane	Subshrub, Forb/herb	FACW
	0.5	*Schoenoplectus americanus* (Pers.) Volkart ex Schinz & R. Keller	chairmaker's bulrush, three square	Graminoid	OBL
	0	*Solidago sempervirens* L.	seaside goldenrod	Forb/herb	FACW
OW3 High	50	*Hudsonia tomentosa* Nutt.	Beach heath, false Heather, woolly hudsonia, woolly beachheather	Subshrub, Shrub	n/a
	10	*Panicum virgatum* L.	switchgrass	Graminoid	FAC
	3	*Ammophila breviligulata* Fernald	American beachgrass	Graminoid	UPL
	3	*Dichanthelium scabriusculum* (Elliott) Gould &	woolly rosette grass	Graminoid	OBL
	3	*Eupatorium hyssopifolium* L.	hyssopleaf thoroughwort, hyssop-leaved eupatorium	Forb/herb	n/a
	3	*Euthamia caroliniana* (L.) Green ex Porter & Britton	slender goldentop, flat-topped goldenrod	Forb/herb	FAC
	3	*Pinus taeda* L.	loblolly pine	Tree	FAC
	0.5	*Baccharis halimifolia* L.	groundsel, eastern baccharis	Tree, Shrub	FAC
	0.5	*Dichanthelium acuminatum* (Sw.) Gould & C.A. Clark var. *acuminatum*	tapered rosette grass, bushy panicgrass	Graminoid	FAC
	0.5	*Dichanthelium scoparium* (Lam.) Gould	velvet panicum	Graminoid	FACW
	0.5	*Eragrostis spectabilis* (Pursh) Steud.	purple lovegrass	Graminoid	FACU
	0.5	*Rubus* L.	blackberry	Subshrub	FAC, FACU, UPL

Site	Cover Class[†]	Scientific Name	Common Name	Growth Habit	Wetland Indicator Status[‡]
OW3 High	0	*Cyperus grayi* Torr.	Gray's cyperus, Gray's flatsedge	Graminoid	n/a
	0	*Juncus dichotomus* Elliott	forked rush	Graminoid	FACW
	0	*Morella cerifera* (L.) Small	wax myrtle	Tree, Subshrub, Shrub	FAC
	0	*Phragmites australis* (Cav.) Trin. Ex Steud.	common reed	subshrub, shrub, graminoid	FACW
	0	*Solidago sempervirens* L.	seaside goldenrod	Forb/herb	FACW
OW4 Low	80	*Phragmites australis* (Cav.) Trin. Ex Steud.	common reed	subshrub, shrub, graminoid	FACW
	50	*Baccharis halimifolia* L.	groundsel, eastern baccharis	Tree, Shrub	FAC
	30	*Panicum virgatum* L.	switchgrass	Graminoid	FAC
	20	*Solidago sempervirens* L.	seaside goldenrod	Forb/herb	FACW
	10	*Juncus scirpoides* Lam.	needlepod rush, rush	Graminoid	FACW
	3	*Andropogon glomeratus* (Walter) Britton, Sterns, & Poggenb.	bushy bluestem, broom-sedge	Graminoid	FACW
	3	*Hypericum gentianoides* (L.) Britton, Sterns & Poggenb.	orangegrass, pinweed	Forb/herb	FACU
	3	*Morella cerifera* (L.) Small	wax myrtle	Tree, Subshrub, Shrub	FAC
	3	*Schoenoplectus americanus* (Pers.) Volkart ex Schinz & R. Keller	chairmaker's bulrush, three square	Graminoid	OBL
	0.5	*Andropogon virginicus* L.	broomsedge bluestem	Graminoid	FAC
	0.5	*Eragrostis spectabilis* (Pursh) Steud.	purple lovegrass	Graminoid	FACU
	0.5	*Euthamia caroliniana* (L.) Green ex Porter & Britton	slender goldentop, flat-topped goldenrod	Forb/herb	FAC

Site	Cover Class[†]	Scientific Name	Common Name	Growth Habit	Wetland Indicator Status[‡]
OW4 Low	0.5	*Fimbristylis caroliniana* (Lam.) Fernald	Carolina fimbry	Graminoid	OBL
	0.5	*Pluchea odorata* (L.) Cass.	sweetscent, marsh fleabane	Subshrub, Forb/herb	FACW
OW4 Mid	40	*Solidago sempervirens* L.	seaside goldenrod	Forb/herb	FACW
	20	*Euthamia caroliniana* (L.) Green ex Porter & Britton	slender goldentop, flat-topped goldenrod	Forb/herb	FAC
	10	*Baccharis halimifolia* L.	groundsel, eastern baccharis	Tree, Shrub	FAC
	3	*Hypericum gentianoides* (L.) Britton, Sterns & Poggenb.	orangegrass, pinweed	Forb/herb	FACU
	3	*Juncus scirpoides* Lam.	needlepod rush, rush	Graminoid	FACW
	3	*Panicum amarum* Elliott	bitter panicgrass, colonial beachgrass	Graminoid	FAC
	3	*Phragmites australis* (Cav.) Trin. Ex Steud.	common reed	subshrub, shrub, graminoid	FACW
	0.5	*Ammophila breviligulata* Fernald	American beachgrass	Graminoid	UPL
	0.5	*Cenchrus tribuloides* L.	sanddune sandbur	Graminoid	FACU
	0.5	*Fimbristylis caroliniana* (Lam.) Fernald	Carolina fimbry	Graminoid	OBL
	0.5	*Fimbristylis castanea* (Michx.) Vahl	coastal fimbry, marsh fimbry	Graminoid	OBL
	0.5	*Panicum virgatum* L.	switchgrass	Graminoid	FAC
	0	*Hypochaeris radicata* L.	hairy cat's ear	Forb/herb	UPL
OW4 High	40	*Baccharis halimifolia* L.	groundsel, eastern baccharis	Tree, Shrub	FAC
	30	*Solidago sempervirens* L.	seaside goldenrod	Forb/herb	FACW
	20	*Panicum amarum* Elliott	bitter panicgrass, colonial beachgrass	Graminoid	FAC

Site	Cover Class[†]	Scientific Name	Common Name	Growth Habit	Wetland Indicator Status[‡]
OW4 High	3	*Cenchrus tribuloides* L.	sanddune sandbur	Graminoid	FACU
	3	*Euthamia caroliniana* (L.) Green ex Porter & Britton	slender goldentop, flat-topped goldenrod	Forb/herb	FAC
	3	*Fimbristylis castanea* (Michx.) Vahl	coastal fimbry, marsh fimbry	Graminoid	OBL
	0.5	*Ammophila breviligulata* Fernald	American beachgrass	Graminoid	UPL

[†] Cover classes: 0 = trace, 0.5 = 0-1% cover, 3 = 1-5% cover, 10 = 5-15% cover, 20 = 15-25% cover, 30 = 25-35% cover, 40 = 35-45% cover, 50 = 45-55% cover, 60 = 55-65% cover, 70 = 65-75% cover, 80 = 75-85% cover

[‡] Wetland Indicator Codes: OBL = obligate wetland, almost always occur in wetlands; FACW = facultative wetland, usually occur in wetlands, but may occur in non-wetlands; FAC = facultative, occur in wetlands and non-wetlands; FACU = facultative upland, usually occur in non-wetlands, but may occur in wetlands; UPL = obligate upland, almost never occur in wetland

APPENDIX K: CARBON AND NITROGEN INPUTS

Herbaceous Aboveground Biomass

			Live Standing Biomass				
Site	Rep	Dead Standing Biomass Dry Weight	Dry Weight	Carbon	Aboveground Carbon Inputs	Nitrogen	Aboveground Nitrogen Inputs
		------- g $m^{-2}yr^{-1}$	-------	%	g C $m^{-2}yr^{-1}$	%	g N $m^{-2}yr^{-1}$
BC1 Low	1	129.79	194.10	47.16	91.5	0.87	1.69
	2	275.30	204.53	46.25	94.6	1.17	2.39
	3	332.14	361.32	45.35	163.8	0.88	3.16
BC1 Mid	1	147.57	95.09	47.98	45.6	0.78	0.74
	2	234.52	101.34	47.78	48.4	0.87	0.88
	3	256.37	256.85	48.05	123.4	1.00	2.57
BC1 High	1	58.76	30.49	47.58	14.5	1.05	0.32
	2	40.49	2.97	43.70	1.3	1.05	0.03
	3	26.85	14.60	45.42	6.6	0.79	0.11
BC2 Low	1	343.91	220.31	46.21	134.8	1.10	3.20
	2	516.76	237.65	46.94	103.4	1.15	2.54
	3	380.92	181.08	45.97	109.2	1.00	2.38
BC2 Mid	1	241.20	173.48	47.06	81.6	1.04	1.81
	2	178.51	98.64	46.51	45.9	1.02	1.01
	3	291.72	137.12	47.19	64.7	1.07	1.47
BC2 High	1	0.72	8.15	33.86	2.8	1.09	0.09
	2	0.57	14.23	40.05[†]	5.7	0.99	0.14
	3	4.36	36.31	46.24	16.8	0.88	0.32
BC3 Low	1	762.32	446.73	48.15	215.1	0.85	3.78
	2	541.08	288.72	48.08	138.8	0.94	2.72
	3	288.00	320.97	45.96	147.5	0.70	2.25
BC3 Mid	1	177.79	244.95	48.48	118.7	0.61	1.50
	2	113.27	191.75	47.50	91.1	0.53	1.01
	3	123.94	164.75	47.65	78.5	0.54	0.89
BC3 High	1	161.50	264.58	47.96	126.9	0.61	1.60
	2	66.39	132.95	46.48	61.8	0.62	0.82
	3	121.62	120.83	47.15	57.0	0.68	0.82
BC4 Low	1	261.33	435.79	51.23	223.2	0.95	4.16
	2	265.90	634.55	46.69	296.3	1.18	7.51
	3	85.78	678.53	48.36	328.1	0.88	5.98
BC4 Mid	1	278.36	519.31	47.74	247.9	0.73	3.77
	2	137.11	423.36	46.80	198.1	0.75	3.18
	3	333.96	617.16	47.43	292.7	0.88	5.45
BC4 High	1	41.04	139.31	46.30	64.5	1.14	1.59
	2	109.60	127.21	47.12	59.9	1.47	1.87
	3	156.35	94.07	46.74	44.0	1.02	0.96
OW1 Low	1	109.17	343.60	48.99	168.3	0.92	3.15
	2	62.69	414.25	48.45	200.7	0.59	2.45
	3	76.46	468.04	47.69	223.2	0.89	4.16
OW1 Mid	1	3.85	36.01	46.78	16.8	1.57	0.56
	2	36.46	234.56	47.52	111.5	0.83	1.95

			Live Standing Biomass				
Site	Rep	Dead Standing Biomass Dry Weight	Dry Weight	Carbon	Aboveground Carbon Inputs	Nitrogen	Aboveground Nitrogen Inputs
		------- g $m^{-2}yr^{-1}$	-------	%	g C $m^{-2}yr^{-1}$	%	g N $m^{-2}yr^{-1}$
OW1 Mid	3	25.47	18.35	45.51	8.4	1.55	0.29
OW1 High	1	18.44	37.39	49.24	18.4	1.57	0.59
	2	20.24	197.52	47.28	93.4	1.27	2.51
	3	15.36	56.51	40.35	22.8	0.85	0.48
OW2 Low	1	185.64	441.44	45.60	201.3	0.94	4.17
	2	308.95	379.03	46.88	177.7	1.15	4.37
	3	117.77	410.77	45.53	187.0	1.02	4.18
OW2 Mid	1	3.49	260.59	47.64	124.1	1.36	3.53
	2	9.86	384.35	47.33	181.9	0.78	2.98
	3	125.67	346.03	48.94	169.3	0.68	2.37
OW2 High	1	16.67	39.47	41.17	16.2	0.79	0.79
	2	12.29	157.62	41.59	65.6	0.93	0.93
	3	31.70	77.14	42.58	32.8	0.93	0.93
OW3 Low	1	351.40	495.26	45.66	226.1	0.89	4.43
	2	293.48	484.08	46.48	225.0	0.93	4.52
	3	106.25	743.43	44.80	333.1	0.86	6.41
OW3 Mid	1	166.93	175.48	47.74	83.8	0.96	1.68
	2	125.93	255.01	47.65	121.5	1.04	2.66
	3	72.80	373.12	46.96	175.2	0.71	2.66
OW3 High	1	0.76	23.73	49.52	11.8	0.94	0.22
	2	34.45	164.70	44.33	73.0	0.81	1.33
	3	95.17	103.89	47.27	49.1	0.98	1.02
OW4 Low	1	0.00	535.59	45.26	242.4	1.12	5.97
	2	19.73	382.62	43.94	168.1	0.99	3.78
	3	86.69	375.09	45.92	172.2	1.24	4.64
OW4 Mid	1	39.52	252.35	47.06	118.7	1.31	3.32
	2	51.03	205.63	44.78	92.1	0.94	1.93
	3	26.31	225.15	46.78	105.3	0.95	2.14
OW4 High	1	0.00	33.12	41.84	13.9	1.32	0.44
	2	16.34	101.51	45.37	46.1	1.17	1.19
	3	0.00	127.23	44.25	56.3	1.45	1.85

[†] Carbon and nitrogen contents are based on average values and were not determined for the individual sample

Leaf Litter

Site	Rep	Leaf Litter Dry Weight Winter	Spring	Summer	Fall	Total	Carbon	Aboveground Carbon Inputs	Nitrogen	Aboveground Nitrogen Inputs
		----------------- g m^{-2}				-----------------	%	g C m^{-2}yr^{-1}	%	g N m^{-2}yr^{-1}
BC1 Low	1	0.00	0.00	0.00	1.12	1.12	47.42†	0.5	0.98†	0.01
	2	0.00	0.00	0.00	0.00	0.00	47.42†	0.0	0.98†	0.00
	3	0.00	0.00	0.00	0.16	0.16	47.42†	0.1	0.98†	0.00
BC1 Mid	1	3.24	27.92	13.32	19.04	63.52	49.62	31.5	1.38	0.88
	2	0.88	6.20	3.28	4.68	15.04	48.90	7.4	1.57	0.24
	3	0.88	6.84	6.52	7.56	21.80	49.80	10.9	0.93	0.20
BC1 High	1	0.04	1.72	1.60	4.24	7.60	49.83	3.8	0.66	0.05
	2	0.80	5.96	1.48	1.72	9.96	47.28	4.7	0.78	0.08
	3	0.52	0.00	0.32	0.92	1.76	47.42†	0.8	0.98†	0.02
BC2 Low	1	0.00	2.96	0.24	0.48	3.68	47.42†	1.7	0.98†	0.04
	2	0.00	2.32	0.24	0.72	3.28	47.42†	1.6	0.98†	0.03
	3	0.00	0.00	0.00	0.00	0.00	47.42†	0.0	0.98†	0.00
BC2 Mid	1	0.64	7.40	0.08	1.48	9.60	50.09	4.8	1.20	0.12
	2	0.56	3.72	0.24	0.68	5.20	51.65	2.7	1.21	0.06
	3	2.68	18.32	7.16	2.68	30.84	49.44	15.2	1.18	0.36
BC2 High	1	16.08	33.64	26.84	164.72	241.28	49.06	118.4	1.20	2.89
	2	1.24	10.20	25.44	5.76	42.64	46.86	20.0	1.33	0.57
	3	4.44	37.72	23.76	40.84	106.76	49.62	53.0	1.24	1.33
BC4 Low	1	7.56	32.36	8.24	526.04	574.20	49.57	284.6	1.39	7.99
	2	0.64	24.60	8.40	870.80	904.44	48.71	440.6	1.39	12.58
	3	0.12	3.40	27.48	582.44	613.44	48.43	297.1	1.29	7.92
BC4 Mid	1	28.36	12.32	0.76	756.00	797.44	45.98	366.6	0.97	7.71
	2	28.64	33.64	11.56	80.84	154.68	49.27	76.2	1.12	1.73

		Leaf Litter Dry Weight								
Site	Rep	Winter	Spring	Summer	Fall	Total	Carbon	Aboveground Carbon Inputs	Nitrogen	Aboveground Nitrogen Inputs
		----------------- g m^{-2}	-----------------				%	g C m^{-2}yr^{-1}	%	g N m^{-2}yr^{-1}
BC4 Mid	3	12.84	15.56	1.60	463.88	493.88	48.82	241.1	1.23	6.09
BC4 High	1	0.32	0.00	22.08	3.04	25.44	44.19	11.2	1.42	0.36
	2	2.56	2.48	23.60	20.00	48.64	34.05	16.6	0.86	0.42
	3	1.32	1.84	3.68	0.52	7.36	34.65	2.5	0.83	0.06
BC5 Low	1	56.12	128.00	230.96	91.24	506.32	50.78	257.1	0.91	4.59
	2	38.80	129.68	212.84	109.60	490.92	49.70	244.0	0.81	3.98
	3	32.36	70.56	94.20	702.60	899.72	50.88	457.8	0.95	8.51
BC5 Mid	1	124.72	203.96	157.08	154.36	640.12	50.28	321.8	0.70	4.49
	2	109.08	195.76	156.44	203.84	665.12	50.78	337.7	0.73	4.86
	3	101.80	165.32	215.16	258.64	740.92	50.76	376.1	0.81	5.97
BC5 High	1	138.52	144.52	93.24	444.16	820.44	51.92	425.9	0.70	5.75
	2	127.00	120.04	110.16	435.44	792.64	49.48	392.2	0.55	4.33
	3	185.20	93.88	78.32	445.52	802.92	50.78	407.7	0.64	5.12
BC6 Low	1	68.80	104.60	91.72	528.68	793.80	49.14	390.1	0.70	5.54
	2	77.60	107.96	97.80	551.04	834.40	50.32	419.8	1.09	9.09
	3	54.52	61.04	43.76	122.96	282.28	51.60	145.6	0.95	2.67
BC6 Mid	1	65.00	119.68	98.28	419.48	702.44	50.13	352.1	0.85	5.97
	2	46.80	99.44	75.20	391.32	612.76	50.23	307.8	0.84	5.13
	3	37.88	92.84	83.00	113.00	326.72	48.68	159.0	1.01	3.31
BC6 High	1	90.12	538.64	121.32	470.88	1220.96	48.63	593.7	0.78	9.51
	2	107.40	574.68	105.40	375.84	1163.32	50.26	584.7	1.01	11.77
	3	99.24	477.76	141.32	160.32	878.64	49.48	434.8	1.04	9.18
OW1 Low	1	0.00	0.00	0.96	0.20	1.16	47.42[†]	0.6	0.98[†]	0.01
	2	0.32	0.00	0.04	0.48	0.84	47.42[†]	0.4	0.98[†]	0.01
	3	1.24	0.00	0.00	2.12	3.36	47.42[†]	1.6	0.98[†]	0.03

		Leaf Litter Dry Weight								
Site	Rep	Winter	Spring	Summer	Fall	Total	Carbon	Aboveground Carbon Inputs	Nitrogen	Aboveground Nitrogen Inputs
		----------------- $g\ m^{-2}$ -----------------					%	$g\ C\ m^{-2} yr^{-1}$	%	$g\ N\ m^{-2} yr^{-1}$
OW1 Mid	1	0.00	0.72	0.68	3.60	5.00	$47.42^{\dagger}$	2.4	$0.98^{\dagger}$	0.05
	2	0.00	1.68	0.36	0.00	2.04	$47.42^{\dagger}$	1.0	$0.98^{\dagger}$	0.02
	3	0.00	1.44	3.36	0.00	4.80	$47.42^{\dagger}$	2.3	$0.98^{\dagger}$	0.05
OW1 High	1	0.80	2.84	0.36	0.00	4.00	$47.42^{\dagger}$	1.9	$0.98^{\dagger}$	0.04
	2	1.00	0.00	1.00	0.00	2.00	$47.42^{\dagger}$	0.9	$0.98^{\dagger}$	0.02
	3	0.00	1.68	0.72	0.00	2.40	$47.42^{\dagger}$	1.1	$0.98^{\dagger}$	0.02
OW2 Low	1	0.20	0.00	0.00	1.44	1.64	$47.42^{\dagger}$	0.8	$0.98^{\dagger}$	0.02
	2	0.00	0.00	0.00	0.00	0.00	$47.42^{\dagger}$	0.0	$0.98^{\dagger}$	0.00
	3	0.00	0.00	0.00	8.08	8.08	$47.42^{\dagger}$	3.8	$0.98^{\dagger}$	0.08
OW2 Mid	1	0.00	0.00	0.00	0.00	0.00	$47.42^{\dagger}$	0.0	$0.98^{\dagger}$	0.00
	2	0.00	0.00	0.00	0.00	0.00	$47.42^{\dagger}$	0.0	$0.98^{\dagger}$	0.00
	3	0.00	0.00	0.00	0.00	0.00	$47.42^{\dagger}$	0.0	$0.98^{\dagger}$	0.00
OW2 High	1	0.00	0.00	1.04	0.00	1.04	$47.42^{\dagger}$	0.5	$0.98^{\dagger}$	0.01
	2	0.00	0.36	0.56	0.00	0.92	$47.42^{\dagger}$	0.4	$0.98^{\dagger}$	0.01
	3	0.00	0.00	0.40	0.12	0.52	$47.42^{\dagger}$	0.2	$0.98^{\dagger}$	0.01
OW3 Low	1	0.00	0.00	0.00	1.88	1.88	$47.42^{\dagger}$	0.9	$0.98^{\dagger}$	0.02
	2	0.00	0.00	0.00	1.44	1.44	$47.42^{\dagger}$	0.7	$0.98^{\dagger}$	0.01
	3	0.00	0.00	0.00	2.56	2.56	$47.42^{\dagger}$	1.2	$0.98^{\dagger}$	0.03
OW3 Mid	1	0.00	0.00	0.00	0.00	0.00	$47.42^{\dagger}$	0.0	$0.98^{\dagger}$	0.00
	2	0.00	0.00	0.00	1.48	1.48	$47.42^{\dagger}$	0.7	$0.98^{\dagger}$	0.01
	3	0.00	0.00	0.12	0.08	0.20	$47.42^{\dagger}$	0.1	$0.98^{\dagger}$	0.00
OW3 High	1	0.24	0.00	0.32	0.96	1.52	$47.42^{\dagger}$	0.7	$0.98^{\dagger}$	0.01
	2	0.12	2.08	0.68	0.44	3.32	$47.42^{\dagger}$	1.6	$0.98^{\dagger}$	0.03
	3	0.00	0.88	0.56	3.68	5.12	$47.42^{\dagger}$	2.4	$0.98^{\dagger}$	0.05

Site	Rep	Leaf Litter Dry Weight Winter	Spring	Summer	Fall	Total	Carbon	Aboveground Carbon Inputs	Nitrogen	Aboveground Nitrogen Inputs
		----------------- g m^{-2}				-----------------	%	g C m^{-2}yr^{-1}	%	g N m^{-2}yr^{-1}
OW4 Low	1	0.00	0.00	0.00	2.04	2.04	47.42†	1.0	0.98†	0.02
	2	0.00	0.00	0.00	0.00	0.00	47.42†	0.0	0.98†	0.00
	3	0.00	0.00	0.00	0.00	0.00	47.42†	0.0	0.98†	0.00
OW4 Mid	1	0.00	1.48	5.84	0.00	7.32	47.42†	3.5	0.98†	0.07
	2	0.00	0.00	1.24	0.00	1.24	47.42†	0.6	0.98†	0.01
	3	0.00	0.00	4.48	0.00	4.48	47.42†	2.1	0.98†	0.04
OW4 High	1	0.00	2.04	4.40	0.00	6.44	47.42†	3.1	0.98†	0.06
	2	0.00	0.00	6.12	0.00	6.12	47.42†	2.9	0.98†	0.06
	3	0.00	0.00	0.00	0.00	0.00	47.42†	0.0	0.98†	0.00

† Carbon and nitrogen contents are based on average values and were not determined for the individual sample

Wood Litter

Site	Rep	Wood Litter Dry Weight Winter	Spring	Summer	Fall	Total	Carbon	Aboveground Carbon Inputs	Nitrogen	Aboveground Nitrogen Inputs
		----------------- g m^{-2}				-----------------	%	g C $m^{-2}yr^{-1}$	%	g N $m^{-2}yr^{-1}$
BC1 Low	1	0.00	0.00	0.00	1.12	1.12	48.90†	0.5	0.58†	0.01
	2	0.00	0.00	0.00	0.00	0.00	na	0.0	na	0.00
	3	0.00	0.00	0.00	0.16	0.16	48.90†	0.1	0.58†	0.00
BC1 Mid	1	0.00	0.00	0.00	9.60	9.60	50.14	4.8	0.67	0.06
	2	0.00	0.00	0.00	39.16	39.16	47.05	18.4	0.54	0.21
	3	0.00	0.00	0.00	0.00	0.00	na	0.0	na	0.00
BC1 High	1	0.00	2.88	0.00	0.00	2.88	48.90†	1.4	0.58†	0.02
	2	0.72	0.00	1.00	0.00	1.72	48.90†	0.8	0.58†	0.01
	3	0.00	3.52	0.00	0.00	3.52	48.90†	1.7	0.58†	0.02
BC2 Low	1	0.00	0.00	0.00	0.00	0.00	na	0.0	na	0.00
	2	0.00	0.00	0.00	0.00	0.00	na	0.0	na	0.00
	3	0.00	0.00	0.00	0.36	0.36	48.90†	0.2	0.58†	0.00
BC2 Mid	1	0.00	0.00	0.00	0.00	0.00	na	0.0	na	0.00
	2	0.00	2.44	1.20	1.32	4.96	48.90†	2.4	0.58†	0.03
	3	82.32	2.68	1.60	0.00	86.60	48.55	42.0	0.46	0.40
BC2 High	1	1.44	1.88	4.52	78.88	86.72	48.66	42.2	0.55	0.48
	2	0.00	2.80	0.96	1.16	4.92	48.90†	2.4	0.58†	0.03
	3	0.00	2.36	0.00	1.84	4.20	48.90†	2.1	0.58†	0.02
BC4 Low	1	0.00	0.00	0.00	62.96	62.96	49.27	31.0	0.71	0.45
	2	0.00	14.52	0.00	88.68	103.20	48.76	50.3	0.79	0.82
	3	0.00	0.00	0.00	149.92	149.92	47.55	71.3	1.61	2.41
BC4 Mid	1	6.80	0.00	0.00	263.48	270.28	48.36	130.7	0.91	2.46
	2	2.20	3.00	0.00	1.36	6.56	50.00	3.3	0.96	0.06

		Wood Litter Dry Weight						Aboveground Carbon Inputs		Aboveground Nitrogen Inputs
Site	Rep	Winter	Spring	Summer	Fall	Total	Carbon		Nitrogen	
		---------------- g m^{-2} ----------------					%	g C m^{-2}yr^{-1}	%	g N m^{-2}yr^{-1}
BC4 Mid	3	2.16	0.00	0.00	32.36	34.52	48.69	16.8	0.73	0.25
BC4 High	1	0.00	2.16	0.00	0.40	2.56	48.90[†]	1.3	0.58[†]	0.01
	2	1.40	0.00	0.80	4.16	6.36	48.65	3.1	0.71	0.04
	3	0.00	0.00	0.00	0.00	0.00	na	0.0	na	0.00
BC5 Low	1	15.04	7.56	5.88	166.96	195.44	50.17	98.0	0.31	0.60
	2	20.28	0.00	4.12	191.40	215.80	48.30	104.2	0.37	0.80
	3	17.48	0.00	4.08	495.60	517.16	48.16	249.0	0.41	2.14
BC5 Mid	1	48.16	18.32	9.44	212.36	288.28	49.47	142.6	0.39	1.12
	2	24.04	47.24	0.40	32.28	103.96	49.20	51.1	0.54	0.56
	3	1.80	19.28	23.76	8.72	53.56	50.51	27.1	0.49	0.26
BC5 High	1	18.04	28.68	4.68	286.80	338.20	49.37	167.0	0.46	1.54
	2	5.00	0.00	24.28	133.64	162.92	50.56	82.4	0.52	0.84
	3	1.76	0.00	76.88	166.36	245.00	49.27	120.7	0.34	0.84
BC6 Low	1	1.52	30.92	2.44	194.28	229.16	48.91	112.1	0.40	0.92
	2	27.24	79.92	0.00	157.44	264.60	49.01	129.7	0.51	1.35
	3	1.96	7.84	0.00	10.36	20.16	49.16	9.9	0.47	0.09
BC6 Mid	1	5.40	4.36	0.96	413.24	423.96	48.83	207.0	0.41	1.73
	2	5.88	8.60	0.32	307.76	322.56	49.28	159.0	0.54	1.74
	3	2.20	1.96	19.20	424.84	448.20	49.85	223.4	0.38	1.69
BC6 High	1	4.76	37.56	33.24	382.76	458.32	48.91	224.1	0.43	1.98
	2	7.56	14.88	61.44	333.92	417.80	49.54	207.0	0.55	2.29
	3	20.12	26.16	0.00	0.00	46.28	49.06	22.7	0.44	0.20
OW1 Low	1	0.00	0.00	0.00	0.00	0.00	na	0.0	na	0.00
	2	0.00	0.00	0.00	0.00	0.00	na	0.0	na	0.00
	3	0.00	0.00	0.00	0.00	0.00	na	0.0	na	0.00

Site	Rep	Wood Litter Dry Weight Winter	 Spring	 Summer	 Fall	 Total	Carbon	Aboveground Carbon Inputs	Nitrogen	Aboveground Nitrogen Inputs
		---------------- g m^{-2}	----------------				%	g C $m^{-2}yr^{-1}$	%	g N $m^{-2}yr^{-1}$
OW1 Mid	1	0.00	0.00	0.00	1.28	1.28	48.90†	0.6	0.58†	0.01
	2	0.00	0.00	0.00	0.00	0.00	na	0.0	na	0.00
	3	0.00	0.00	0.00	0.00	0.00	na	0.0	na	0.00
OW1 High	1	0.00	0.00	0.00	0.00	0.00	na	0.0	na	0.00
	2	0.00	0.00	0.32	0.00	0.32	48.90†	0.2	0.58†	0.00
	3	0.00	0.00	0.00	0.00	0.00	na	0.0	na	0.00
OW2 Low	1	0.00	0.00	0.00	0.00	0.00	na	0.0	na	0.00
	2	0.00	0.00	0.00	0.00	0.00	na	0.0	na	0.00
	3	0.00	0.00	0.00	0.00	0.00	na	0.0	na	0.00
OW2 Mid	1	0.00	0.00	0.00	0.00	0.00	na	0.0	na	0.00
	2	0.00	0.00	0.00	0.00	0.00	na	0.0	na	0.00
	3	0.00	0.00	0.00	0.00	0.00	na	0.0	na	0.00
OW2 High	1	0.00	2.52	0.00	0.00	2.52	48.90†	1.2	0.58†	0.01
	2	0.00	0.00	0.00	0.00	0.00	na	0.0	na	0.00
	3	0.00	0.00	0.00	0.04	0.04	48.90†	0.0	0.58†	0.00
OW3 Low	1	0.00	0.00	0.00	0.00	0.00	na	0.0	na	0.00
	2	0.00	0.00	0.00	0.00	0.00	na	0.0	na	0.00
	3	0.00	0.00	0.00	0.00	0.00	na	0.0	na	0.00
OW3 Mid	1	0.00	0.00	0.00	0.00	0.00	na	0.0	na	0.00
	2	0.00	0.00	0.00	0.00	0.00	na	0.0	na	0.00
	3	0.00	0.00	0.00	0.00	0.00	na	0.0	na	0.00
OW3 High	1	0.00	0.00	0.00	0.00	0.00	na	0.0	na	0.00
	2	0.72	0.00	0.00	0.00	0.72	48.90†	0.4	0.58†	0.00
	3	0.00	0.00	0.00	0.76	0.76	48.90†	0.4	0.58†	0.00

Site	Rep	Wood Litter Dry Weight Winter	Spring	Summer	Fall	Total	Carbon	Aboveground Carbon Inputs	Nitrogen	Aboveground Nitrogen Inputs
		---------------- g m^{-2}				----------------	%	g C $m^{-2}yr^{-1}$	%	g N $m^{-2}yr^{-1}$
OW4 Low	1	0.00	0.00	0.00	0.00	0.00	na	0.0	na	0.00
	2	0.00	0.00	0.00	0.00	0.00	na	0.0	na	0.00
	3	0.00	0.00	0.00	0.00	0.00	na	0.0	na	0.00
OW4 Mid	1	0.00	0.00	14.84	0.00	14.84	47.31	7.0	0.50	0.07
	2	0.16	19.08	0.00	0.00	19.24	48.90†	9.4	0.58†	0.11
	3	0.00	0.00	30.20	0.00	30.20	47.62	14.4	0.38	0.11
OW4 High	1	0.00	0.00	0.16	2.88	3.04	48.90†	1.5	0.58†	0.02
	2	0.40	0.00	3.36	0.00	3.76	46.86	1.8	1.09	0.04
	3	0.00	0.00	0.00	0.00	0.00	48.90†	0.0	0.58†	0.00

† Carbon and nitrogen contents are based on average values and were not determined for the individual sample

na = not applicable

APPENDIX L: DECOMPOSITION STAKE ASSAY

Whole Stick Summary

		Weight Loss†			
Site	Stick	March (90 days)	June (176 days)	September (272 days)	December (364 days)
		-------------------------	%	-------------------------	
BC2 Low	1	2.53	1.86	6.53	12.62
	2	1.89	1.07	6.56	10.22
	3	2.54	1.22	6.30	13.04
	4	1.85	0.93	5.71	na
	5	2.48	1.69	5.99	11.69
	mean	2.26	1.36	6.22	11.89
BC2 Mid	1	1.91	2.65	10.60	10.48
	2	2.73	2.09	15.18	16.49
	3	2.02	1.56	14.38	17.56
	4	2.29	1.97	14.21	15.38
	5	2.12	2.92	14.60	9.14
	mean	2.21	2.24	13.79	13.81
BC2 High	1	2.12	3.44	17.06	36.88
	2	2.20	2.63	19.21	20.17
	3	1.76	2.73	12.95	20.41
	4	1.98	2.57	19.10	18.66
	5	1.58	3.07	9.69	48.60
	mean	1.93	2.89	15.60	28.95
BC6 Low	1	2.06	2.15	5.64	7.18
	2	1.31	2.25	4.34	8.56
	3	1.56	2.43	4.98	7.18
	4	1.82	1.88	4.97	7.88
	5	1.83	2.42	5.20	6.02
	mean	1.72	2.23	5.03	7.37
BC6 Mid	1	1.21	2.30	11.73	11.25
	2	2.08	3.61	14.86	11.79
	3	2.02	4.17	9.16	12.01
	4	1.83	2.63	14.25	14.18
	5	2.37	2.48	14.79	10.22
	mean	1.90	3.04	12.96	11.89
BC6 High	1	1.16	1.96	8.43	10.66
	2	0.75	1.61	7.39	13.15
	3	2.19	2.41	5.19	10.99
	4	2.38	1.58	11.24	9.89
	5	1.37	2.02	6.90	10.48
	mean	1.57	1.92	7.83	11.04
OW3 Low	1	1.61	2.05	8.35	7.44
	2	2.12	2.34	7.30	12.07
	3	1.82	1.62	7.28	9.72

		Weight Loss[†]			
Site	Stick	March (90 days)	June (176 days)	September (272 days)	December (364 days)
		------------------------- % -------------------------			
OW3 Low	4	1.30	1.61	6.33	9.59
	5	2.53	2.15	8.76	6.90
	mean	1.88	1.95	7.61	9.14
OW3 Mid	1	2.57	2.27	6.02	7.80
	2	1.98	2.42	7.00	6.52
	3	1.91	1.74	6.38	5.97
	4	1.69	1.57	7.35	6.30
	5	2.19	2.91	5.61	6.15
	mean	2.07	2.18	6.47	6.55
OW3 High	1	1.69	24.49	8.29	18.60
	2	1.75	6.04	8.40	26.75
	3	2.04	1.96	4.10	18.37
	4	2.12	2.47	6.23	na
	5	1.30	0.48	12.48	19.84
	mean	1.78	7.09	7.90	20.89

[†] nd = not determined, stick was not recovered

Stick Section Summary

Site	Depth[†]	Weight Loss[‡] March (90 days)	 June (176 days)	 September (272 days)	 December (364 days)
		------------------------	%	------------------------	
BC2 Low	a	2.09	0.79	12.51	19.71
	b	3.09	1.72	6.75	17.08
	c	3.06	0.48	3.01	14.38
	d	1.27	0.83	3.19	7.26
	e	1.79	0.63	2.47	3.49
	f	3.79	2.87	8.25	10.10
BC2 Mid	a	-1.06	4.68	25.65	20.70
	b	1.53	1.04	22.30	19.83
	c	1.97	1.50	14.75	16.63
	d	3.46	1.47	7.93	11.80
	e	3.00	0.57	3.06	4.16
	f	6.29	3.40	7.17	9.01
BC2 High	a	2.21	6.66	21.43	26.60
	b	2.53	4.50	23.16	23.82
	c	1.49	3.59	18.94	23.03
	d	1.01	1.20	11.88	16.74
	e	0.71	-0.16	7.93	11.77
	f	4.90	1.37	6.87	15.98
BC6 Low	a	2.04	2.71	7.65	13.51
	b	2.07	1.16	4.38	6.93
	c	1.92	1.89	4.08	6.13
	d	1.35	2.31	3.01	4.12
	e	1.52	2.28	3.00	4.05
	f	2.02	3.04	6.53	8.99
BC6 Mid	a	1.26	11.92	35.68	35.36
	b	2.03	0.36	20.76	17.42
	c	0.98	0.16	8.74	6.22
	d	1.11	0.40	2.39	3.06
	e	1.73	0.77	2.05	1.67
	f	7.32	5.65	7.21	7.38
BC6 High	a	0.76	4.45	18.76	20.65
	b	1.56	1.17	11.47	14.73
	c	2.26	0.86	6.81	9.00
	d	1.49	1.15	4.51	6.23
	e	0.46	-0.47	1.43	4.80
	f	5.03	4.76	3.62	11.94
OW3 Low	a	1.95	1.09	15.54	17.59
	b	2.61	2.64	9.67	12.64
	c	2.18	2.45	6.65	7.95
	d	1.92	1.35	5.31	4.88

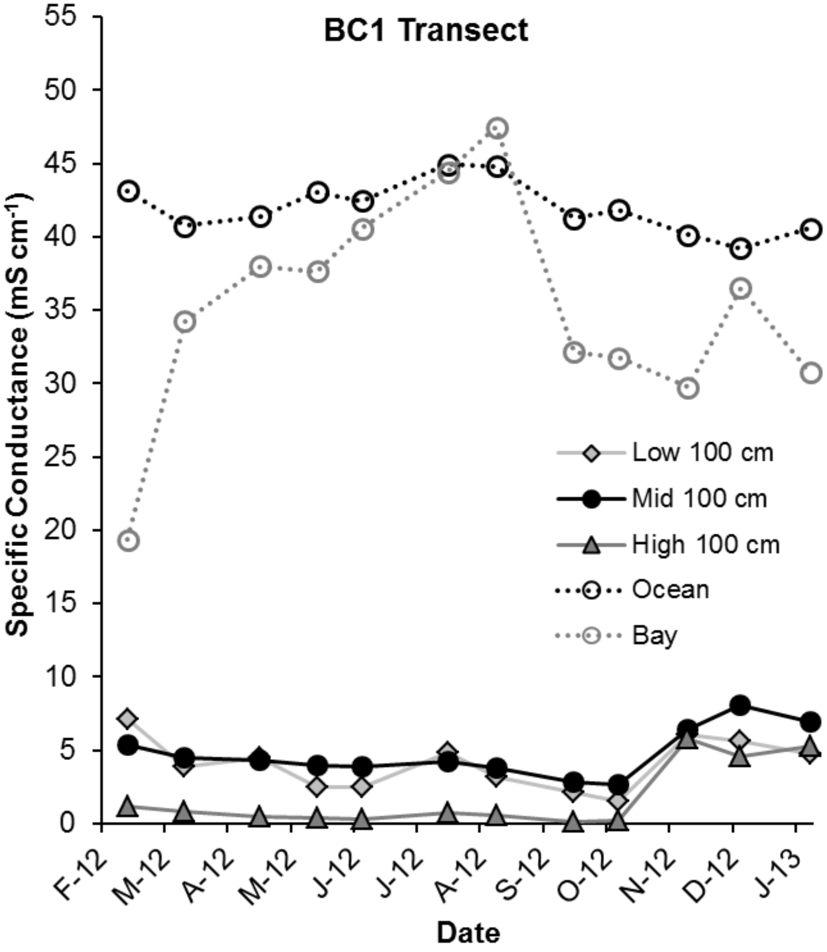
		Weight Loss[‡]			
Site	Depth[†]	March (90 days)	June (176 days)	September (272 days)	December (364 days)
		------------------------- % -------------------------			
OW3 Low	e	1.31	1.07	4.29	3.34
	f	1.90	3.08	2.28	8.79
OW3 Mid	a	3.30	3.35	15.41	14.92
	b	2.46	0.60	7.34	7.15
	c	1.56	1.49	5.13	5.13
	d	1.93	1.77	6.49	3.02
	e	0.35	1.19	2.95	1.39
	f	4.32	3.91	-0.47	9.15
OW3 High	a	1.68	9.07	6.38	25.95
	b	1.60	10.05	11.42	26.77
	c	0.86	6.09	10.95	22.12
	d	1.47	5.23	7.64	18.28
	e	0.85	3.48	5.62	14.98
	f	6.06	2.19	4.45	17.45

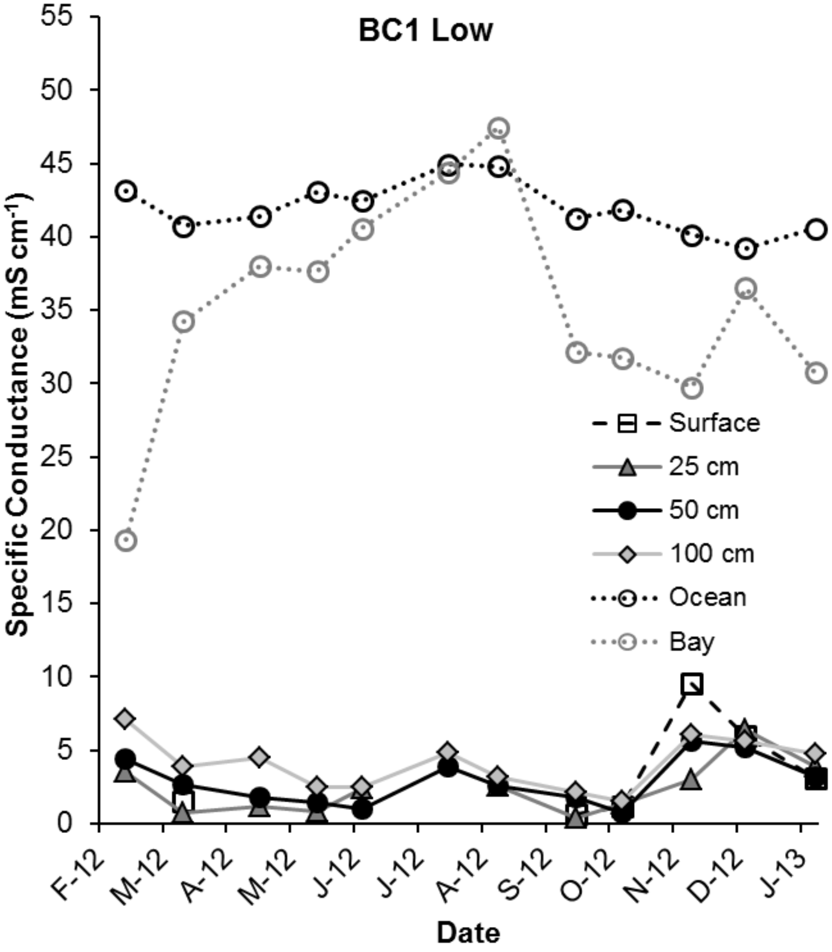
[†] Depth intervals: a = 0-5 cm, b = 5-10 cm, c = 10-15 cm, d = 15-20 cm, e = 20-25 cm, f = 25-30 cm

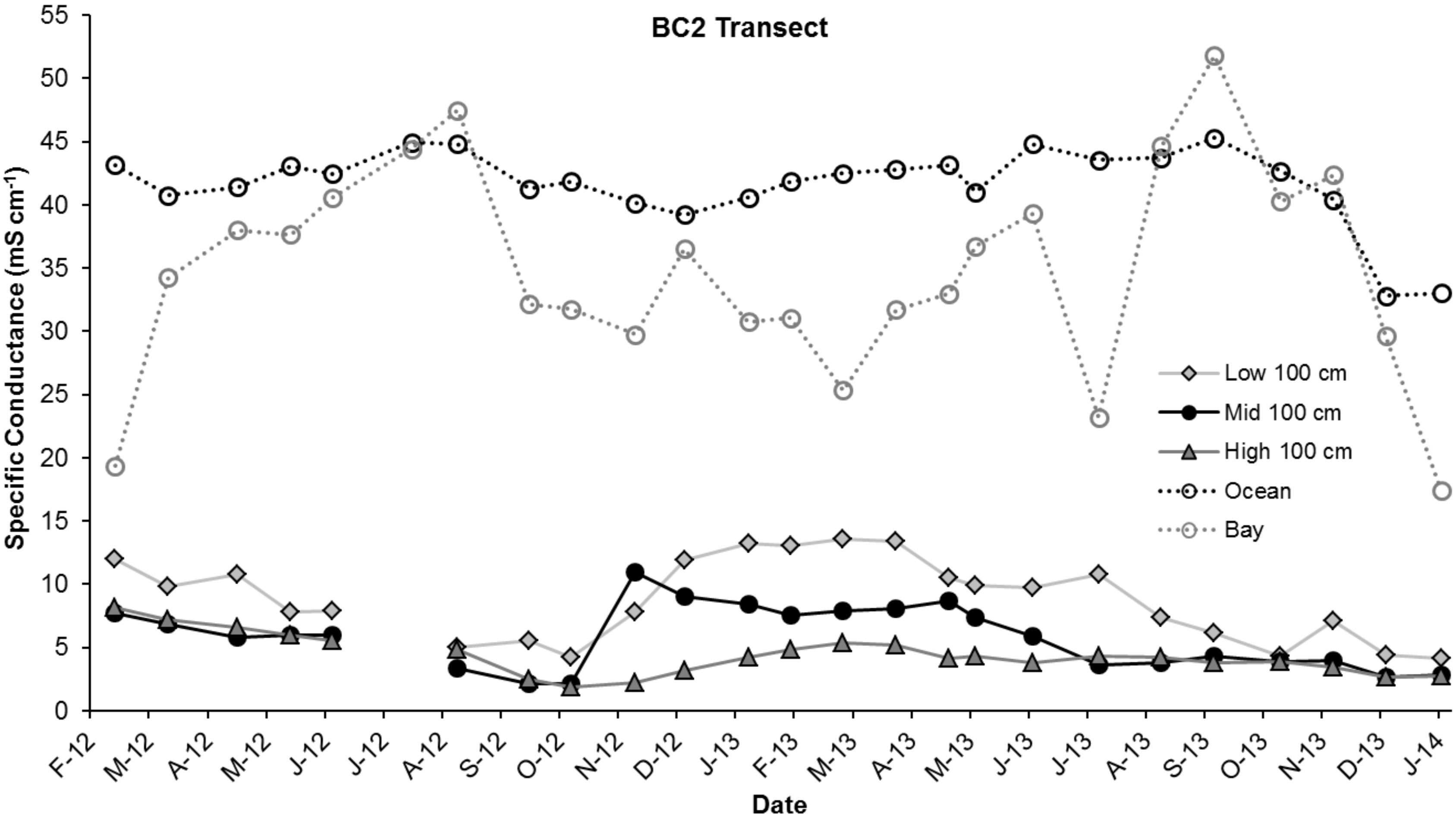
[‡] Weight loss is the average of 5 sticks

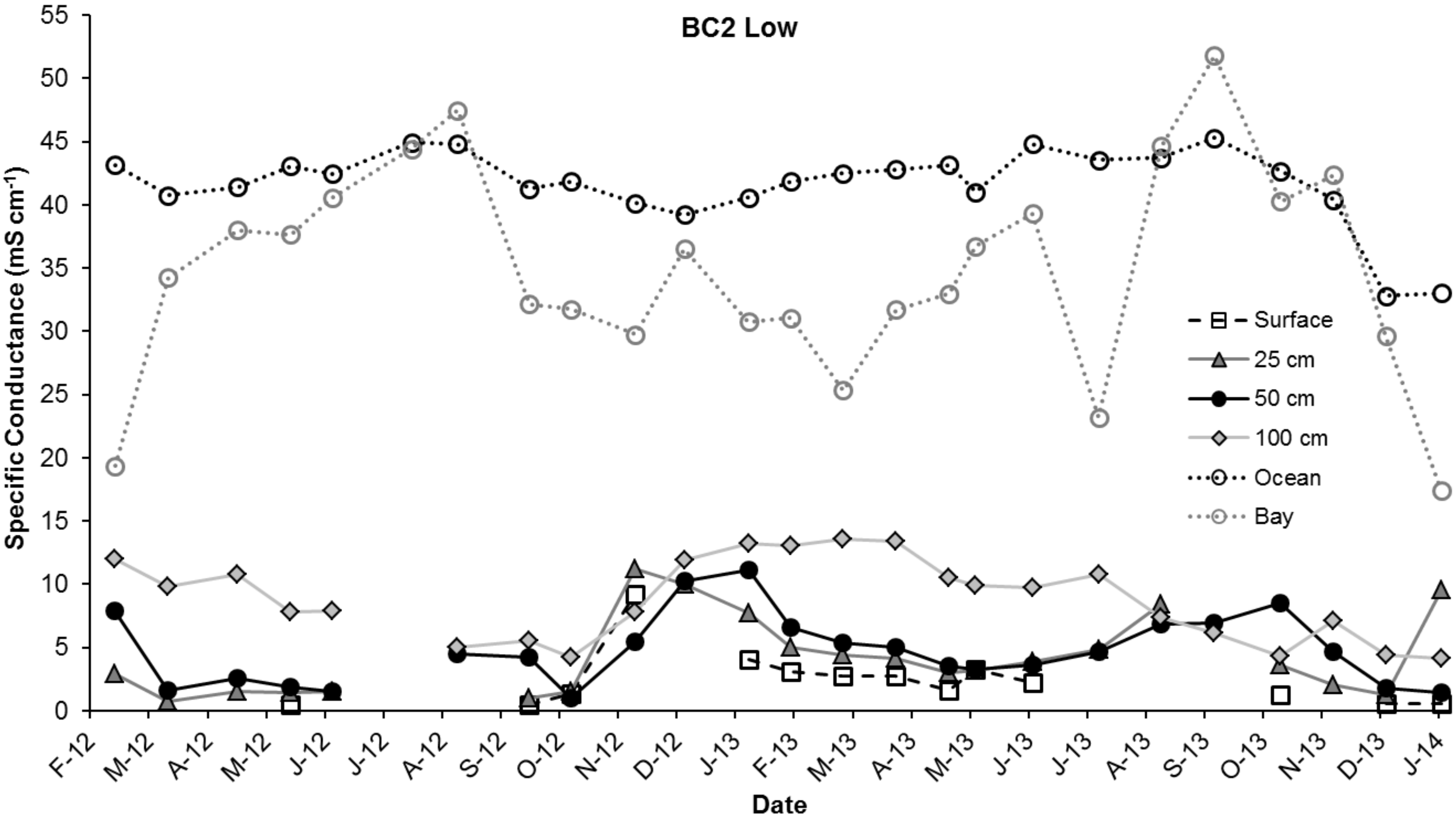
APPENDIX M: WATER CHEMISTRY DATA

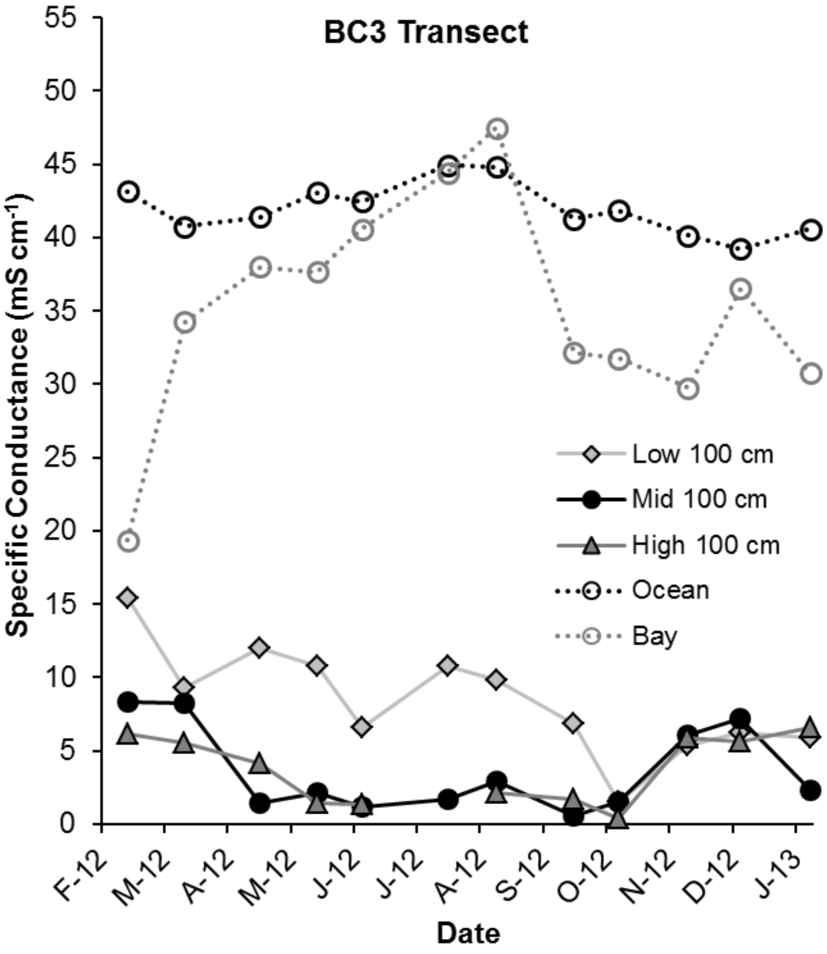
Specific Conductance

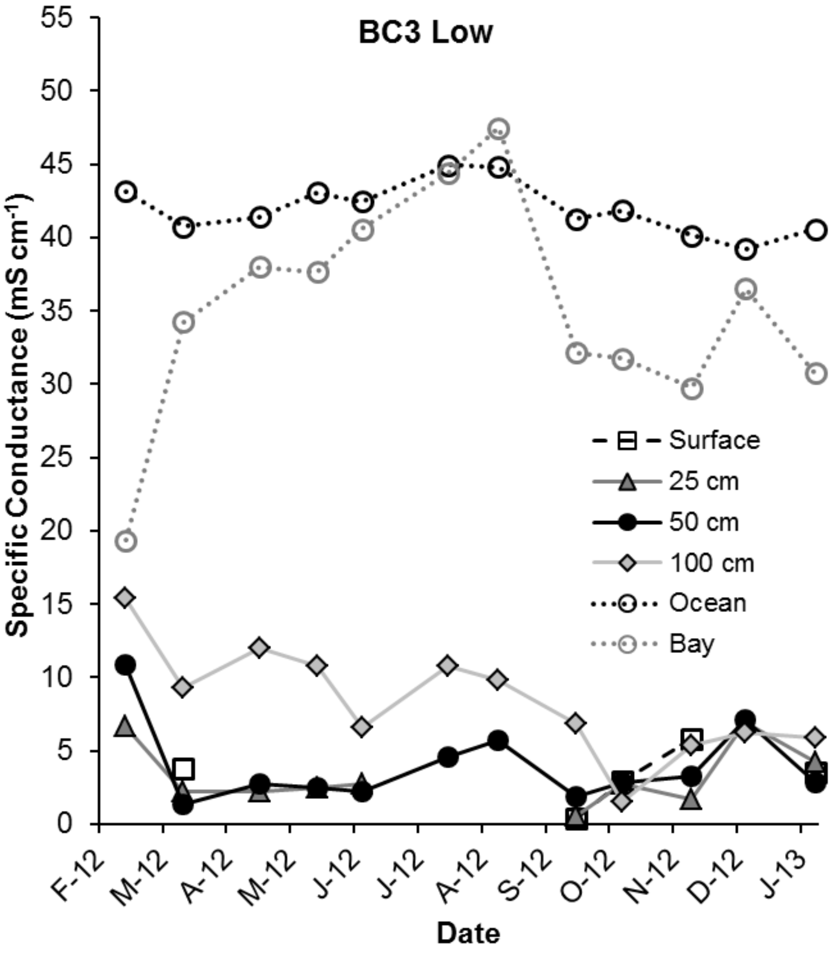


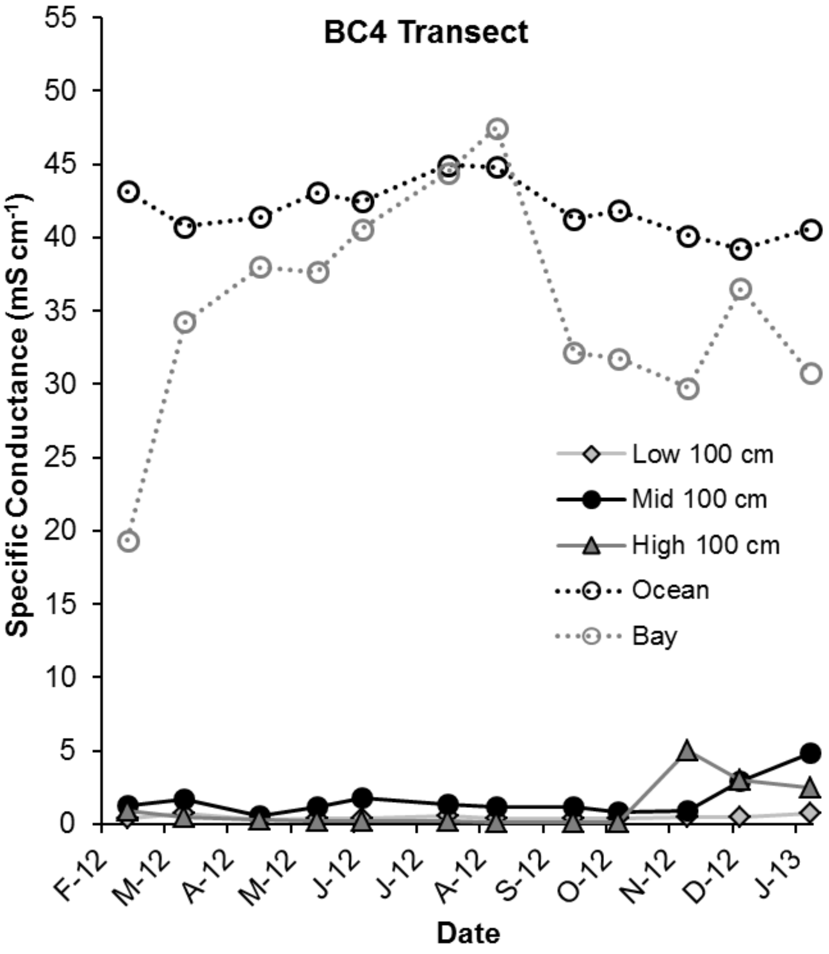



BC2 Transect
Specific Conductance (mS cm-1)
55
50
45
40
35
30
25
20
15
10
5
0
Date
F-12
M-12
A-12
M-12
J-12
J-12
A-12
S-12
O-12
N-12
D-12
J-13
F-13
M-13
A-13
M-13
J-13
J-13
A-13
S-13
O-13
N-13
D-13
J-14
Low 100 cm
Mid 100 cm
High 100 cm
Ocean
Bay

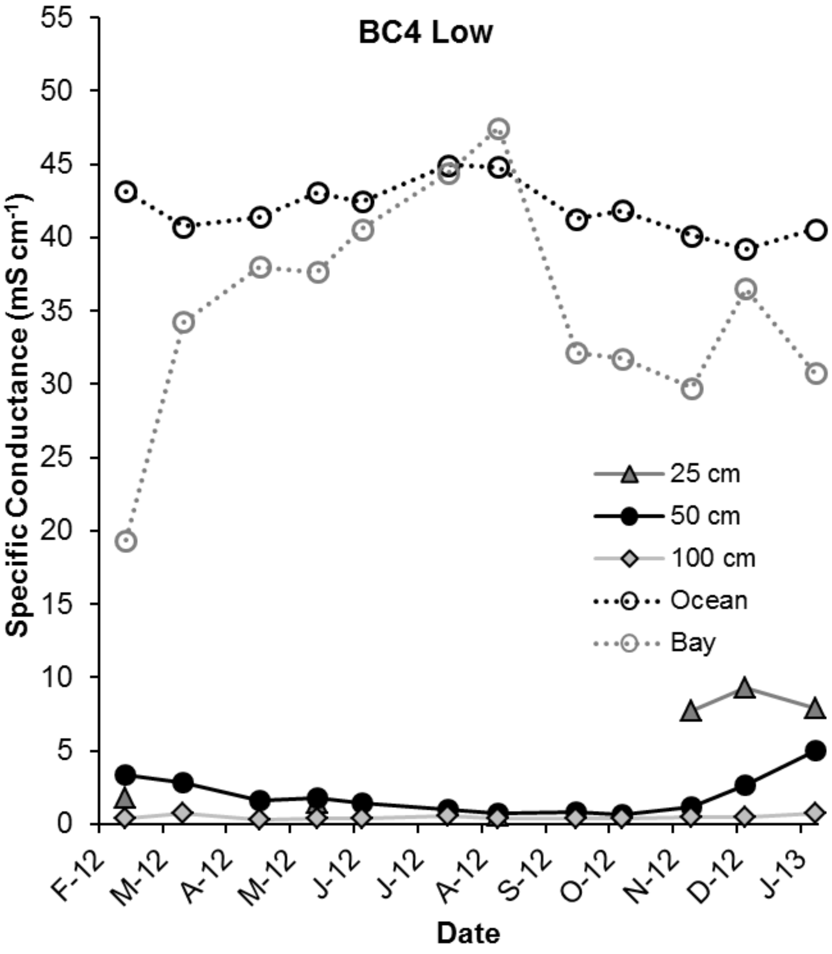

BC2 Low
Specific Conductance (mS cm^{-1})
55
50
45
40
35
30
25
20
15
10
5
0
F-12
M-12
A-12
M-12
J-12
J-12
A-12
S-12
O-12
N-12
D-12
J-13
F-13
M-13
A-13
M-13
J-13
J-13
A-13
S-13
O-13
N-13
D-13
J-14
Date
Surface
25 cm
50 cm
100 cm
Ocean
Bay


BC3 Transect
Specific Conductance (mS cm-1)
55
50
45
40
35
30
25
20
15
10
5
0
Low 100 cm
Mid 100 cm
High 100 cm
Ocean
Bay
F-12
M-12
A-12
M-12
J-12
J-12
A-12
S-12
O-12
N-12
D-12
J-13
Date

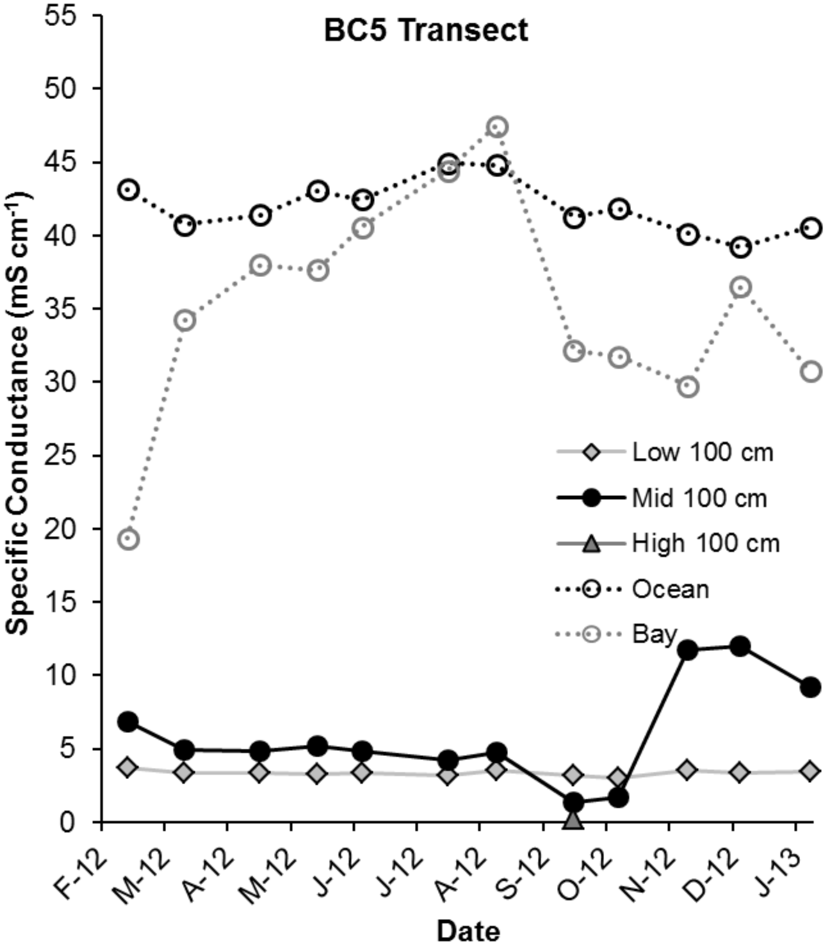

BC3 Low
Specific Conductance (mS cm-1)
55
50
45
40
35
30
25
20
15
10
5
0
Surface
25 cm
50 cm
100 cm
Ocean
Bay
F-12
M-12
A-12
M-12
J-12
J-12
A-12
S-12
O-12
N-12
D-12
J-13
Date



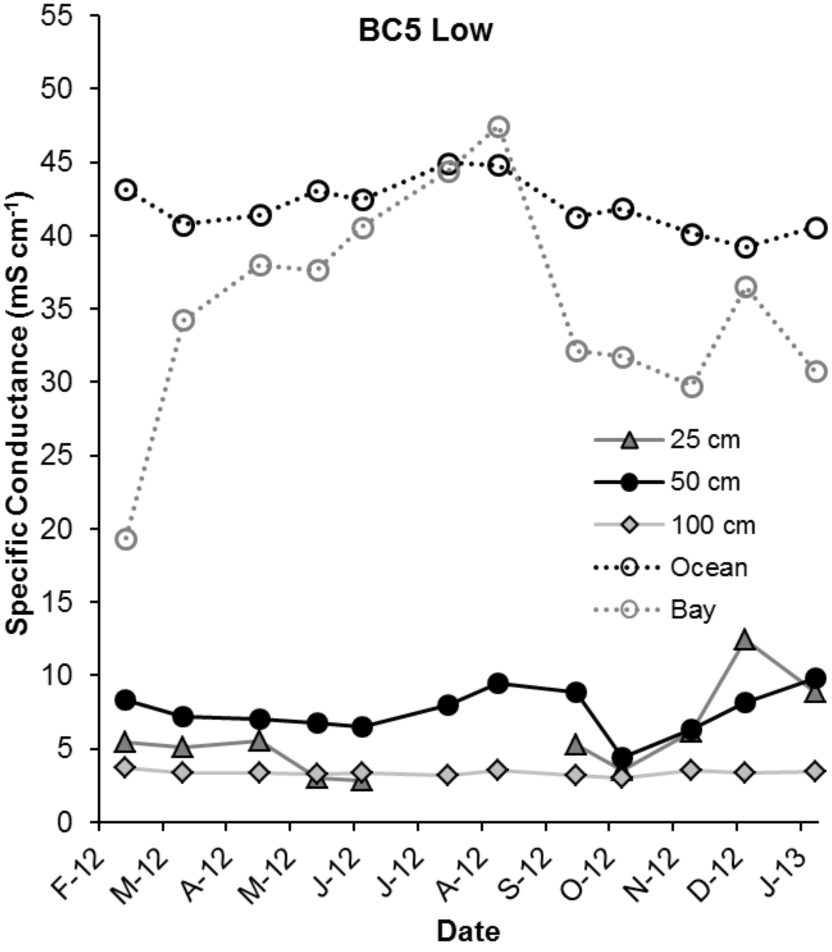
BC4 Transect
Specific Conductance (mS cm-1)
55
50
45
40
35
30
25
20
15
10
5
0
Low 100 cm
Mid 100 cm
High 100 cm
Ocean
Bay
F-12
M-12
A-12
M-12
J-12
J-12
A-12
S-12
O-12
N-12
D-12
J-13
Date



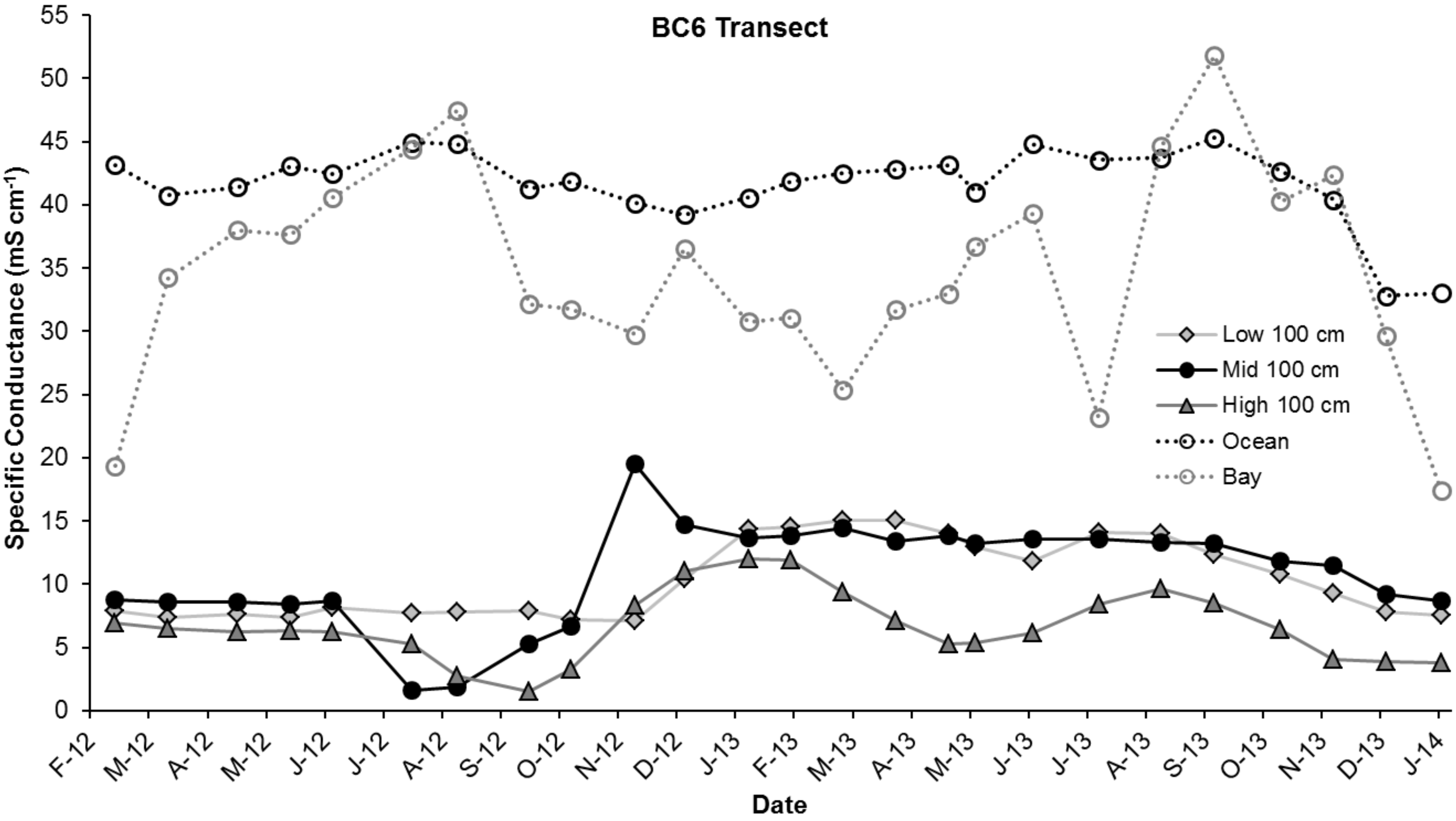
BC4 Low
Specific Conductance (mS cm-1)
55
50
45
40
35
30
25
20
15
10
5
0
25 cm
50 cm
100 cm
Ocean
Bay
F-12
M-12
A-12
M-12
J-12
J-12
A-12
S-12
O-12
N-12
D-12
J-13
Date

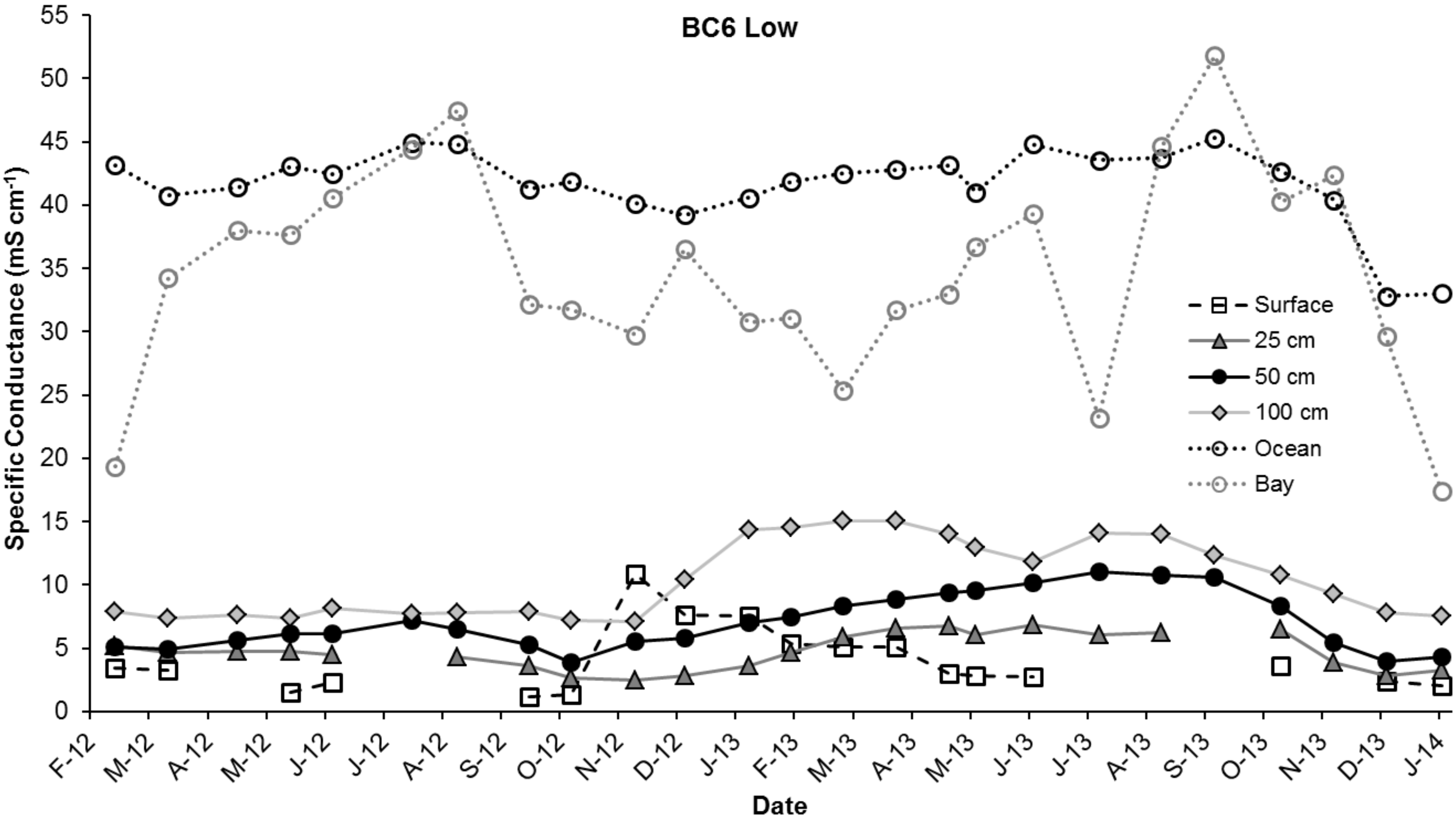


BC5 Transect
Specific Conductance (mS cm^{-1})
55
50
45
40
35
30
25
20
15
10
5
0
Low 100 cm
Mid 100 cm
High 100 cm
Ocean
Bay
F-12
M-12
A-12
M-12
J-12
J-12
A-12
S-12
O-12
N-12
D-12
J-13
Date

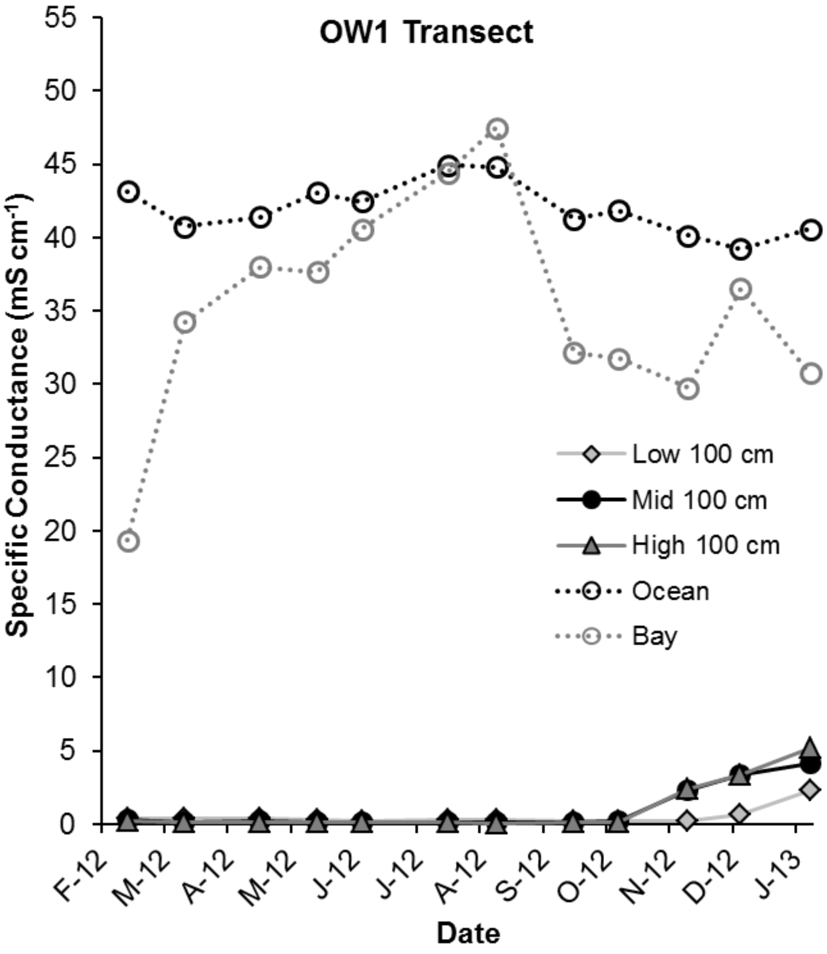


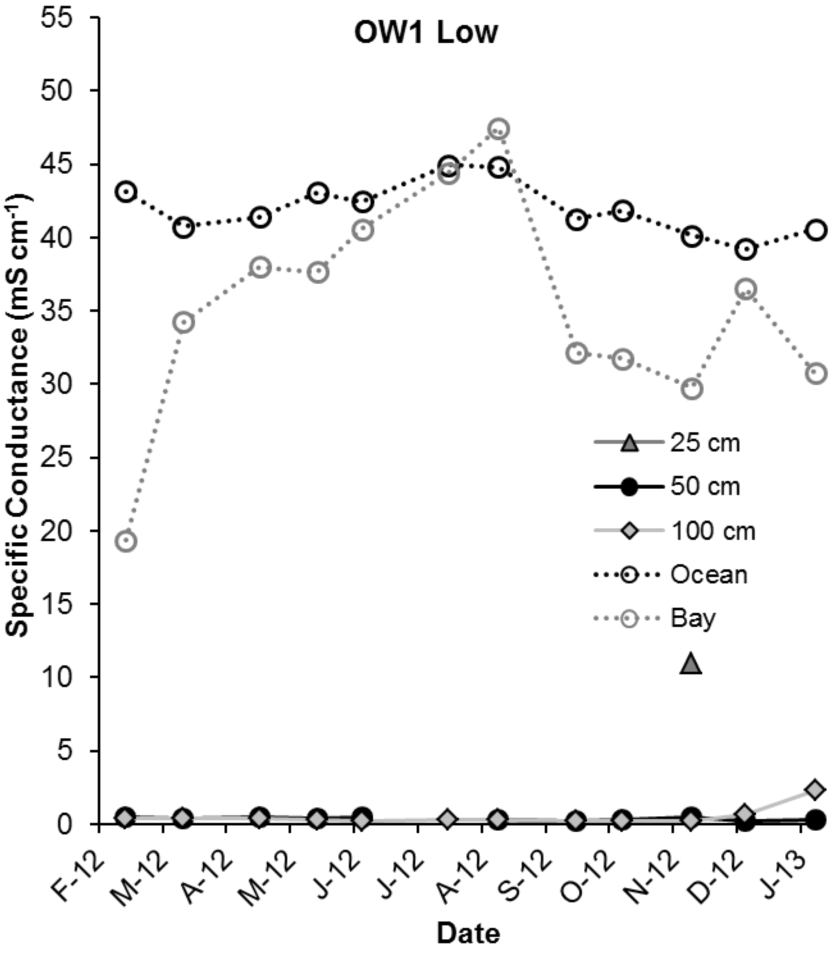
BC5 Low
Specific Conductance (mS cm^{-1})
55
50
45
40
35
30
25
20
15
10
5
0
25 cm
50 cm
100 cm
Ocean
Bay
F-12
M-12
A-12
M-12
J-12
J-12
A-12
S-12
O-12
N-12
D-12
J-13
Date

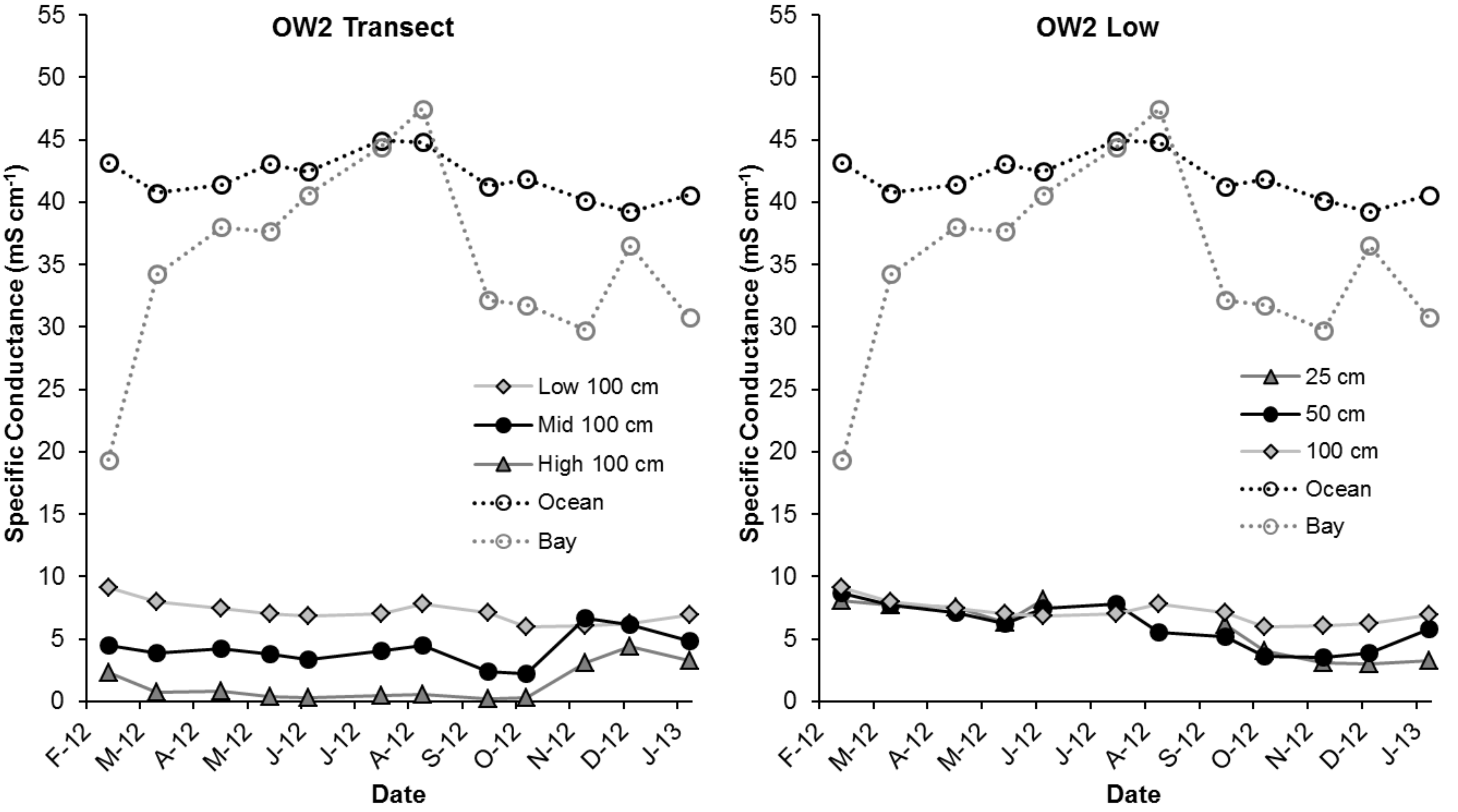

BC6 Transect
Specific Conductance (mS cm^{-1})
55
50
45
40
35
30
25
20
15
10
5
0
F-12
M-12
A-12
M-12
J-12
J-12
A-12
S-12
O-12
N-12
D-12
J-13
F-13
M-13
A-13
M-13
J-13
J-13
A-13
S-13
O-13
N-13
D-13
J-14
Date
Low 100 cm
Mid 100 cm
High 100 cm
Ocean
Bay

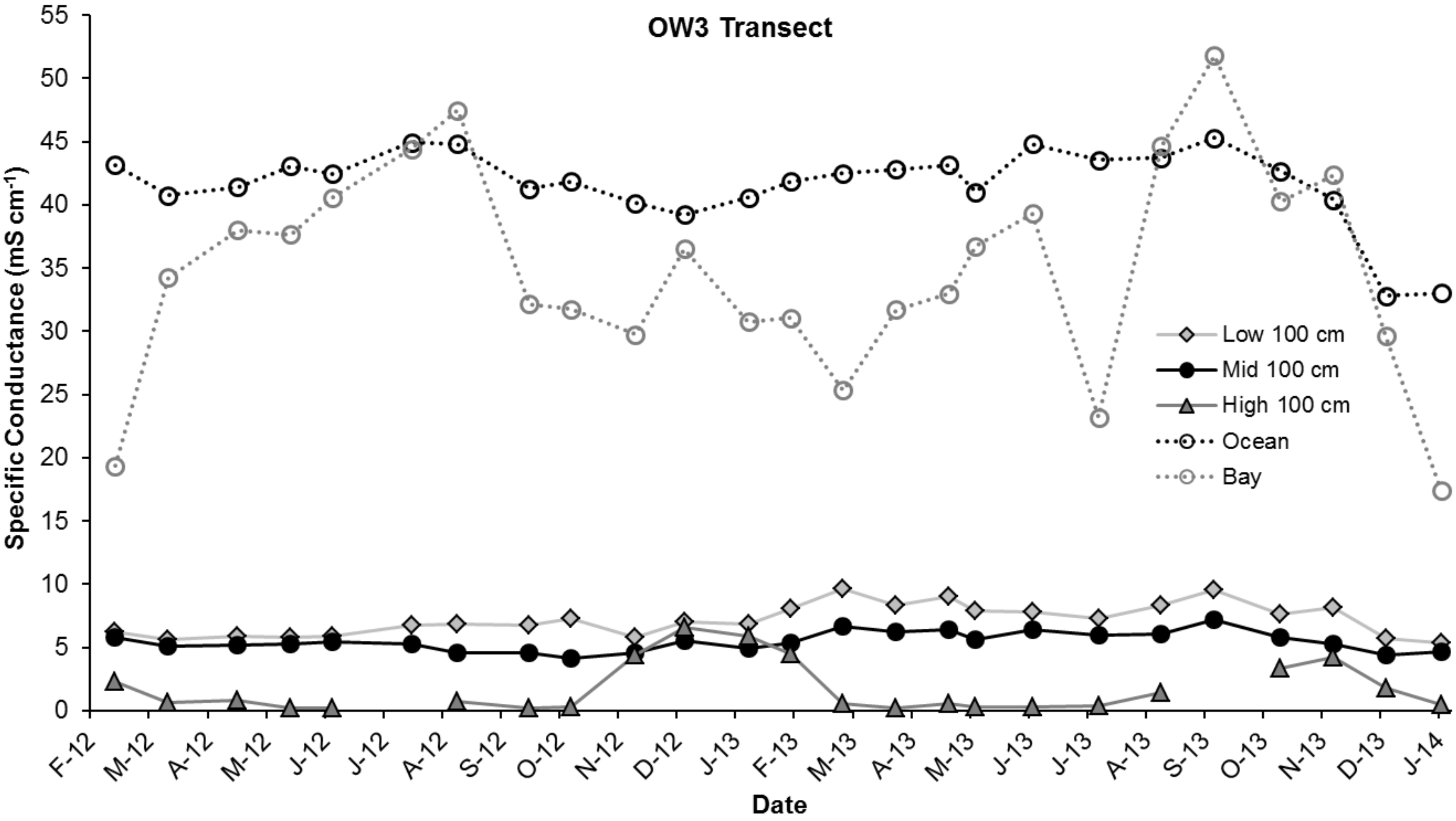


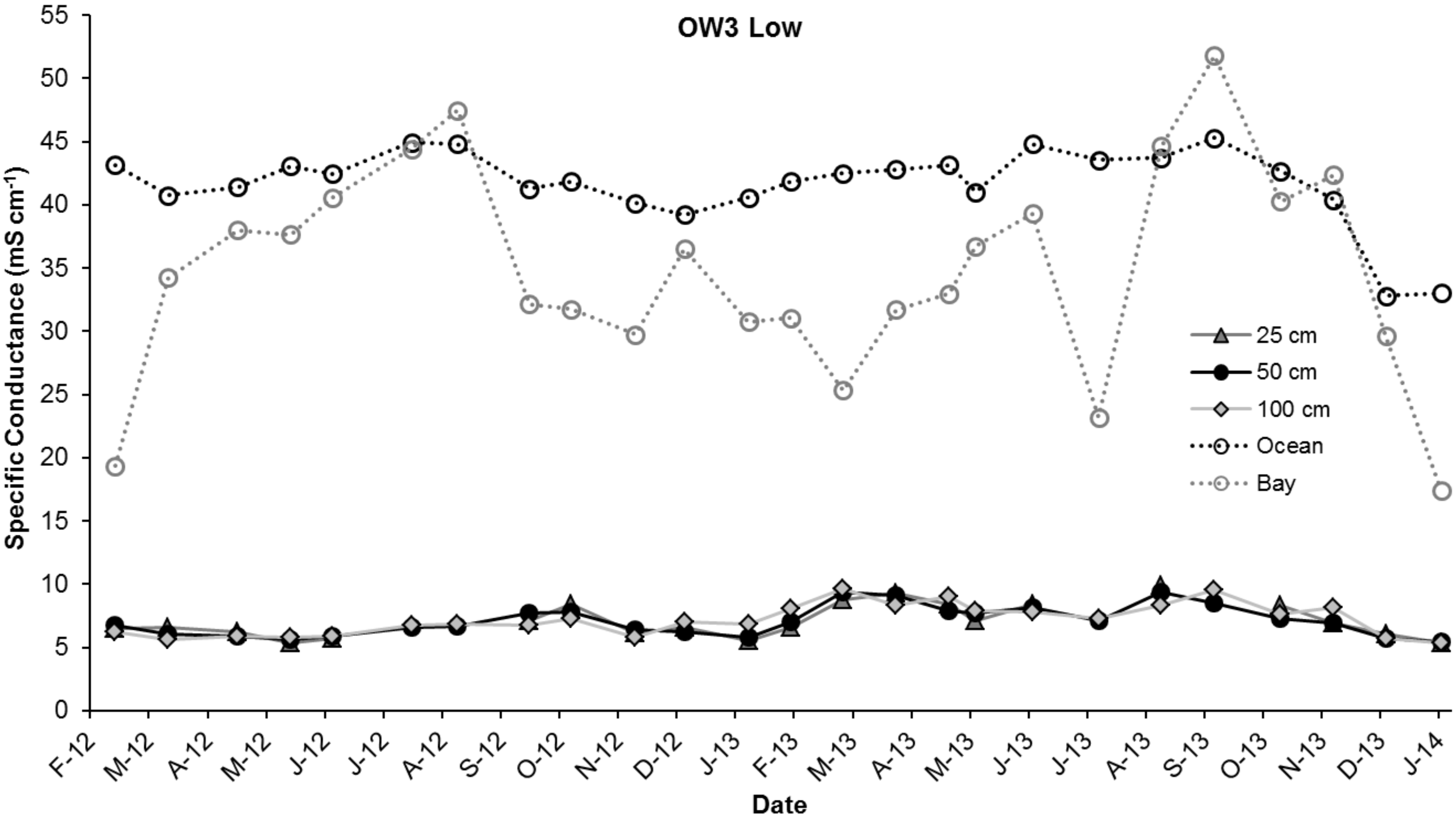
BC6 Low
Specific Conductance (mS cm⁻¹)
Date
55
50
45
40
35
30
25
20
15
10
5
0
F-12
M-12
A-12
M-12
J-12
J-12
A-12
S-12
O-12
N-12
D-12
J-13
F-13
M-13
A-13
M-13
J-13
J-13
A-13
S-13
O-13
N-13
D-13
J-14
Surface
25 cm
50 cm
100 cm
Ocean
Bay

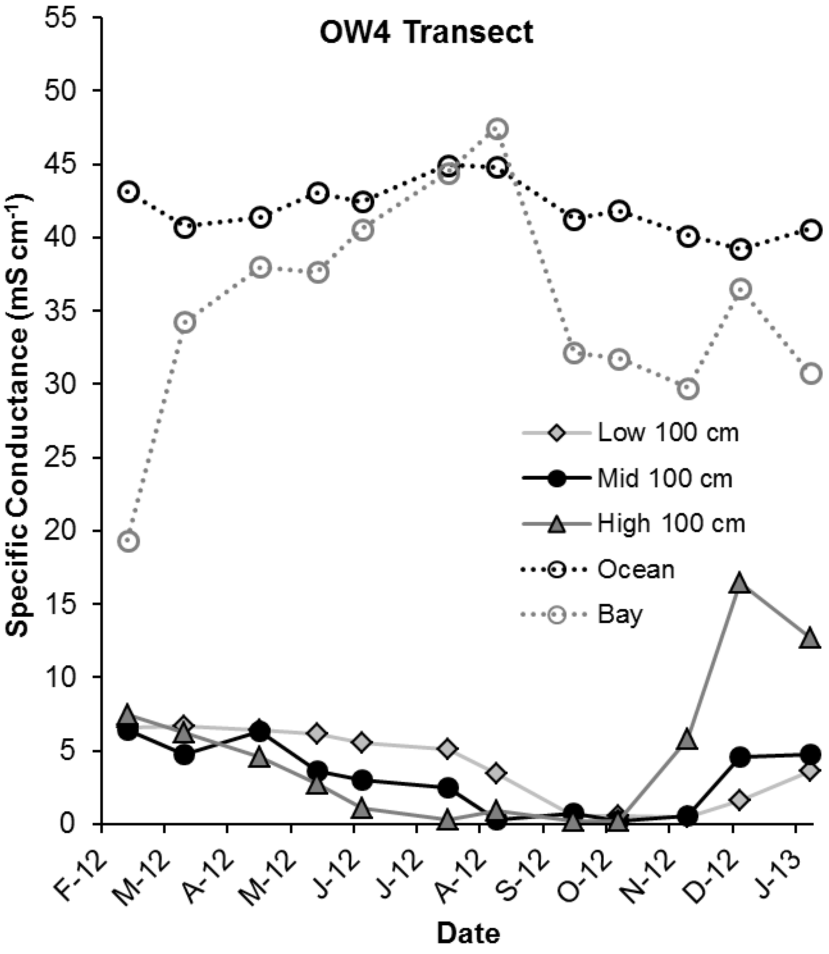

OW1 Transect
Specific Conductance (mS cm-1)
55
50
45
40
35
30
25
20
15
10
5
0
F-12
M-12
A-12
M-12
J-12
J-12
A-12
S-12
O-12
N-12
D-12
J-13
Date
Low 100 cm
Mid 100 cm
High 100 cm
Ocean
Bay

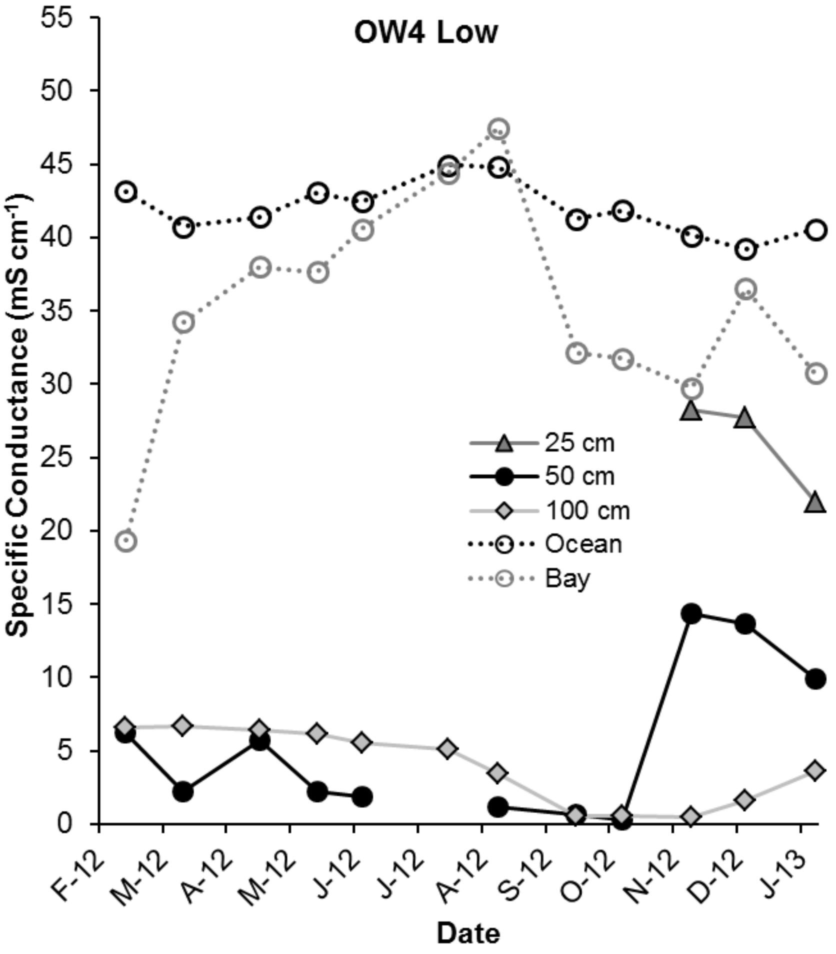

OW1 Low
Specific Conductance (mS cm-1)
55
50
45
40
35
30
25
20
15
10
5
0
F-12
M-12
A-12
M-12
J-12
J-12
A-12
S-12
O-12
N-12
D-12
J-13
Date
25 cm
50 cm
100 cm
Ocean
Bay


OW2 Transect
OW2 Low
Specific Conductance (mS cm^{-1})
55
50
45
40
35
30
25
20
15
10
5
0
Low 100 cm
Mid 100 cm
High 100 cm
Ocean
Bay
25 cm
50 cm
100 cm
F-12
M-12
A-12
M-12
J-12
J-12
A-12
S-12
O-12
N-12
D-12
J-13
Date

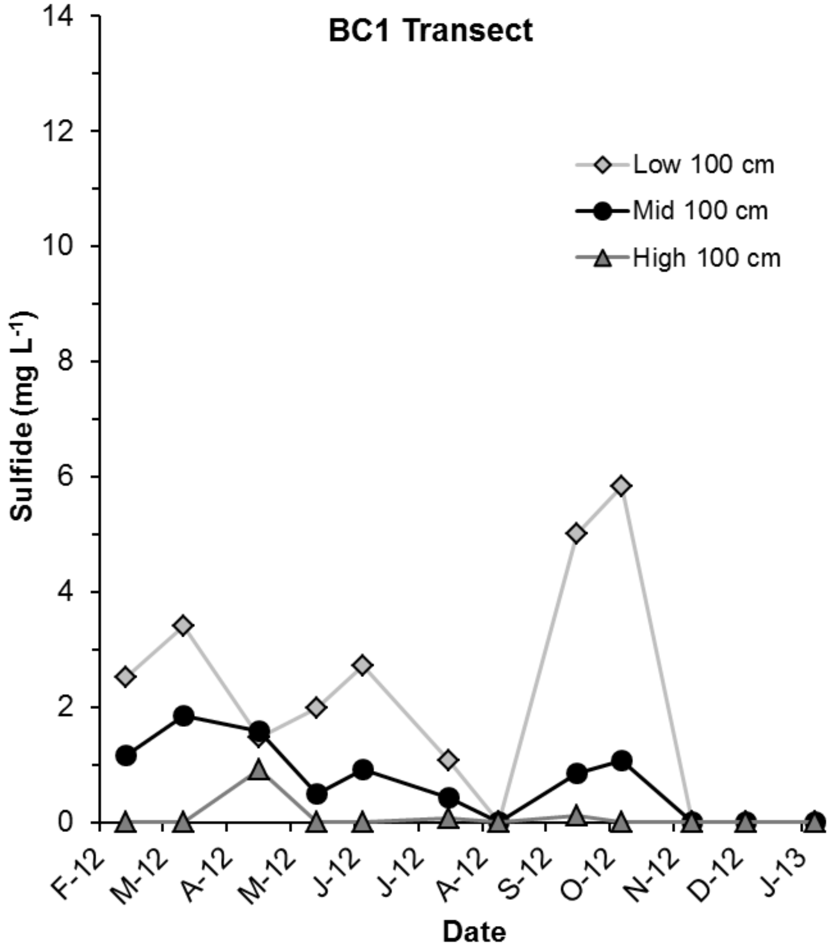

OW3 Transect
Specific Conductance (mS cm^{-1})
55
50
45
40
35
30
25
20
15
10
5
0
F-12
M-12
A-12
M-12
J-12
J-12
A-12
S-12
O-12
N-12
D-12
J-13
F-13
M-13
A-13
M-13
J-13
J-13
A-13
S-13
O-13
N-13
D-13
J-14
Date
Low 100 cm
Mid 100 cm
High 100 cm
Ocean
Bay

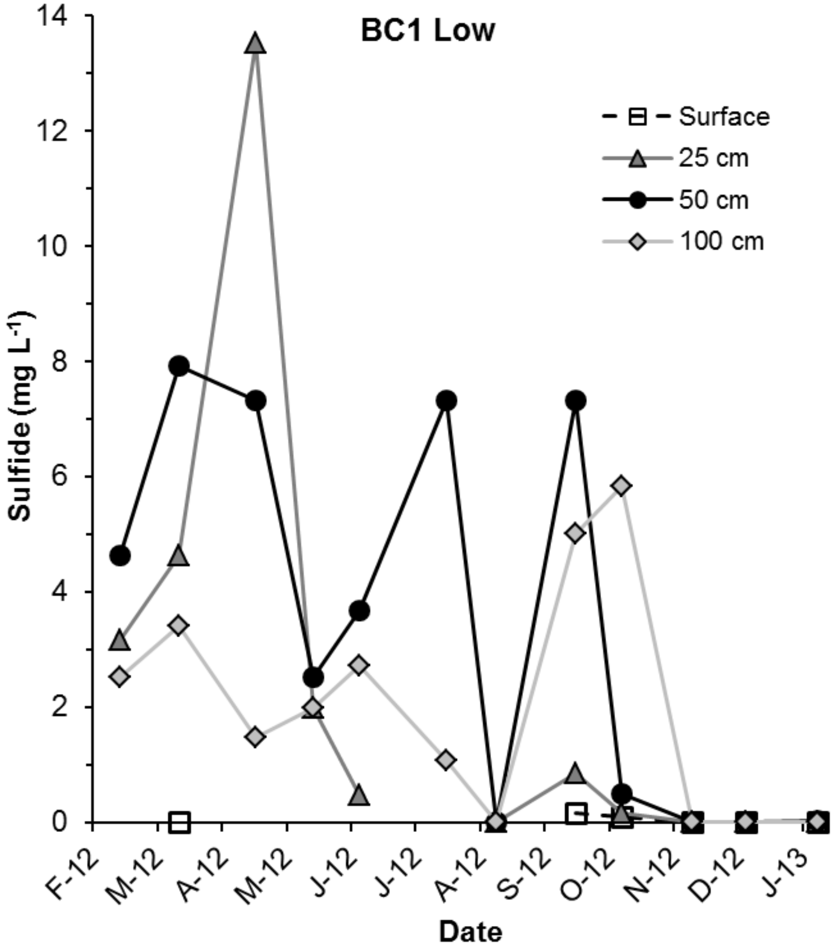

OW3 Low
Specific Conductance (mS cm-1)
55
50
45
40
35
30
25
20
15
10
5
0
F-12
M-12
A-12
M-12
J-12
J-12
A-12
S-12
O-12
N-12
D-12
J-13
F-13
M-13
A-13
M-13
J-13
J-13
A-13
S-13
O-13
N-13
D-13
J-14
Date
25 cm
50 cm
100 cm
Ocean
Bay

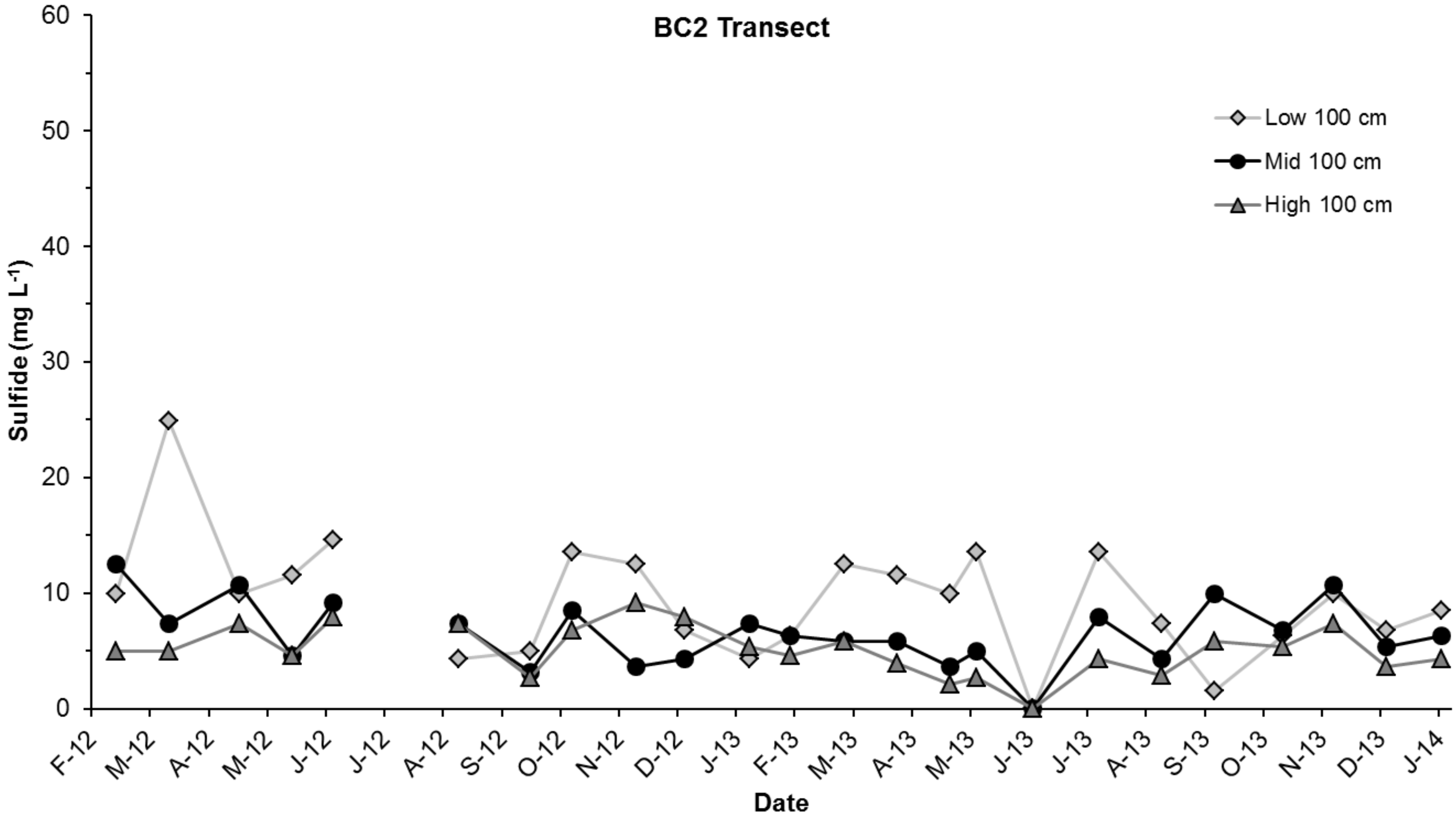

OW4 Transect
Specific Conductance (mS cm^{-1})
55
50
45
40
35
30
25
20
15
10
5
0
Low 100 cm
Mid 100 cm
High 100 cm
Ocean
Bay
F-12
M-12
A-12
M-12
J-12
J-12
A-12
S-12
O-12
N-12
D-12
J-13
Date

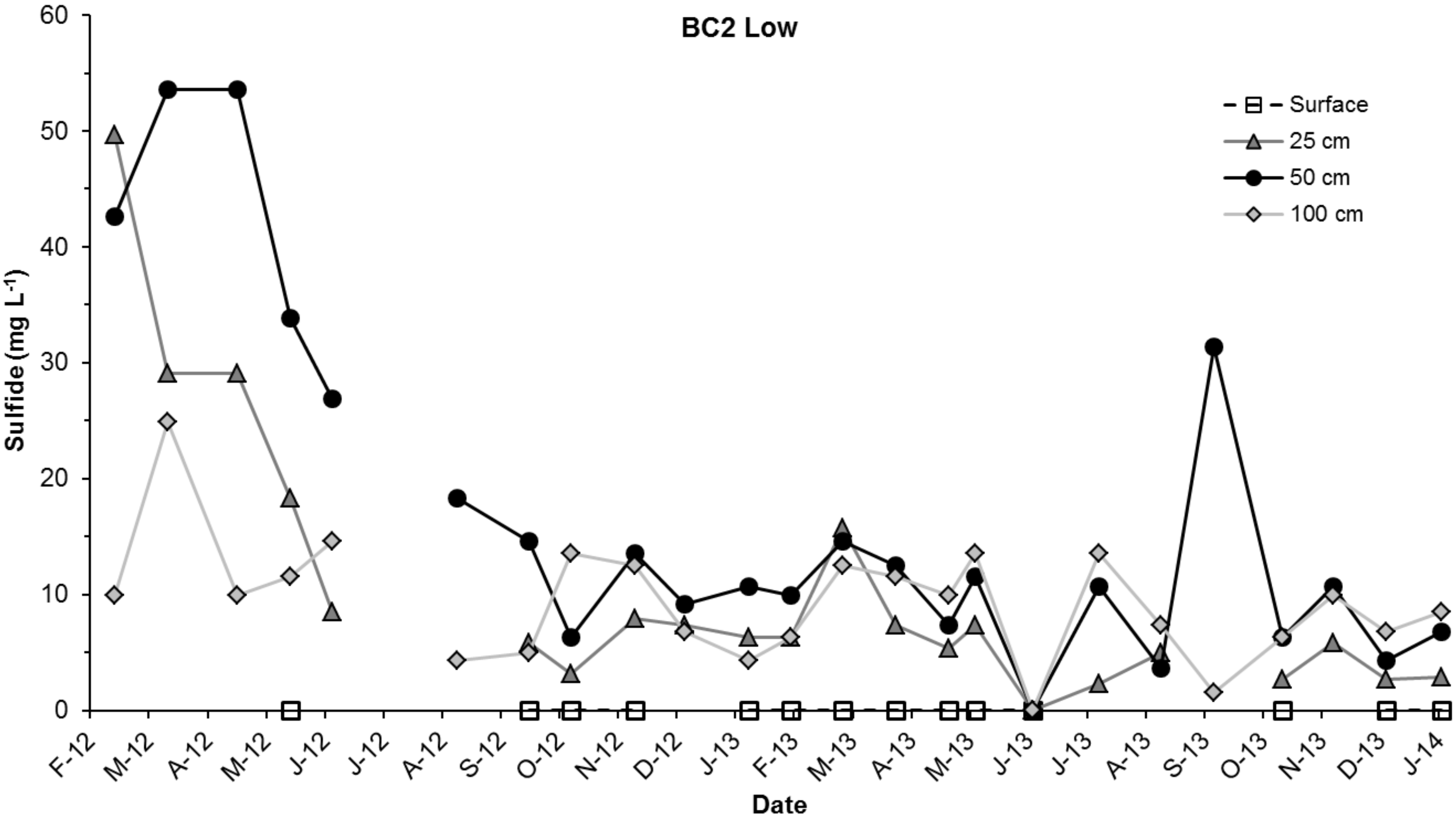

OW4 Low
Specific Conductance (mS cm^{-1})
55
50
45
40
35
30
25
20
15
10
5
0
25 cm
50 cm
100 cm
Ocean
Bay
F-12
M-12
A-12
M-12
J-12
J-12
A-12
S-12
O-12
N-12
D-12
J-13
Date

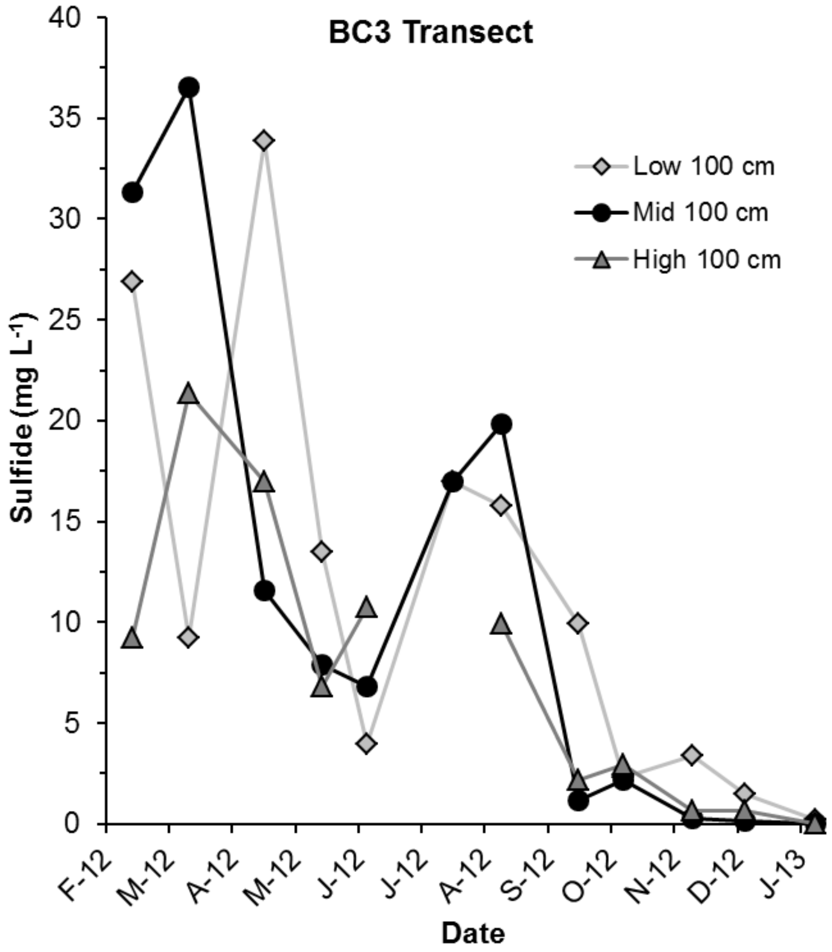
Sulfide Concentration

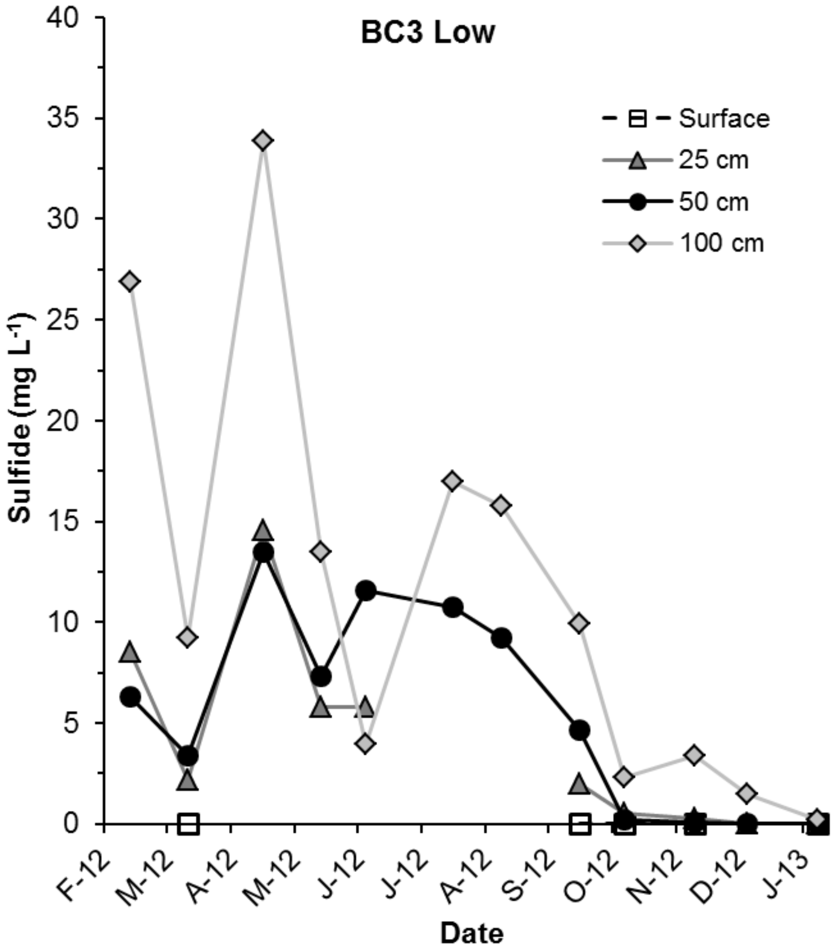


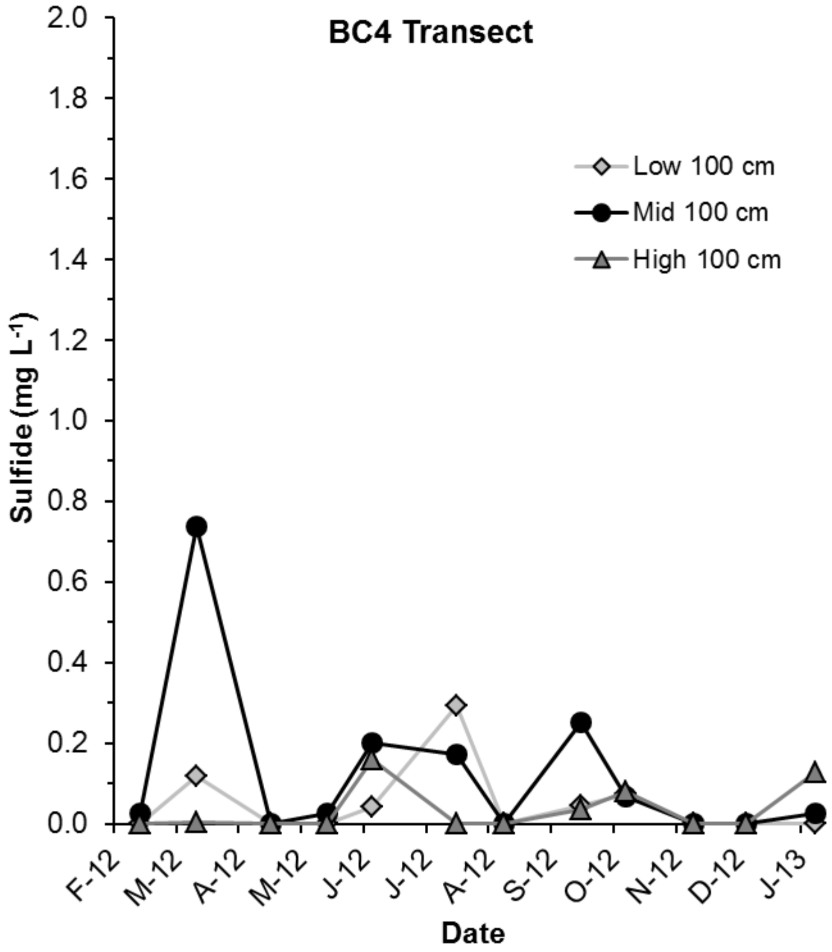



BC2 Transect
Sulfide (mg L⁻¹)
0
10
20
30
40
50
60
Date
F-12
M-12
A-12
M-12
J-12
J-12
A-12
S-12
O-12
N-12
D-12
J-13
F-13
M-13
A-13
M-13
J-13
J-13
A-13
S-13
O-13
N-13
D-13
J-14
Low 100 cm
Mid 100 cm
High 100 cm

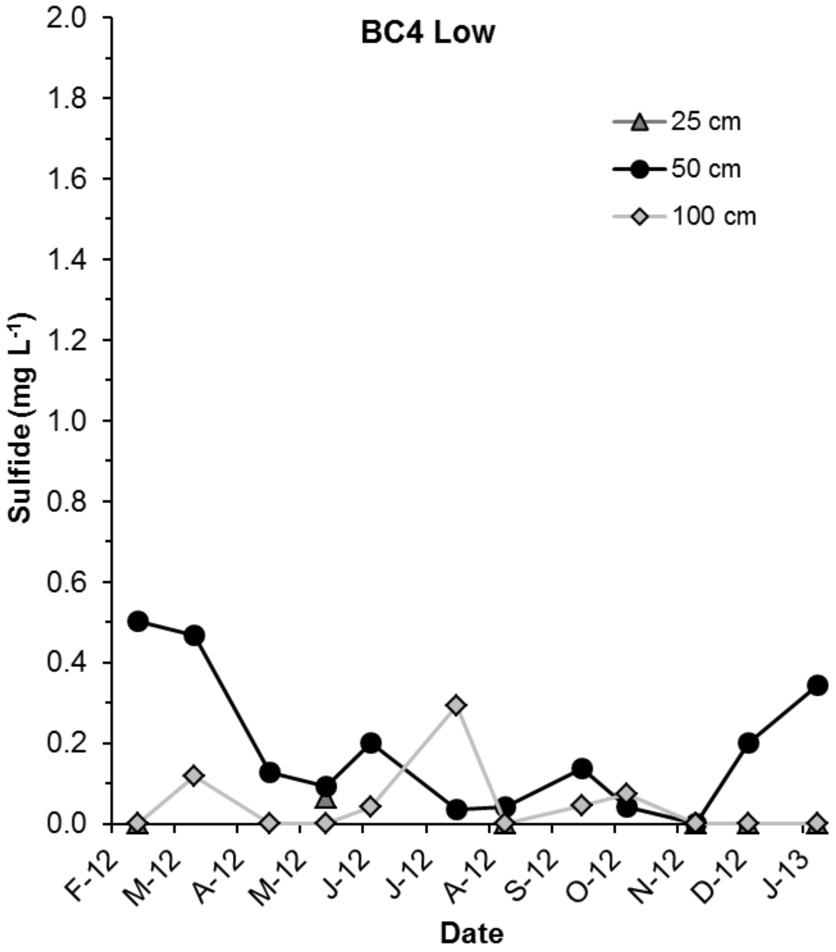

BC2 Low
Sulfide (mg L^{-1})
60
50
40
30
20
10
0
Surface
25 cm
50 cm
100 cm
F-12
M-12
A-12
M-12
J-12
J-12
A-12
S-12
O-12
N-12
D-12
J-13
F-13
M-13
A-13
M-13
J-13
J-13
A-13
S-13
O-13
N-13
D-13
J-14
Date


BC3 Transect
Low 100 cm
Mid 100 cm
High 100 cm
Sulfide (mg L^{-1})
0
5
10
15
20
25
30
35
40
F-12
M-12
A-12
M-12
J-12
J-12
A-12
S-12
O-12
N-12
D-12
J-13
Date

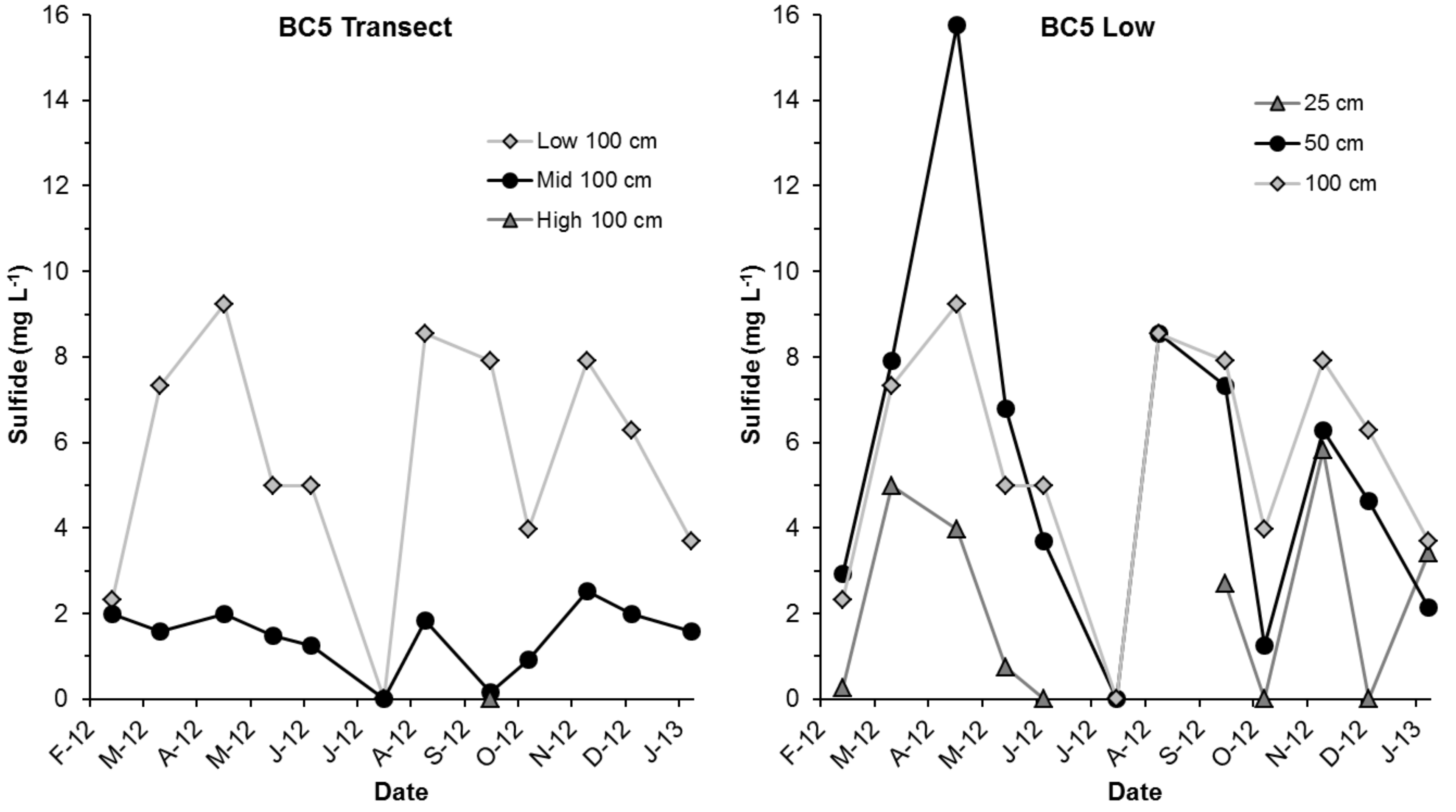

BC3 Low
Surface
25 cm
50 cm
100 cm
Sulfide (mg L^{-1})
0
5
10
15
20
25
30
35
40
F-12
M-12
A-12
M-12
J-12
J-12
A-12
S-12
O-12
N-12
D-12
J-13
Date

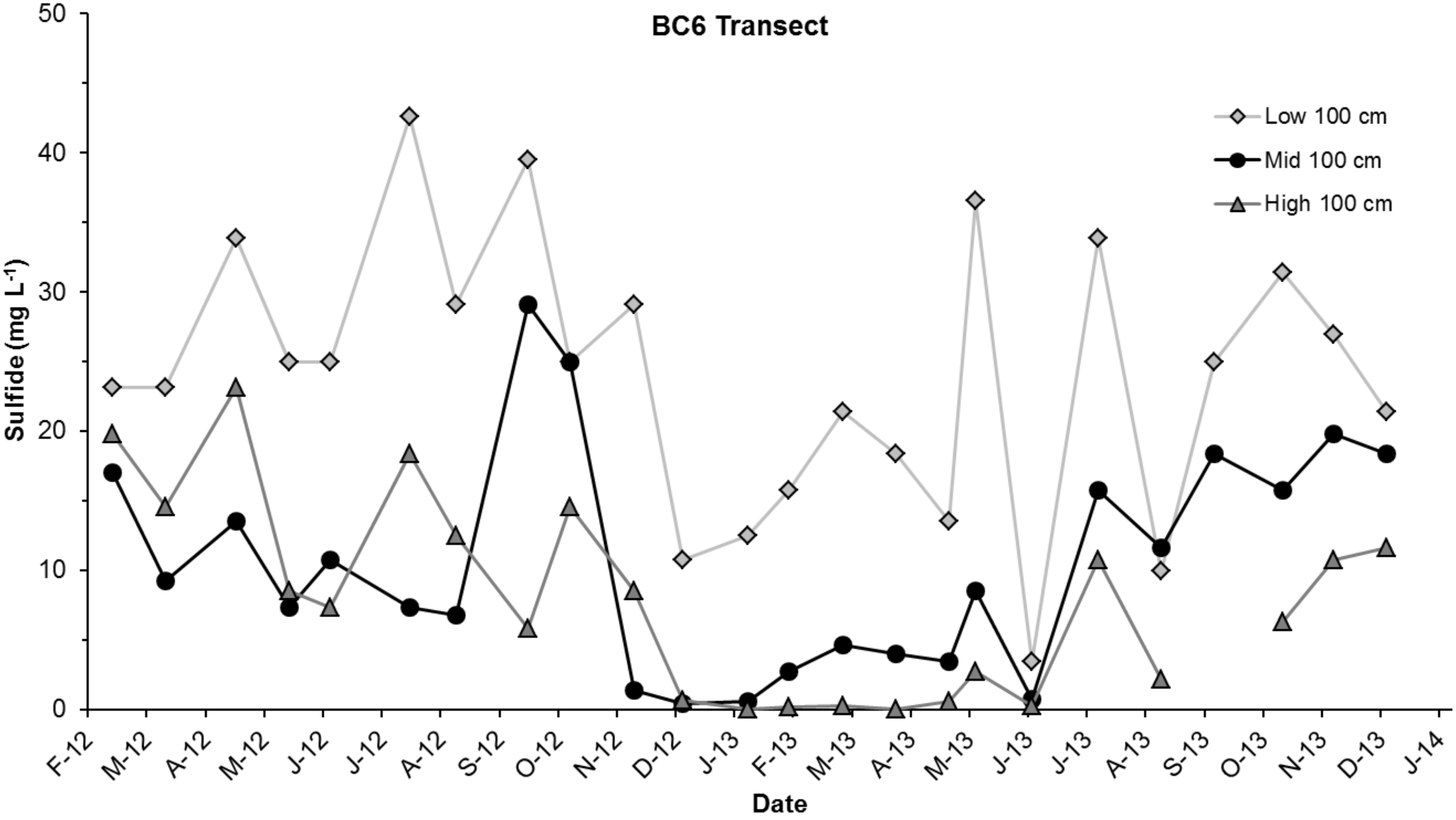


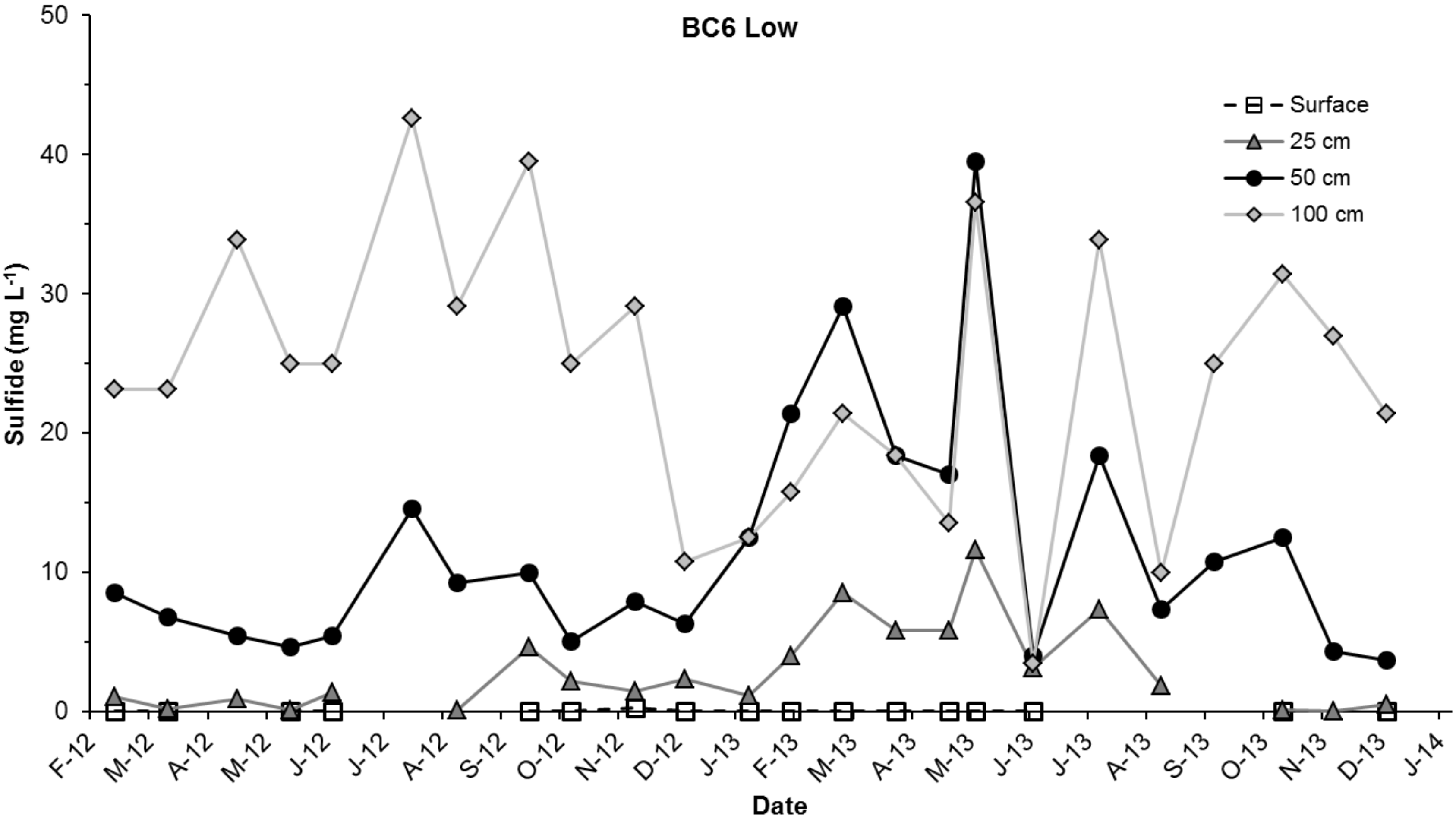
BC4 Transect
Low 100 cm
Mid 100 cm
High 100 cm
Sulfide (mg L-1)
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
F-12
M-12
A-12
M-12
J-12
J-12
A-12
S-12
O-12
N-12
D-12
J-13
Date

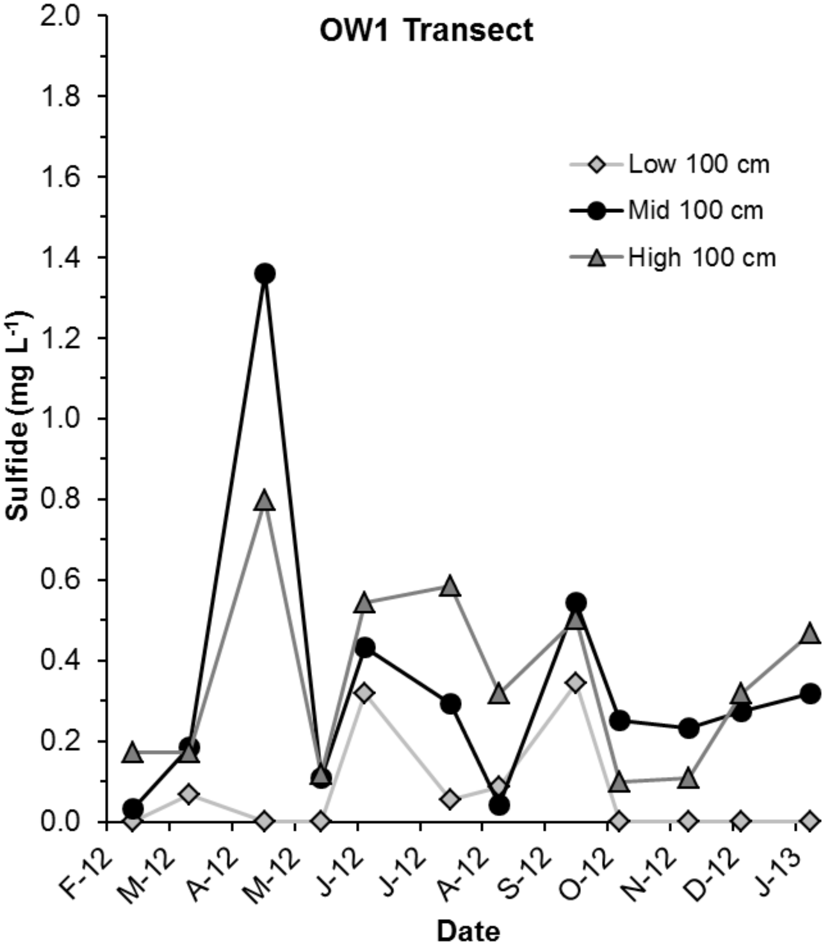


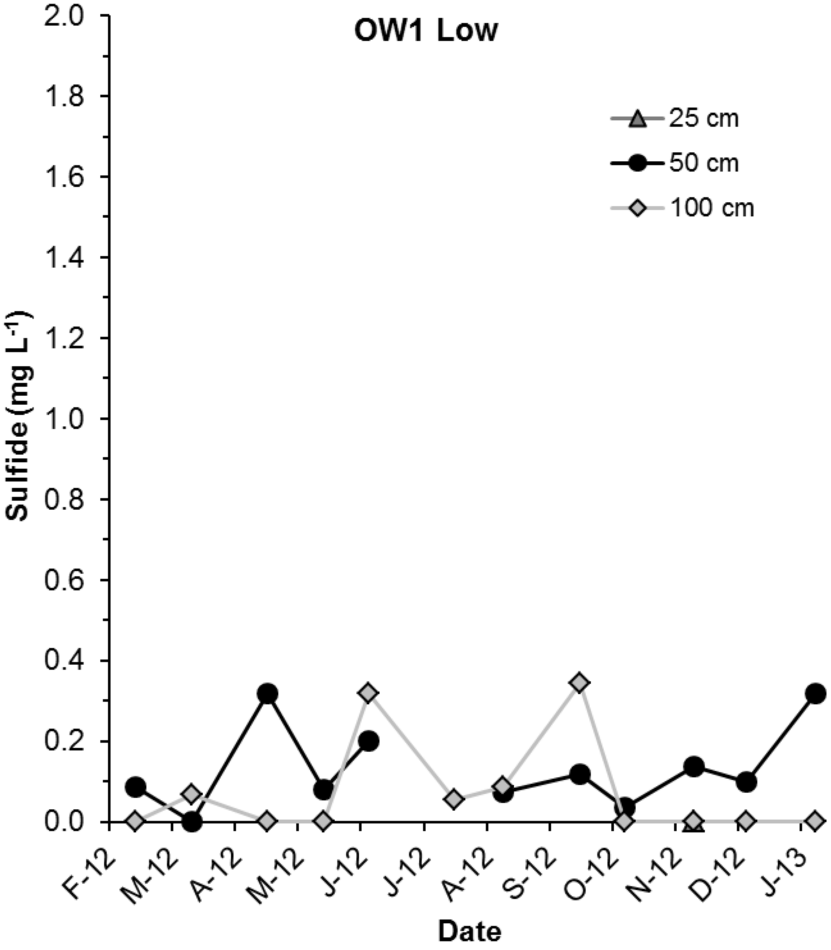
BC4 Low
25 cm
50 cm
100 cm
Sulfide (mg L-1)
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
F-12
M-12
A-12
M-12
J-12
J-12
A-12
S-12
O-12
N-12
D-12
J-13
Date

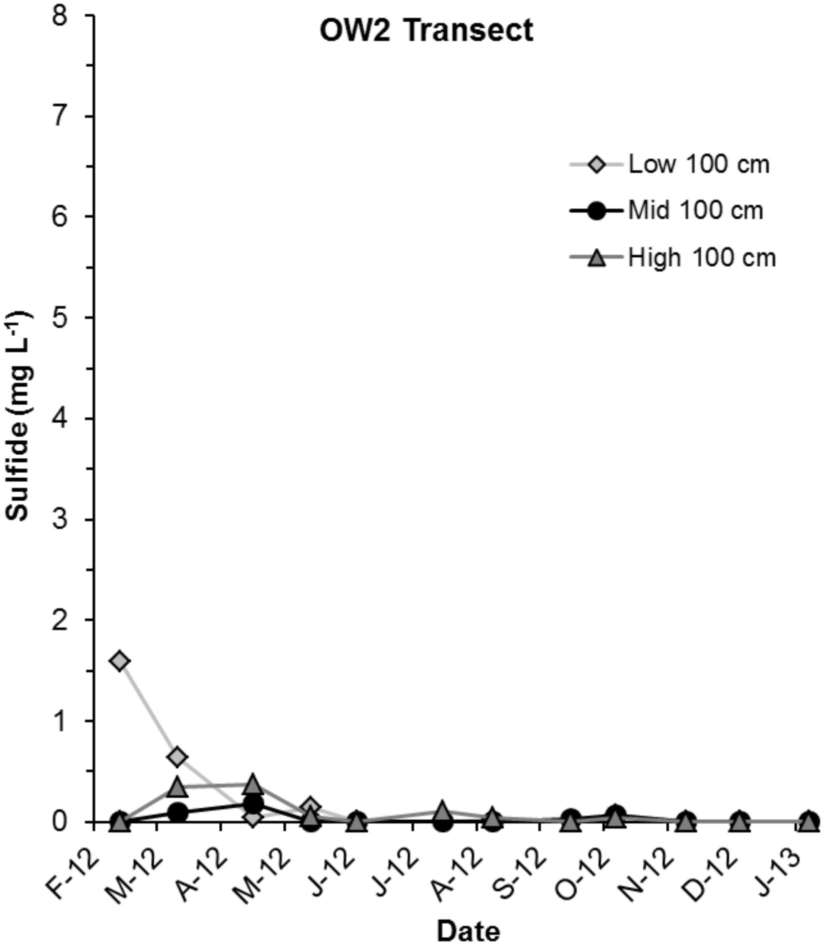

BC5 Transect
Low 100 cm
Mid 100 cm
High 100 cm
Sulfide (mg L-1)
Date
16
14
12
10
8
6
4
2
0
F-12
M-12
A-12
M-12
J-12
J-12
A-12
S-12
O-12
N-12
D-12
J-13
BC5 Low
25 cm
50 cm
100 cm
Sulfide (mg L-1)
Date

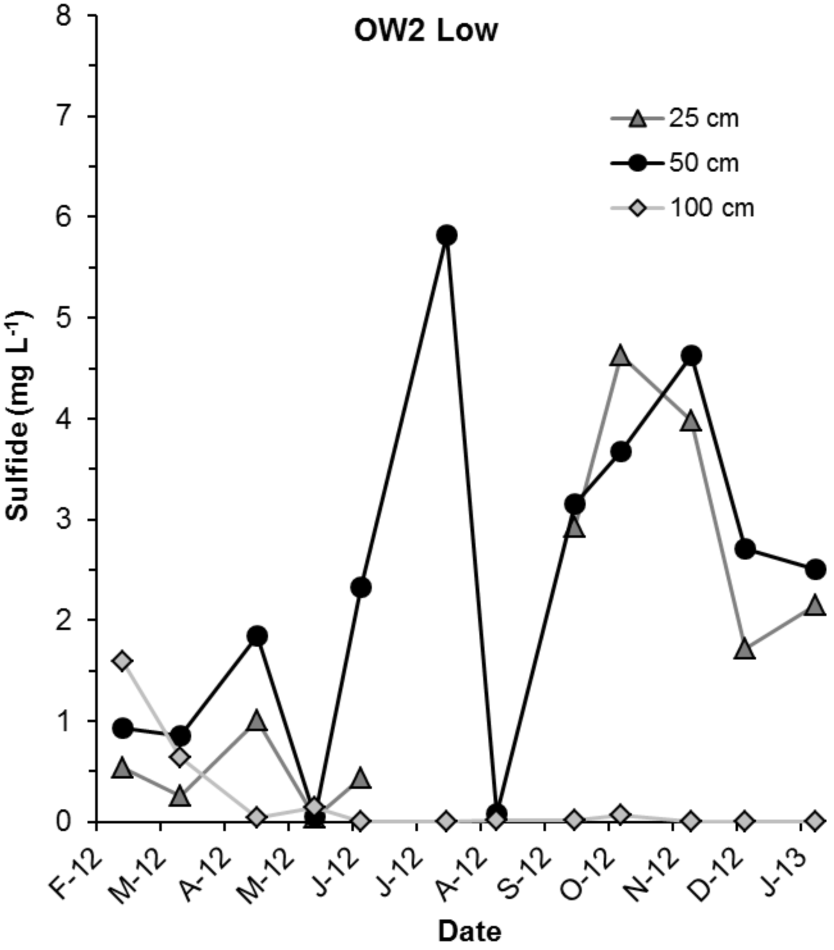

BC6 Transect
Sulfide (mg L^{-1})
0
10
20
30
40
50
F-12
M-12
A-12
M-12
J-12
J-12
A-12
S-12
O-12
N-12
D-12
J-13
F-13
M-13
A-13
M-13
J-13
J-13
A-13
S-13
O-13
N-13
D-13
J-14
Date
Low 100 cm
Mid 100 cm
High 100 cm

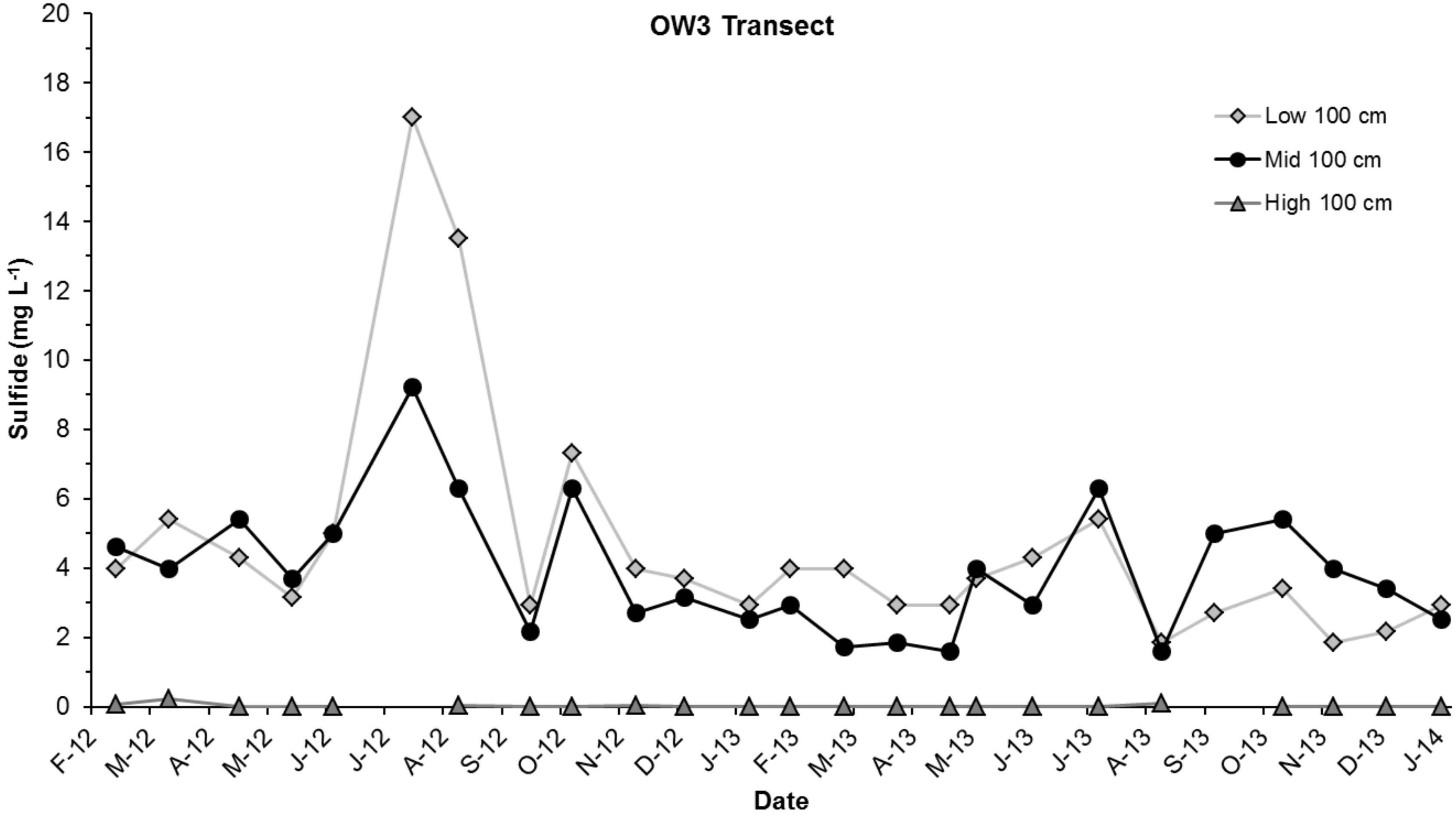

BC6 Low
Sulfide (mg L-1)
Date
50
40
30
20
10
0
F-12
M-12
A-12
M-12
J-12
J-12
A-12
S-12
O-12
N-12
D-12
J-13
F-13
M-13
A-13
M-13
J-13
J-13
A-13
S-13
O-13
N-13
D-13
J-14
Surface
25 cm
50 cm
100 cm


OW1 Transect
Low 100 cm
Mid 100 cm
High 100 cm
Sulfide (mg L^{-1})
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
F-12
M-12
A-12
M-12
J-12
J-12
A-12
S-12
O-12
N-12
D-12
J-13
Date

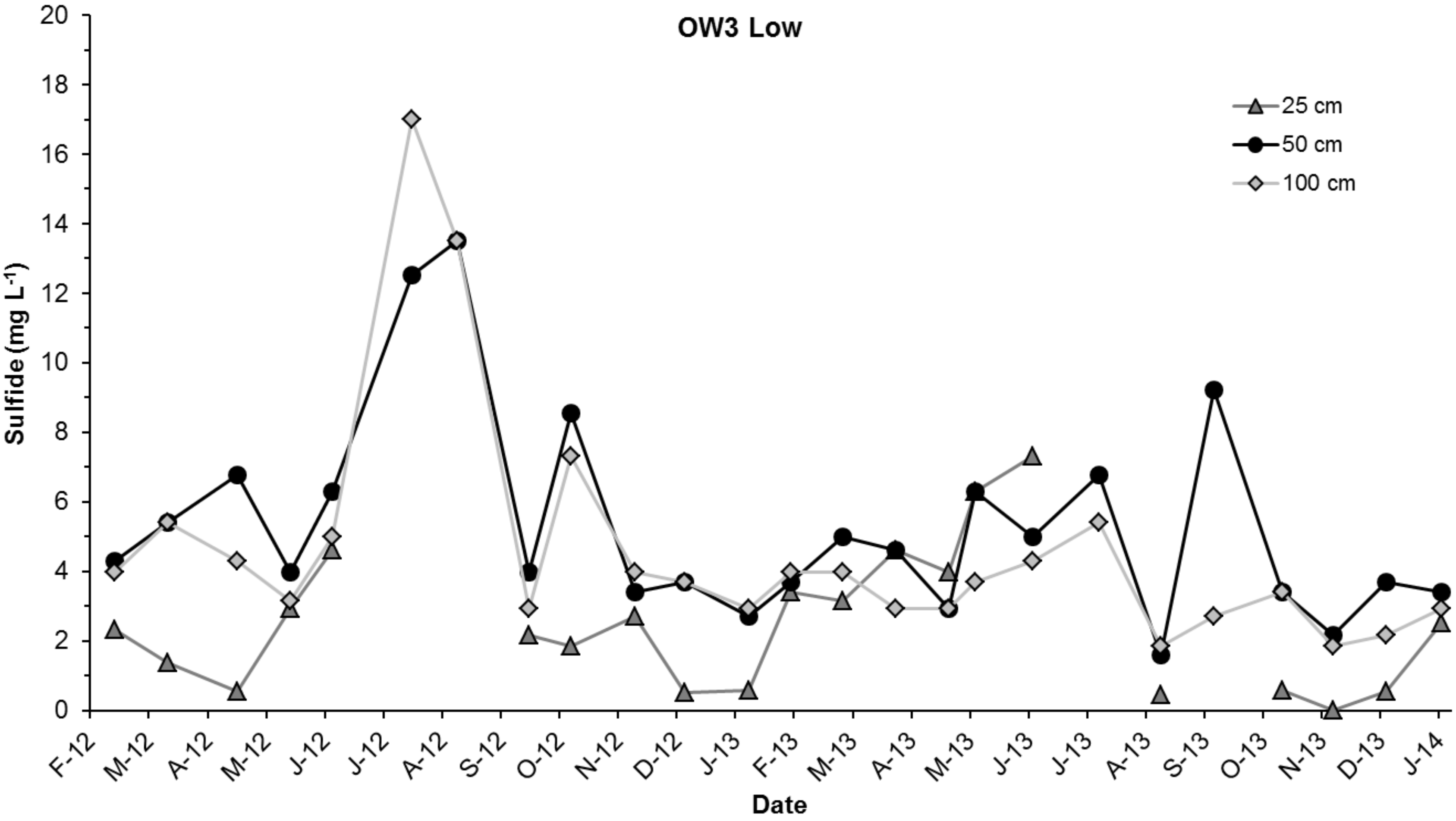

OW1 Low
25 cm
50 cm
100 cm
Sulfide (mg L^{-1})
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
F-12
M-12
A-12
M-12
J-12
J-12
A-12
S-12
O-12
N-12
D-12
J-13
Date

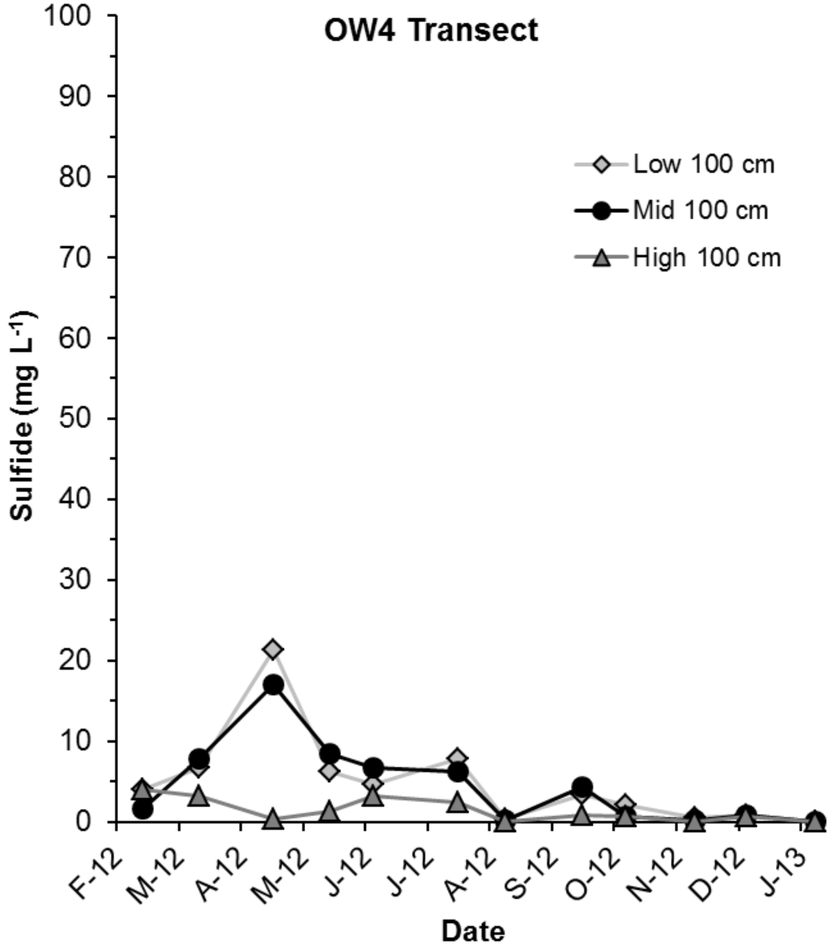

OW2 Transect
Sulfide (mg L-1)
Date
0
1
2
3
4
5
6
7
8
Low 100 cm
Mid 100 cm
High 100 cm
F-12
M-12
A-12
M-12
J-12
J-12
A-12
S-12
O-12
N-12
D-12
J-13

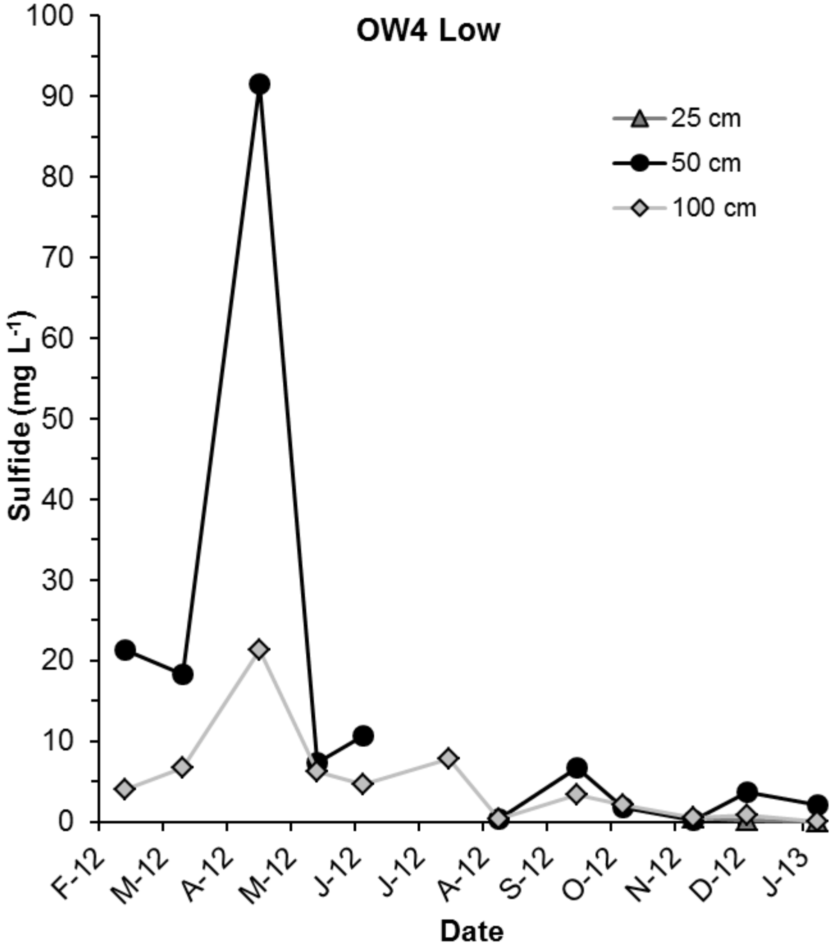

OW2 Low
Sulfide (mg L-1)
Date
0
1
2
3
4
5
6
7
8
25 cm
50 cm
100 cm
F-12
M-12
A-12
M-12
J-12
J-12
A-12
S-12
O-12
N-12
D-12
J-13



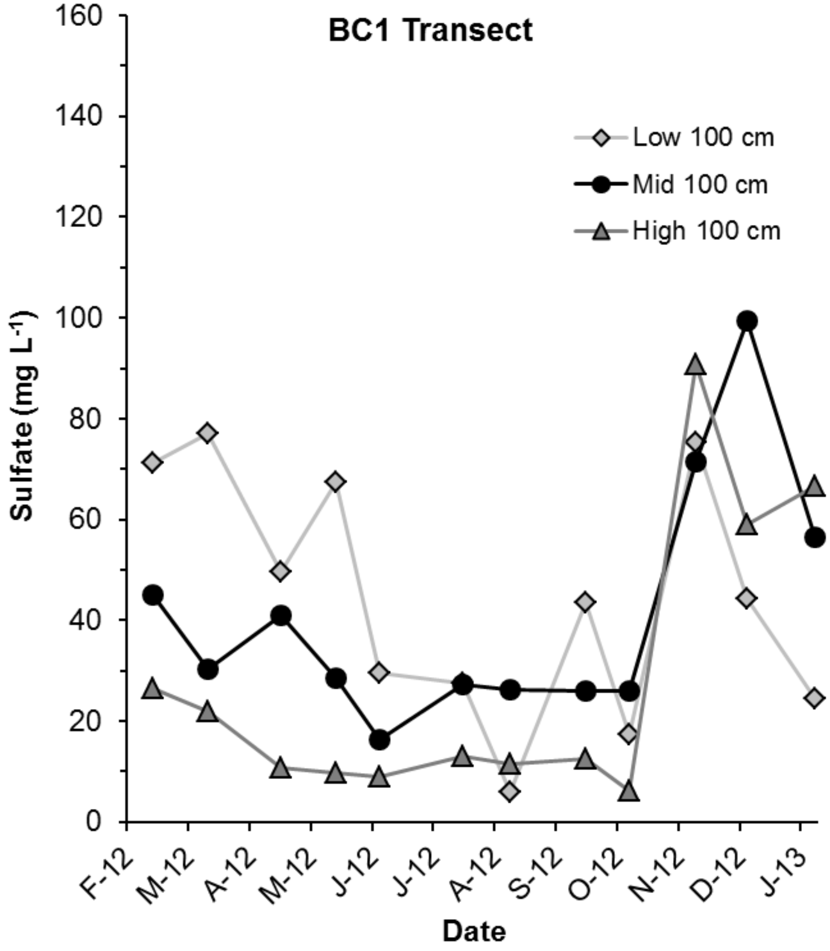
OW3 Transect
Sulfide (mg L-1)
20
18
16
14
12
10
8
6
4
2
0
Low 100 cm
Mid 100 cm
High 100 cm
F-12
M-12
A-12
M-12
J-12
J-12
A-12
S-12
O-12
N-12
D-12
J-13
F-13
M-13
A-13
M-13
J-13
J-13
A-13
S-13
O-13
N-13
D-13
J-14
Date

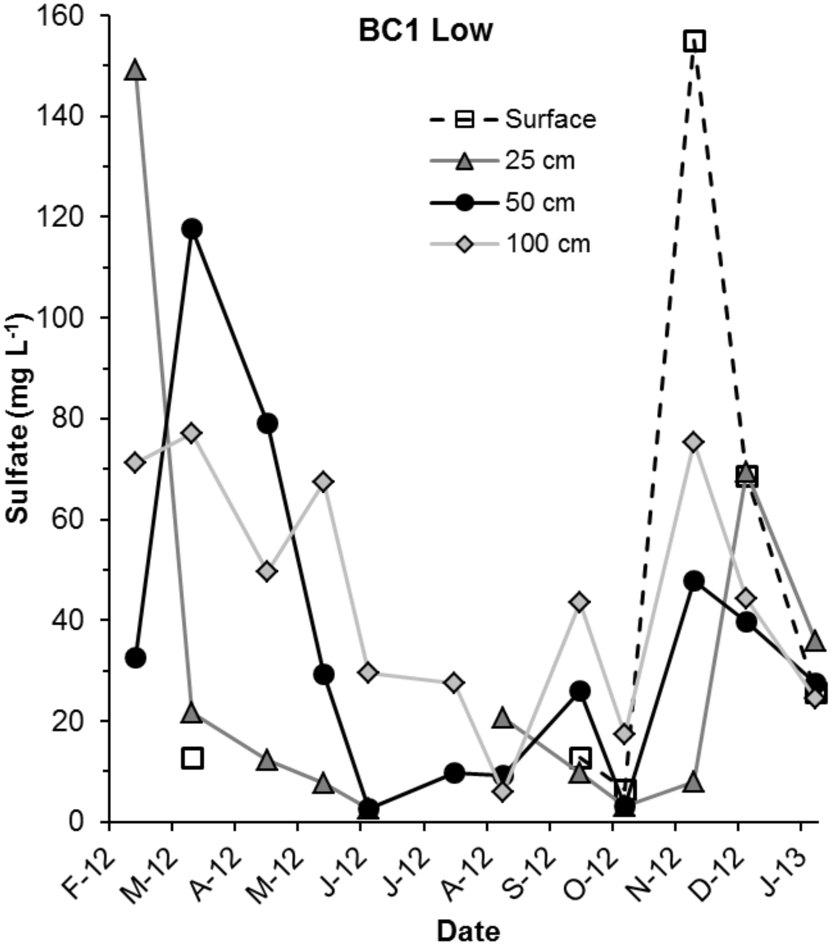

OW3 Low
Sulfide (mg L^{-1})
20
18
16
14
12
10
8
6
4
2
0
25 cm
50 cm
100 cm
F-12
M-12
A-12
M-12
J-12
J-12
A-12
S-12
O-12
N-12
D-12
J-13
F-13
M-13
A-13
M-13
J-13
J-13
A-13
S-13
O-13
N-13
D-13
J-14
Date

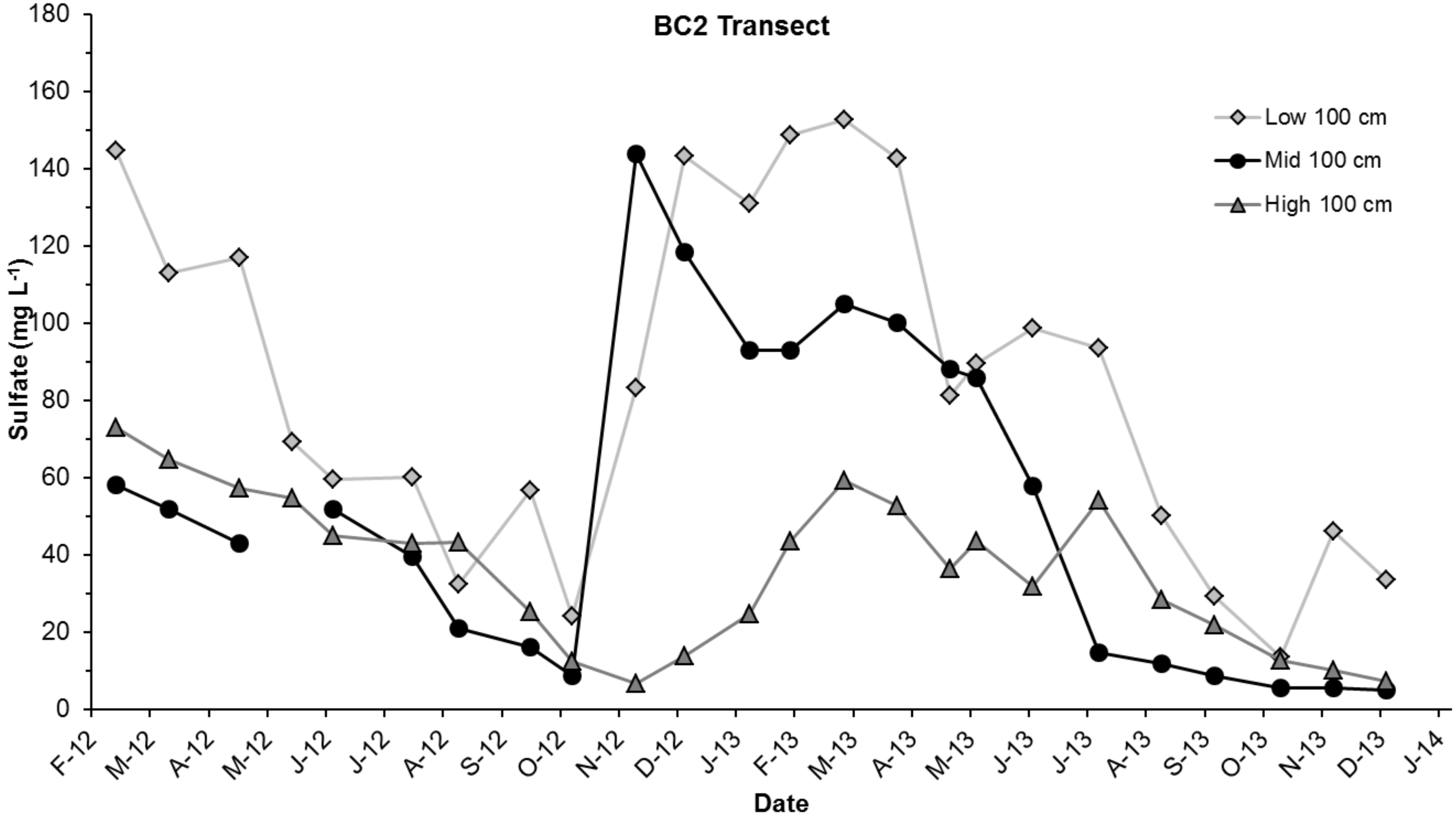

OW4 Transect
Sulfide (mg L⁻¹)
100
90
80
70
60
50
40
30
20
10
0
Low 100 cm
Mid 100 cm
High 100 cm
F-12
M-12
A-12
M-12
J-12
J-12
A-12
S-12
O-12
N-12
D-12
J-13
Date


OW4 Low
Sulfide (mg L⁻¹)
100
90
80
70
60
50
40
30
20
10
0
25 cm
50 cm
100 cm
F-12
M-12
A-12
M-12
J-12
J-12
A-12
S-12
O-12
N-12
D-12
J-13
Date

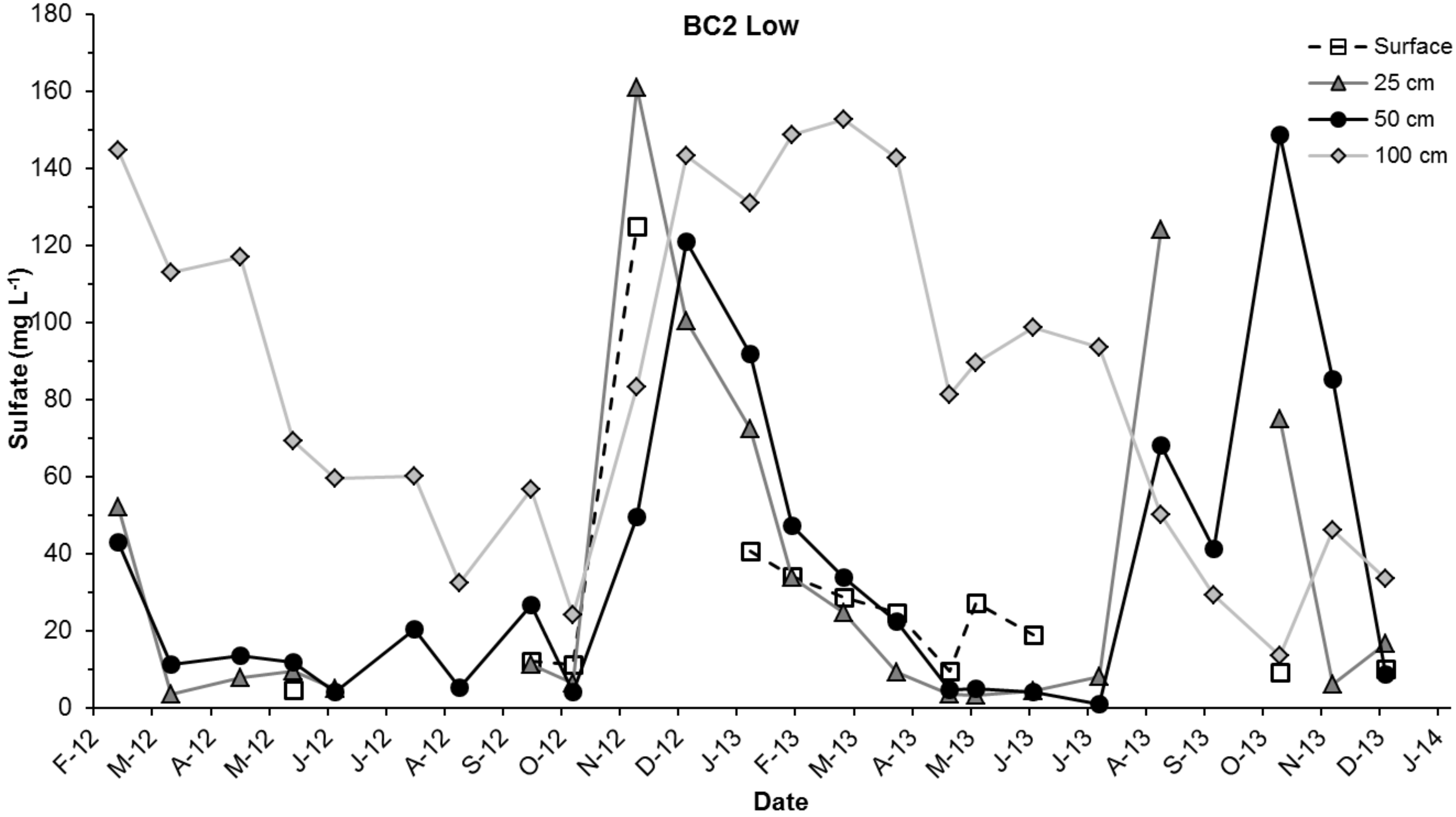
Sulfate Concentration

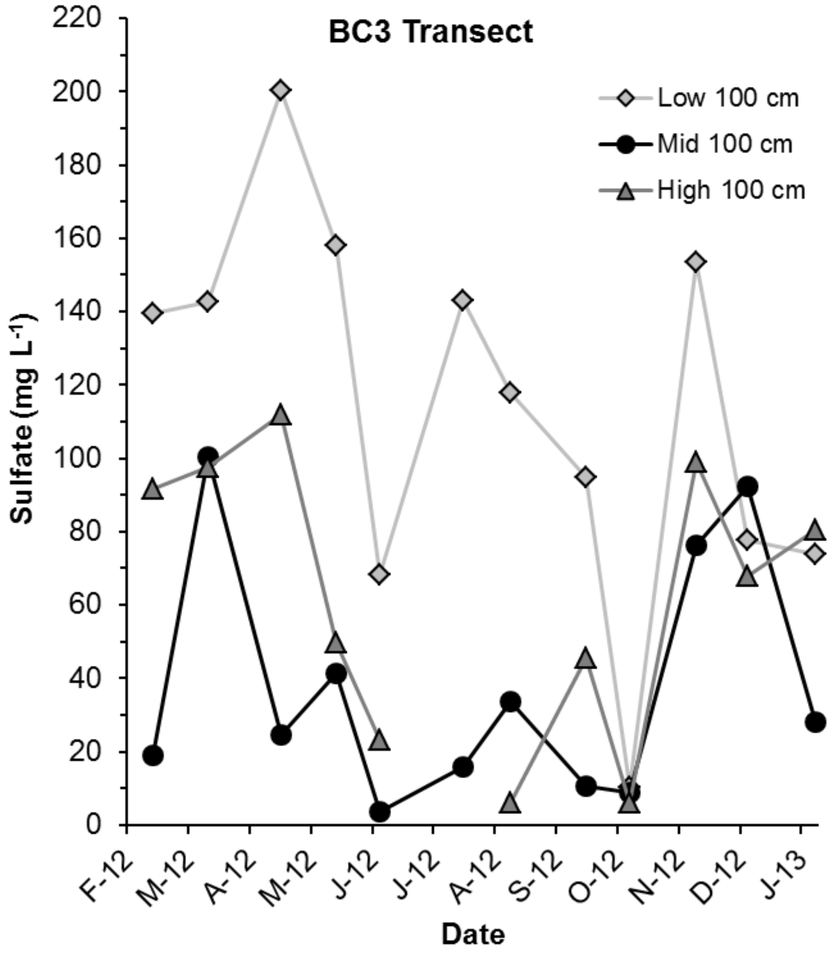


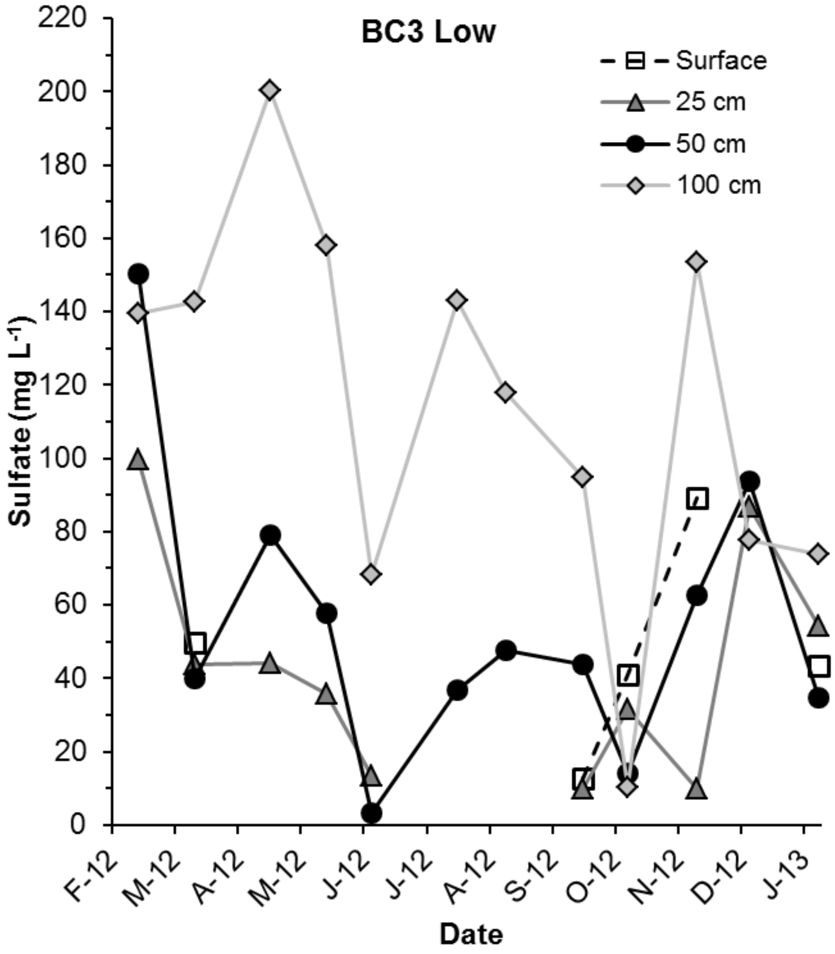


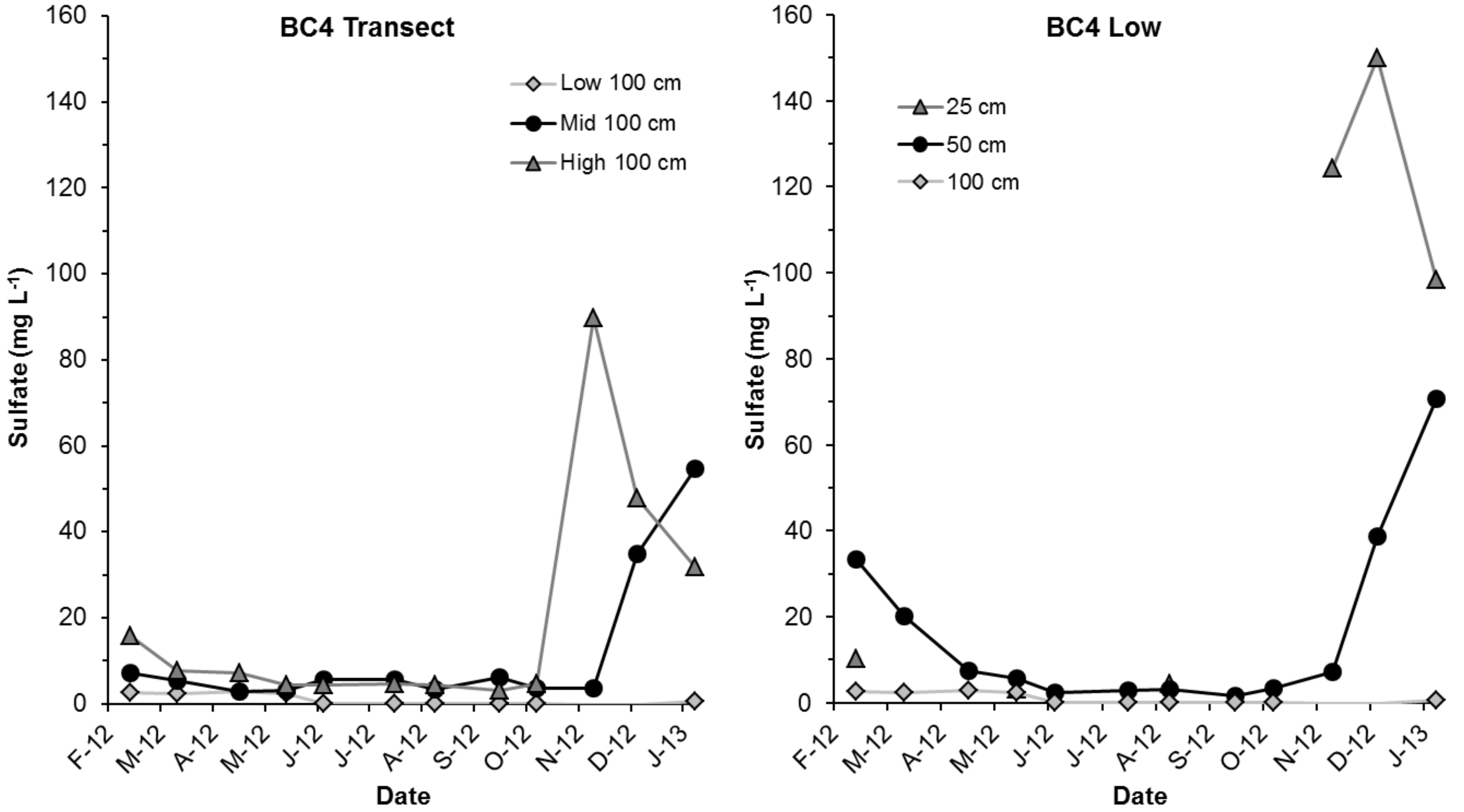


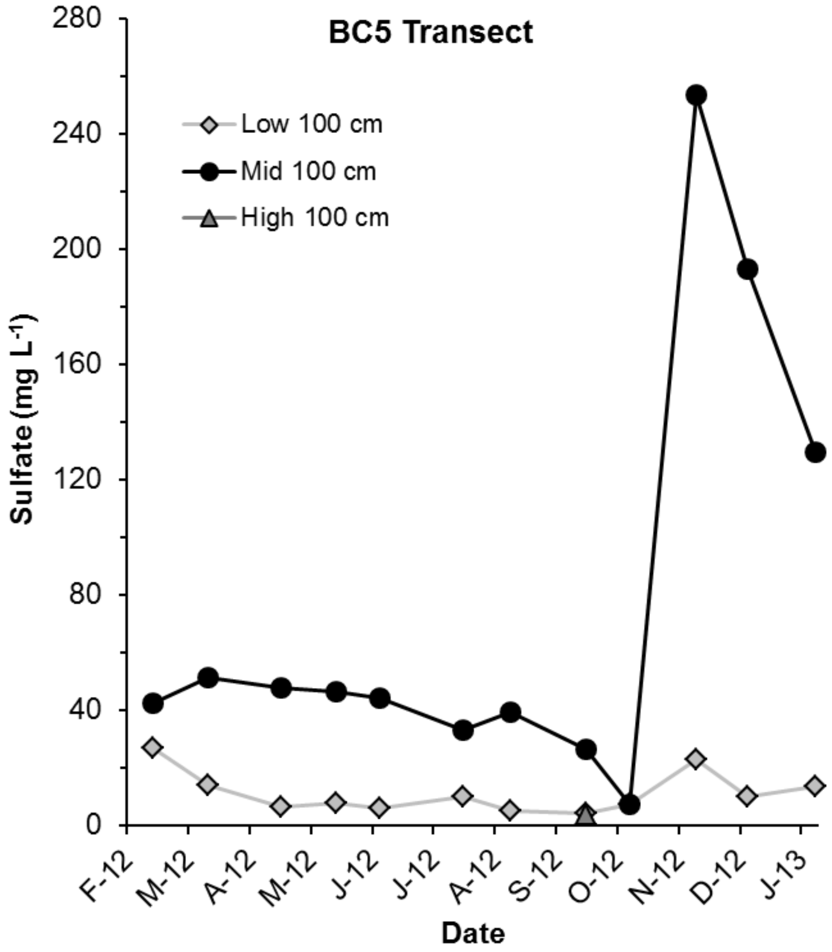
BC2 Transect
Low 100 cm
Mid 100 cm
High 100 cm
Sulfate (mg L^{-1})
0
20
40
60
80
100
120
140
160
180
F-12
M-12
A-12
M-12
J-12
J-12
A-12
S-12
O-12
N-12
D-12
J-13
F-13
M-13
A-13
M-13
J-13
J-13
A-13
S-13
O-13
N-13
D-13
J-14
Date


BC2 Low
Surface
25 cm
50 cm
100 cm
Sulfate (mg L-1)
0
20
40
60
80
100
120
140
160
180
F-12
M-12
A-12
M-12
J-12
J-12
A-12
S-12
O-12
N-12
D-12
J-13
F-13
M-13
A-13
M-13
J-13
J-13
A-13
S-13
O-13
N-13
D-13
J-14
Date

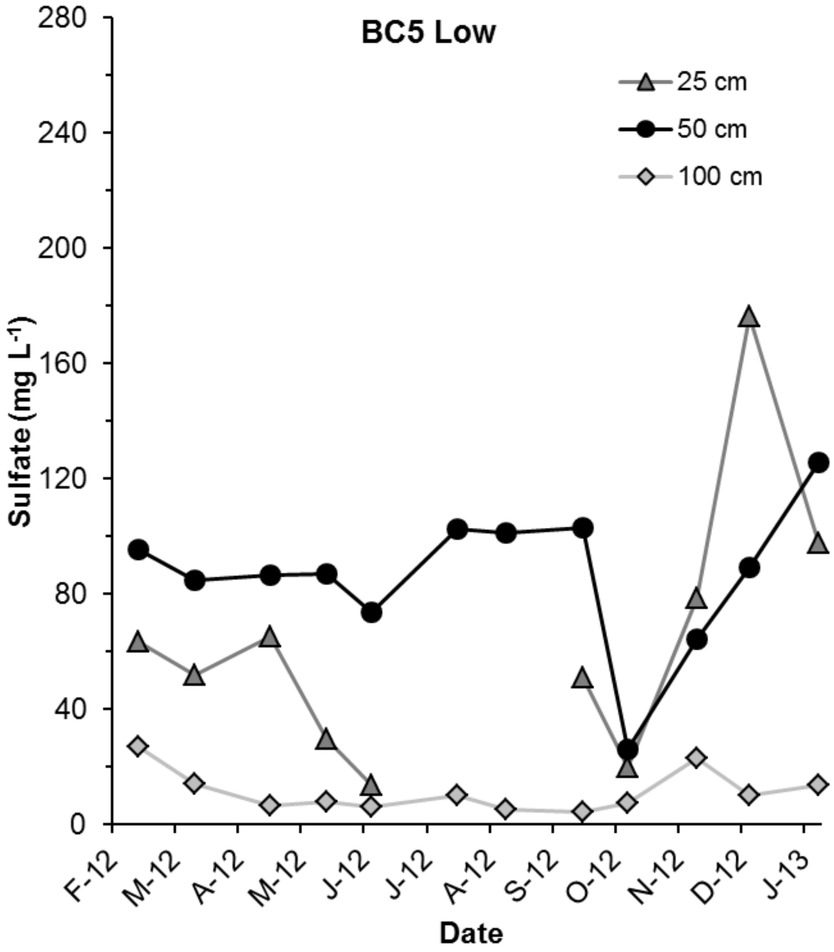

BC3 Transect
Low 100 cm
Mid 100 cm
High 100 cm
Sulfate (mg L^{-1})
220
200
180
160
140
120
100
80
60
40
20
0
F-12
M-12
A-12
M-12
J-12
J-12
A-12
S-12
O-12
N-12
D-12
J-13
Date


BC3 Low
Surface
25 cm
50 cm
100 cm
Sulfate (mg L^{-1})
220
200
180
160
140
120
100
80
60
40
20
0
F-12
M-12
A-12
M-12
J-12
J-12
A-12
S-12
O-12
N-12
D-12
J-13
Date

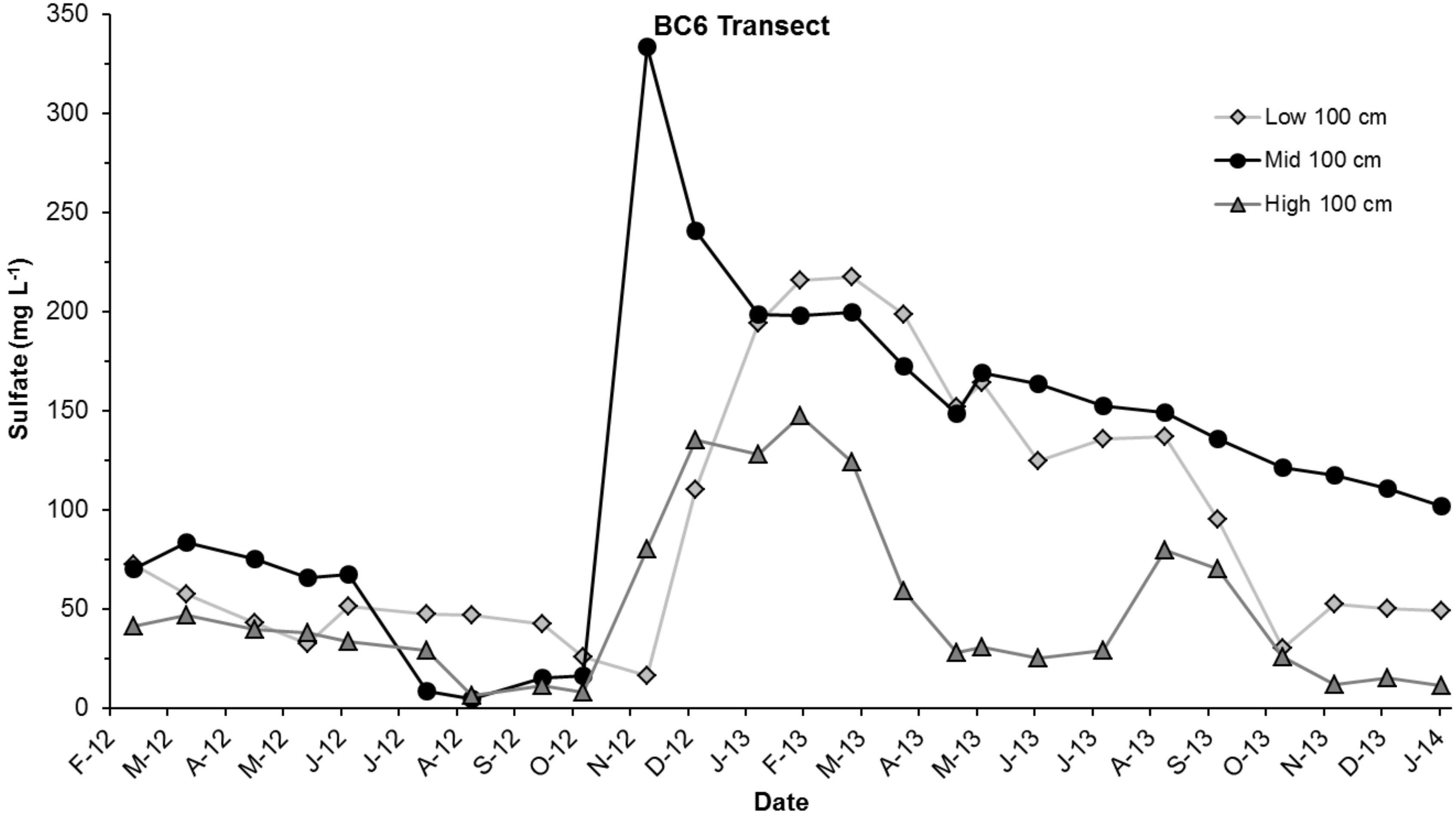

BC4 Transect
Low 100 cm
Mid 100 cm
High 100 cm
Sulfate (mg L-1)
160
140
120
100
80
60
40
20
0
F-12
M-12
A-12
M-12
J-12
J-12
A-12
S-12
O-12
N-12
D-12
J-13
Date
BC4 Low
25 cm
50 cm
100 cm
Sulfate (mg L-1)
Date

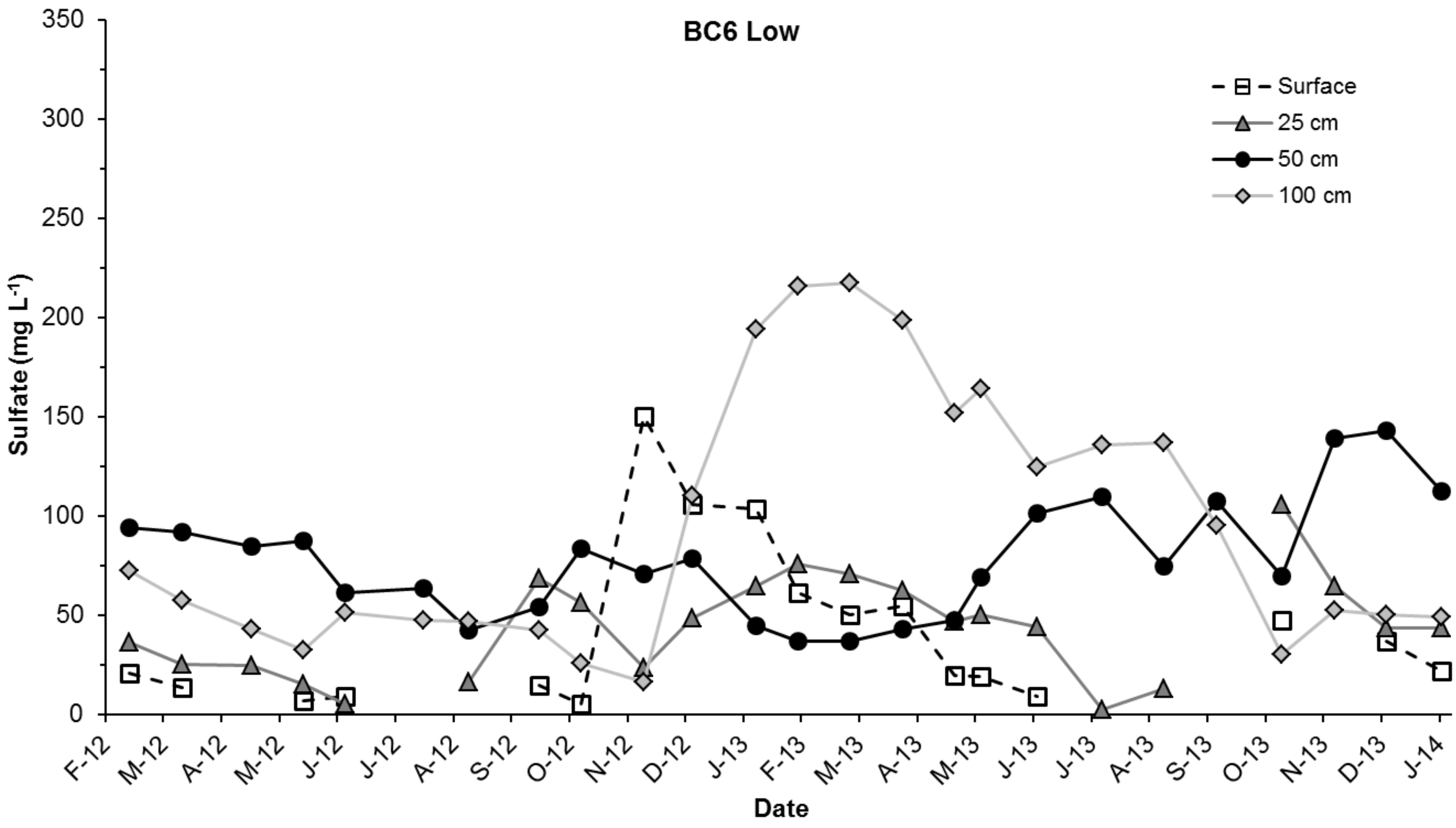


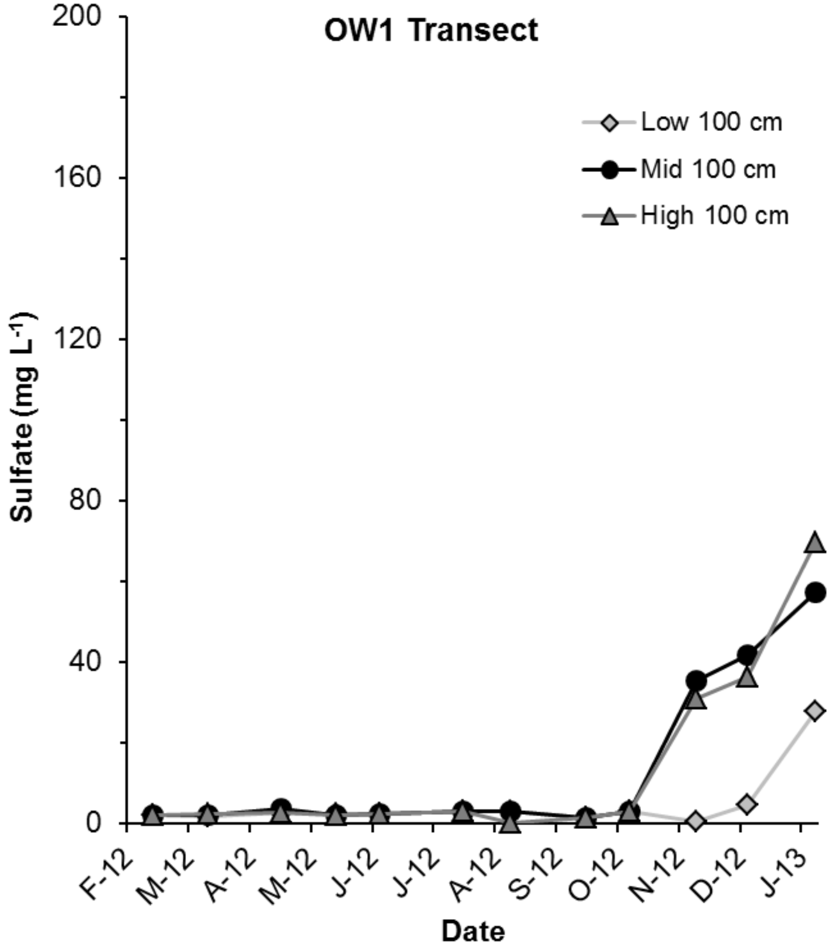
BC5 Transect
Low 100 cm
Mid 100 cm
High 100 cm
Sulfate (mg L-1)
280
240
200
160
120
80
40
0
F-12
M-12
A-12
M-12
J-12
J-12
A-12
S-12
O-12
N-12
D-12
J-13
Date

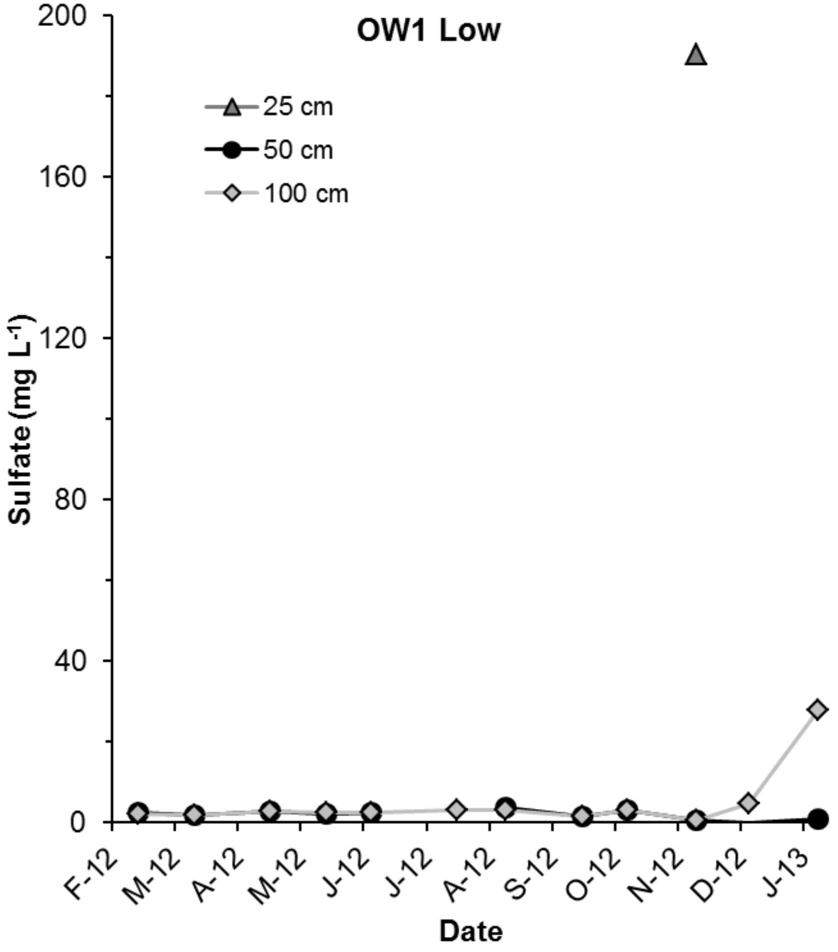


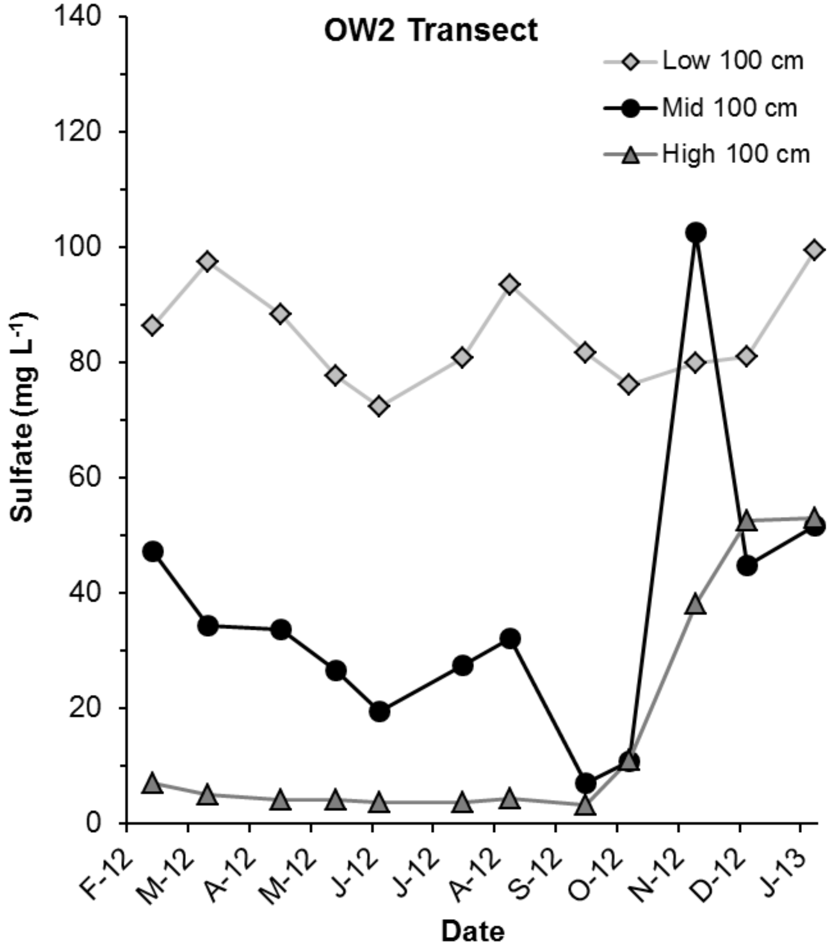
BC5 Low
25 cm
50 cm
100 cm
Sulfate (mg L-1)
280
240
200
160
120
80
40
0
F-12
M-12
A-12
M-12
J-12
J-12
A-12
S-12
O-12
N-12
D-12
J-13
Date

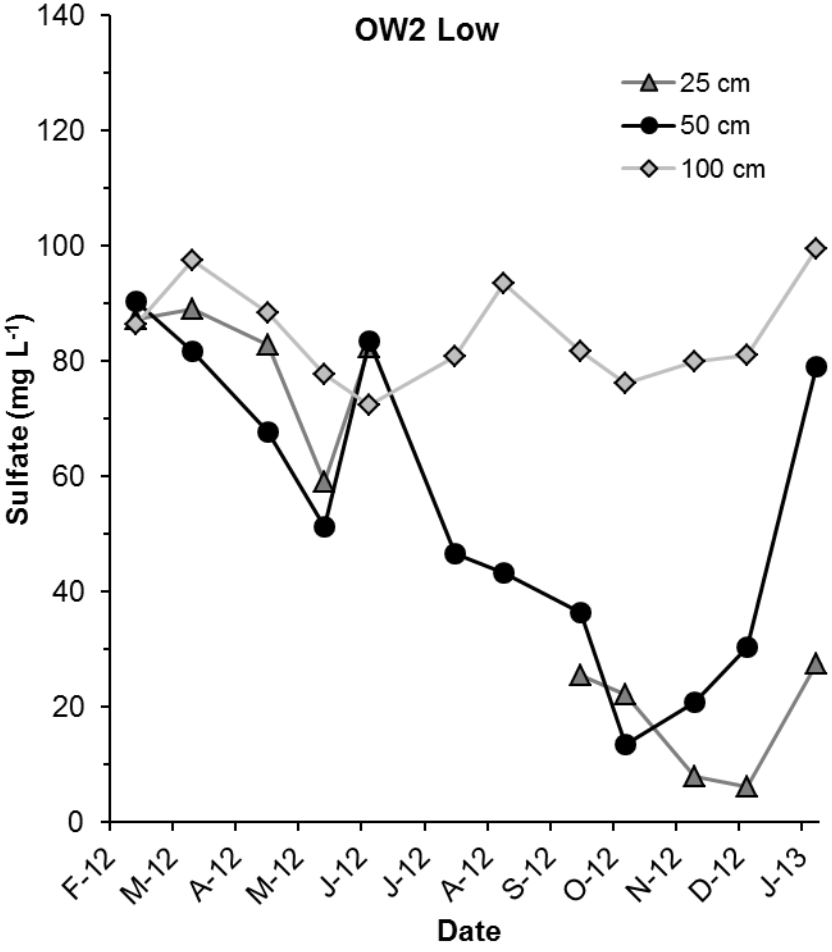

BC6 Transect
Sulfate (mg L-1)
0
50
100
150
200
250
300
350
Date
F-12
M-12
A-12
M-12
J-12
J-12
A-12
S-12
O-12
N-12
D-12
J-13
F-13
M-13
A-13
M-13
J-13
J-13
A-13
S-13
O-13
N-13
D-13
J-14
Low 100 cm
Mid 100 cm
High 100 cm

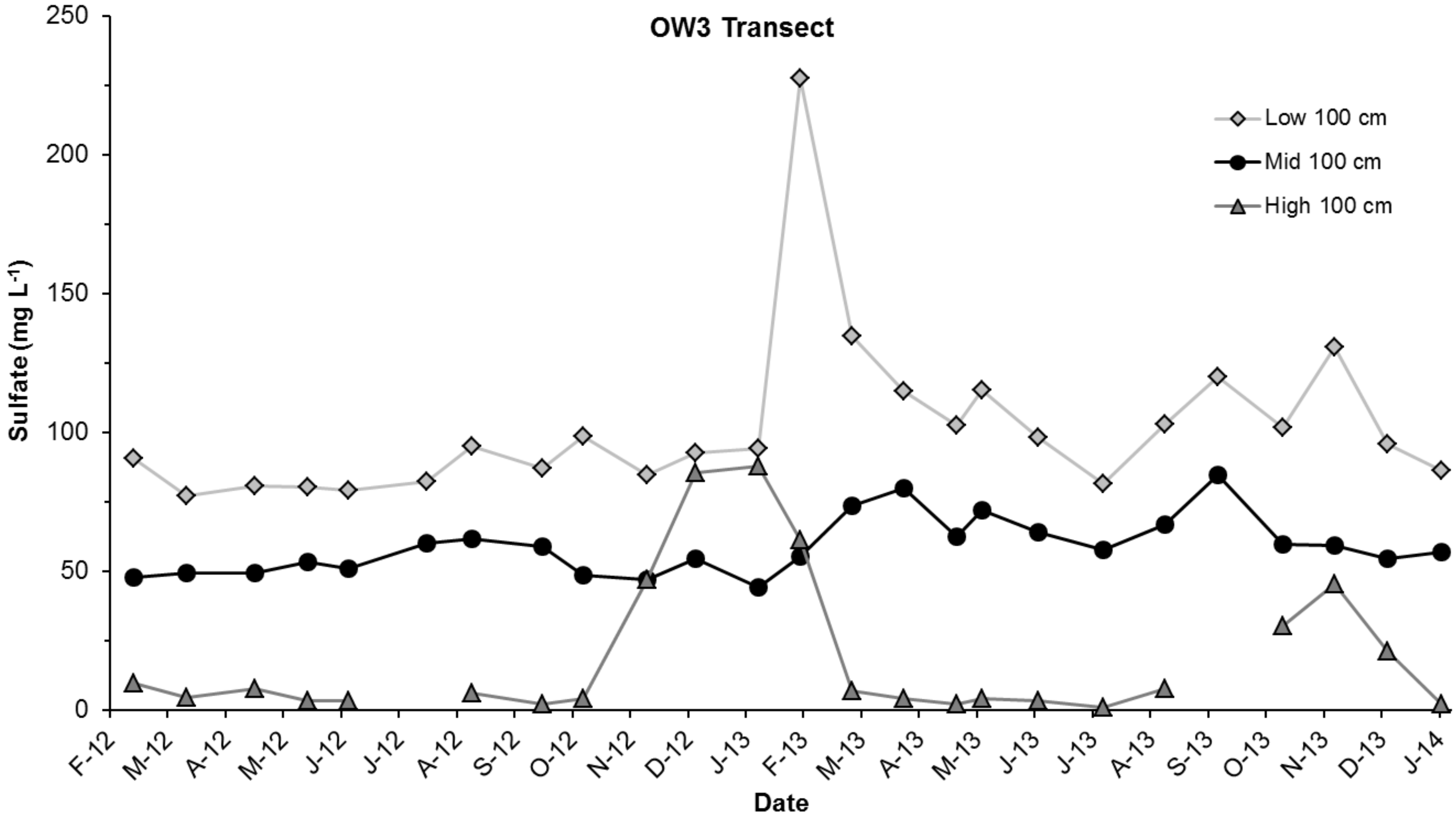

BC6 Low
Surface
25 cm
50 cm
100 cm
Sulfate (mg L⁻¹)
0
50
100
150
200
250
300
350
Date
F-12
M-12
A-12
M-12
J-12
J-12
A-12
S-12
O-12
N-12
D-12
J-13
F-13
M-13
A-13
M-13
J-13
J-13
A-13
S-13
O-13
N-13
D-13
J-14

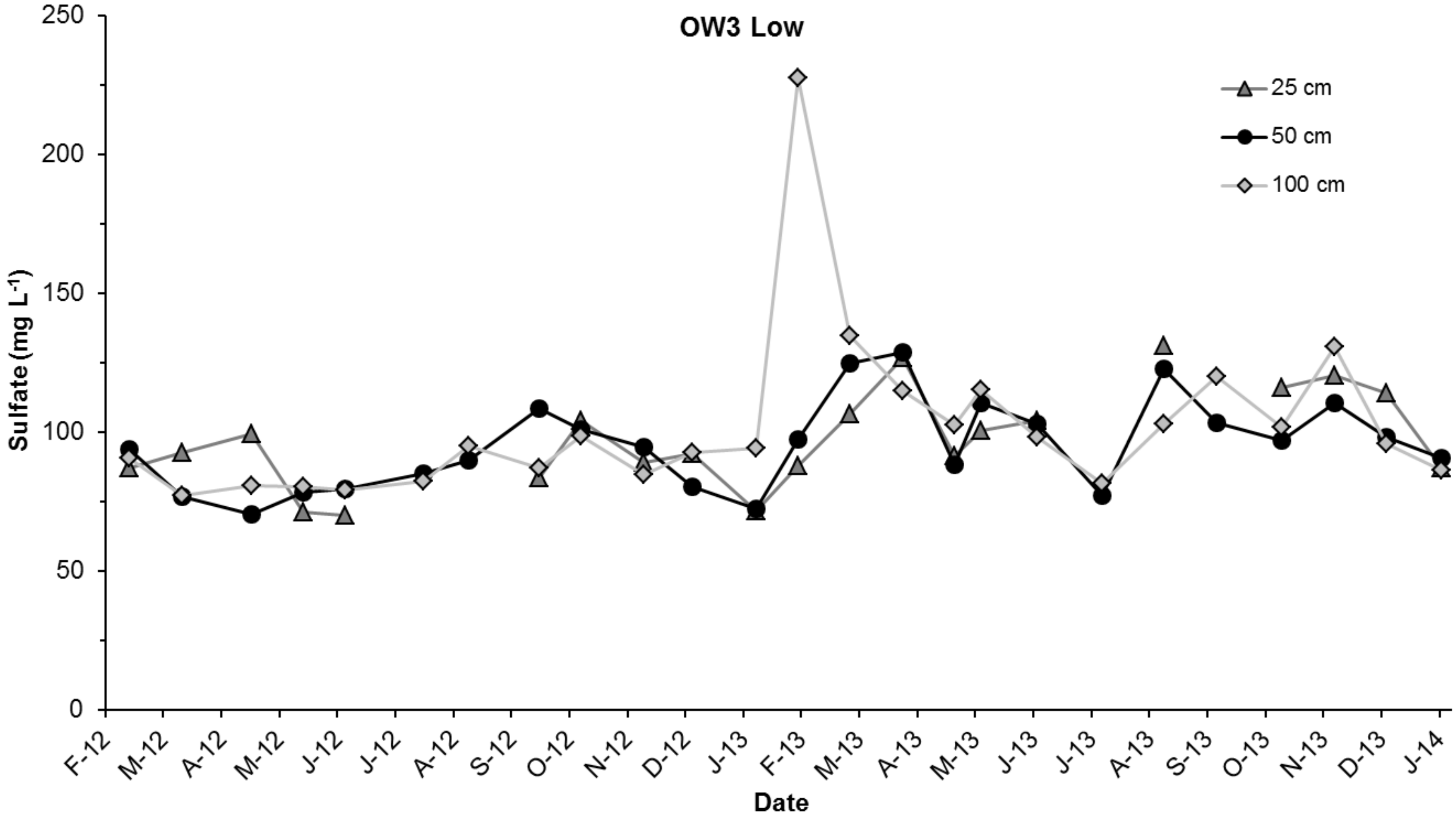

OW1 Transect
Low 100 cm
Mid 100 cm
High 100 cm
Sulfate (mg L-1)
200
160
120
80
40
0
F-12
M-12
A-12
M-12
J-12
J-12
A-12
S-12
O-12
N-12
D-12
J-13
Date

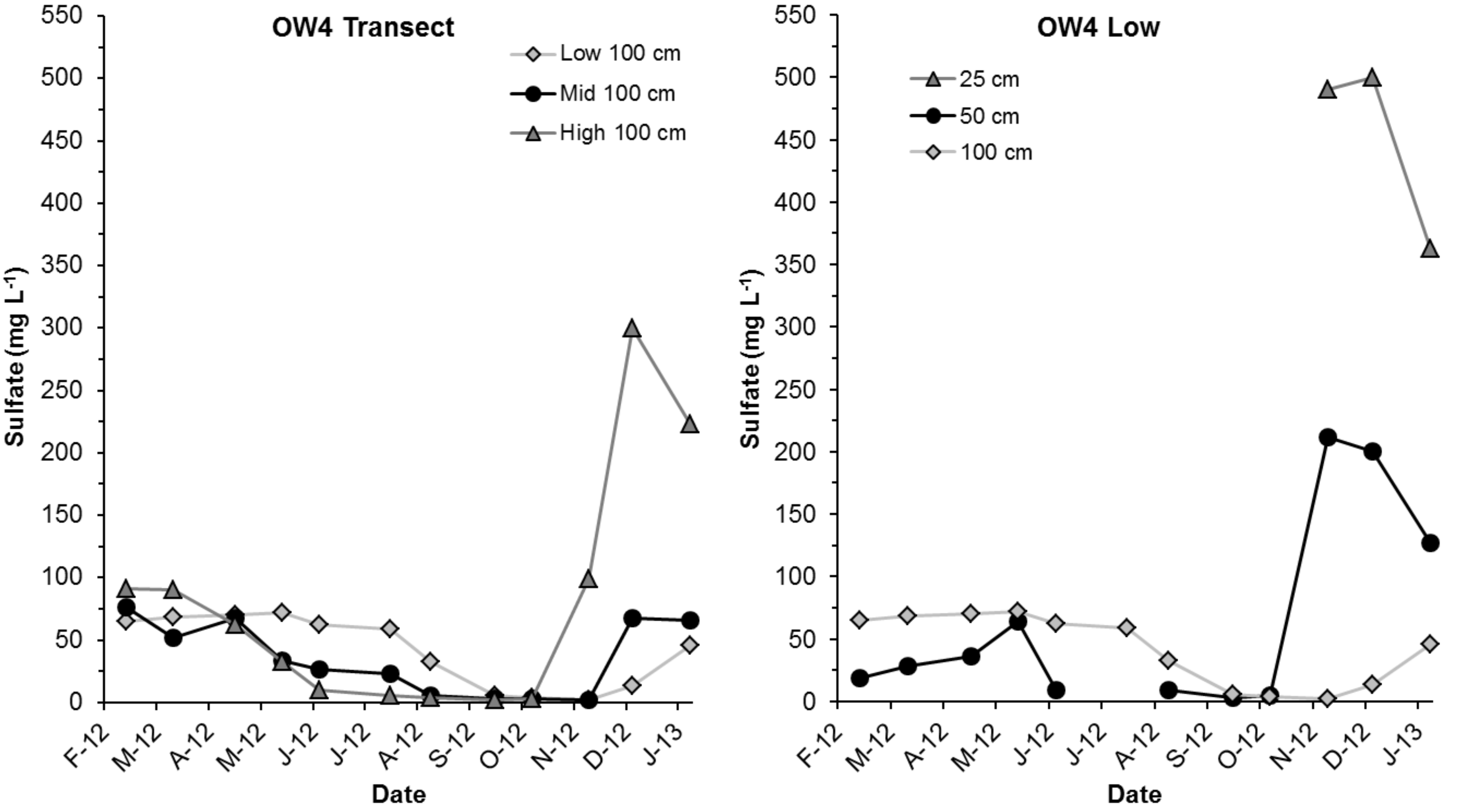

OW1 Low
25 cm
50 cm
100 cm
Sulfate (mg L-1)
200
160
120
80
40
0
F-12
M-12
A-12
M-12
J-12
J-12
A-12
S-12
O-12
N-12
D-12
J-13
Date


OW2 Transect
Low 100 cm
Mid 100 cm
High 100 cm
Sulfate (mg L-1)
0
20
40
60
80
100
120
140
F-12
M-12
A-12
M-12
J-12
J-12
A-12
S-12
O-12
N-12
D-12
J-13
Date


OW2 Low
25 cm
50 cm
100 cm
Sulfate (mg L-1)
0
20
40
60
80
100
120
140
F-12
M-12
A-12
M-12
J-12
J-12
A-12
S-12
O-12
N-12
D-12
J-13
Date


OW3 Transect
Sulfate (mg L-1)
250
200
150
100
50
0
Low 100 cm
Mid 100 cm
High 100 cm
F-12
M-12
A-12
M-12
J-12
J-12
A-12
S-12
O-12
N-12
D-12
J-13
F-13
M-13
A-13
M-13
J-13
J-13
A-13
S-13
O-13
N-13
D-13
J-14
Date


OW3 Low
25 cm
50 cm
100 cm
Sulfate (mg L-1)
250
200
150
100
50
0
F-12
M-12
A-12
M-12
J-12
J-12
A-12
S-12
O-12
N-12
D-12
J-13
F-13
M-13
A-13
M-13
J-13
J-13
A-13
S-13
O-13
N-13
D-13
J-14
Date


OW4 Transect
Low 100 cm
Mid 100 cm
High 100 cm
Sulfate (mg L-1)
550
500
450
400
350
300
250
200
150
100
50
0
F-12
M-12
A-12
M-12
J-12
J-12
A-12
S-12
O-12
N-12
D-12
J-13
Date
OW4 Low
25 cm
50 cm
100 cm
Sulfate (mg L-1)
Date

Additional Water Chemistry Data
February 2012

Site	Position	Depth	Dissolved O_2	Temp.	pH	ααd	Cl^-	NO_2^--N	NO_3^{2-}-N	PO_4^{3-}-P	SO_4^{2-}-S
		cm	mg L^{-1}	^oC			---------- mg L^{-1} ----------				
BC1	High	100	1.46	9.0	6.45	4.0	255	0	0	0	27
	Mid	100	0.50	8.5	6.51	0.0	1525	0	0	0	45
	Low	Surface	--	--	--	--	--	--	--	--	--
	Low	25	4.32	5.9	6.31	2.0	856	0	0	0	149
	Low	50	0.95	6.3	6.51	0.0	1240	0	0	2	33
	Low	100	0.36	7.6	6.51	0.5	2063	0	0	0	71
BC2	High	100	0.41	9.2	6.38	0.0	2689	0	0	0	73
	Mid	100	0.23	9.5	6.58	0.0	2494	0	0	0	58
	Low	Surface	--	--	--	--	--	--	--	--	--
	Low	25	0.83	9.5	6.88	0.0	715	0	0	0	52
	Low	50	0.43	8.5	6.82	0.0	2513	0	0	0	43
	Low	100	0.14	8.4	6.32	0.0	4108	0	0	0	145
BC3	High	100	1.08	8.6	7.03	0.0	1703	0	0	0	92
	Mid	100	0.39	7.7	6.96	0.0	2490	0	0	0	19
	Low	Surface	--	--	--	--	--	--	--	--	--
	Low	25	5.45	9.4	7.39	0.0	1898	0	0	0	100
	Low	50	0.59	6.1	6.91	0.0	3305	0	0	0	150
	Low	100	0.09	7.8	6.79	0.0	4792	0	0	0	140
BC4	High	100	1.50	9.8	6.55	1.0	241	0	0	0	16
	Mid	100	0.94	9.4	6.63	4.5	350	0	0	0	7
	Low	Surface	--	--	--	--	--	--	--	--	--
	Low	25	2.74	9.3	8.12	4.0	443	0	0	0	10
	Low	50	1.31	8.4	6.16	5.0	1083	0	0	0	33
	Low	100	0.37	9.4	7.49	0.0	36	0	0	0	3
BC5	High	100	--	--	--	--	--	--	--	--	--
	Mid	100	0.45	11.1	5.67	5.0	2165	0	0	0	42
	Low	Surface	--	--	--	--	--	--	--	--	--
	Low	25	1.79	8.0	4.40	2.5	1660	0	0	0	63
	Low	50	0.56	8.3	5.53	3.5	2517	0	0	0	95
	Low	100	3.88	9.0	7.13	0.0	1086	0	0	2	27

Site	Position	Depth	Dissolved O_2	Temp.	pH	ααd	Cl^-	NO_2^--N	NO_3^{2-}-N	PO_4^{3-}-P	SO_4^{2-}-S
		cm	mg L^{-1}	°C			---------------------- mg L^{-1} ----------------------				
BC6	High	100	0.15	9.3	6.71	0.0	2326	0	0	5	41
	Mid	100	0.17	9.6	6.61	0.0	3042	0	0	5	70
	Low	Surface	4.15	9.8	6.54	0.5	1063	0	0	0	21
	Low	25	0.81	8.3	6.28	1.5	1732	0	0	0	37
	Low	50	0.37	8.2	6.28	0.0	1614	0	0	0	94
	Low	100	2.10	8.5	6.65	0.0	2650	0	0	5	72
OW1	High	100	0.66	9.8	6.55	3.0	25	0	0	0	2
	Mid	100	0.58	9.8	6.24	3.0	42	0	0	0	2
	Low	Surface	--	--	--	--	--	--	--	--	--
	Low	25	--	--	--	--	--	--	--	--	--
	Low	50	1.24	9.5	6.01	5.0	114	0	0	0	2
	Low	100	0.32	9.8	7.33	2.0	31	0	0	0	2
OW2	High	100	0.63	8.2	6.73	4.0	585	0	0	0	7
	Mid	100	0.51	8.5	6.91	2.5	1374	0	0	0	47
	Low	Surface	--	--	--	--	--	--	--	--	--
	Low	25	1.26	6.9	6.67	0.5	2464	0	0	0	87
	Low	50	0.63	7.0	6.73	0.0	2668	0	0	0	90
	Low	100	0.34	8.3	7.20	1.0	2743	0	0	0	86
OW3	High	100	1.43	9.5	7.33	0.0	634	0	0	0	10
	Mid	100	0.09	9.5	7.37	0.0	1770	0	0	0	48
	Low	Surface	--	--	--	--	--	--	--	--	--
	Low	25	0.60	9.3	7.14	0.0	1982	0	0	0	87
	Low	50	0.28	9.6	7.25	0.0	2019	0	0	0	94
	Low	100	0.16	8.7	7.54	0.0	1910	0	0	0	91
OW4	High	100	0.48	8.2	6.56	1.0	2358	0	0	0	92
	Mid	100	0.51	7.5	6.67	0.0	1987	0	0	0	76
	Low	Surface	--	--	--	--	--	--	--	--	--
	Low	25	--	--	--	--	--	--	--	--	--
	Low	50	1.19	6.4	6.79	0.0	1885	0	0	3	19
	Low	100	0.52	7.7	6.95	0.0	2064	0	0	0	65
Bay			12.12	4.5	7.82	0.0	17456	0	0	0	819
Ocean			10.00	8.6	7.91	0.0	16719	0	0	0	784

March 2012

Site	Position	Depth	Dissolved O_2	Temp.	pH	ααd	Cl^-	NO_2^--N	NO_3^{2-}-N	PO_4^{3-}-P	SO_4^{2-}-S
		cm	mg L^{-1}	°C			---------------------- mg L^{-1} ----------------------				
BC1	High	100	0.71	11.0	6.38	5.0	166	0	0	0	22
	Mid	100	0.18	10.4	6.44	0.0	1420	0	0	0	30
	Low	Surface	6.48	19.8	6.62	0.5	441	0	0	0	13
	Low	25	0.33	12.5	6.26	2.0	162	0	0	0	22
	Low	50	0.24	11.2	6.34	0.0	684	0	0	0	118
	Low	100	0.17	11.4	6.31	0.0	1183	0	0	0	77
BC2	High	100	0.42	12.4	6.18	0.0	2528	0	2	0	65
	Mid	100	0.22	12.3	6.37	0.0	2431	0	2	0	52
	Low	Surface	--	--	--	--	--	--	--	--	--
	Low	25	0.46	14.0	6.70	0.0	82	0	2	0	4
	Low	50	0.28	13.8	6.84	0.0	368	0	2	0	11
	Low	100	0.05	12.6	6.39	0.0	3674	0	2	0	113
BC3	High	100	0.44	11.0	6.94	0.0	1667	0	0	0	98
	Mid	100	0.14	10.3	6.77	0.0	2684	0	0	0	100
	Low	Surface	7.52	21.20	6.90	0.00	1121	0	0	0	50
	Low	25	0.35	11.7	6.52	2.0	619	0	0	0	44
	Low	50	0.16	10.5	6.77	0.0	330	0	0	0	40
	Low	100	0.11	10.1	6.78	0.0	3108	0	0	0	143
BC4	High	100	1.82	13.6	6.31	1.0	107	0	2	0	8
	Mid	100	0.38	12.9	6.09	5.0	523	0	2	0	6
	Low	Surface	--	--	--	--	--	--	--	--	--
	Low	25	--	--	--	--	--	--	--	--	--
	Low	50	1.59	14.3	6.57	5.0	893	0	2	0	20
	Low	100	0.23	12.1	6.63	1.5	163	0	2	0	2
BC5	High	100	--	--	--	--	--	--	--	--	--
	Mid	100	0.43	12.0	4.33	5.0	1653	0	0	0	51
	Low	Surface	--	--	--	--	--	--	--	--	--
	Low	25	0.72	10.8	5.20	4.5	1666	0	0	0	52
	Low	50	0.47	10.4	5.33	3.0	2425	0	0	0	85
	Low	100	1.92	11.5	6.56	0.0	1048	0	0	6	14

Site	Position	Depth	Dissolved O_2	Temp.	pH	ααd	Cl^-	NO_2^--N	NO_3^{2-}-N	PO_4^{3-}-P	SO_4^{2-}-S
		cm	mg L^{-1}	^oC			---------------------- mg L^{-1} ----------------------				
BC6	High	100	0.36	11.6	6.56	0.0	2388	0	2	5	47
	Mid	100	0.32	11.4	6.43	0.0	3161	0	4	6	84
	Low	Surface	4.30	13.4	6.63	0.0	1099	0	3	0	13
	Low	25	0.68	13.0	6.27	1.0	1716	0	3	0	25
	Low	50	0.26	12.6	6.17	0.0	1726	0	3	0	92
	Low	100	0.07	11.7	6.58	0.0	2617	0	2	5	57
OW1	High	100	1.34	14.2	6.12	2.0	8	0	0	0	2
	Mid	100	0.55	13.2	6.07	3.0	23	0	2	0	2
	Low	Surface	--	--	--	--	--	--	--	--	--
	Low	25	--	--	--	--	--	--	--	--	--
	Low	50	0.87	14.1	5.87	5.0	77	0	2	0	2
	Low	100	0.29	13.0	7.05	3.0	30	0	2	0	2
OW2	High	100	0.34	10.4	6.83	2.0	153	0	0	0	5
	Mid	100	0.22	10.7	6.73	2.0	1174	0	0	0	34
	Low	Surface	--	--	--	--	--	--	--	--	--
	Low	25	0.75	13.9	6.64	0.0	2483	0	0	0	89
	Low	50	0.31	11.5	6.77	0.0	2421	0	0	0	82
	Low	100	0.17	11.7	7.10	0.5	2642	0	4	0	97
OW3	High	100	2.27	13.4	7.50	0.0	147	0	3	0	5
	Mid	100	0.09	12.8	7.19	0.0	1774	0	3	0	49
	Low	Surface	--	--	--	--	--	--	--	--	--
	Low	25	1.00	13.5	7.04	0.0	2077	0	3	0	93
	Low	50	0.25	12.6	7.18	0.0	1945	0	3	0	77
	Low	100	0.07	11.8	7.36	0.0	1739	0	13	0	77
OW4	High	100	0.17	10.0	6.52	0.5	2077	0	0	0	91
	Mid	100	0.12	9.9	6.61	0.0	1586	0	3	0	52
	Low	Surface	--	--	--	--	--	--	--	--	--
	Low	25	--	--	--	--	--	--	--	--	--
	Low	50	0.58	11.3	6.71	0.0	592	0	3	6	29
	Low	100	0.13	10.7	6.61	0.0	2252	0	0	0	68
Bay			7.22	13.1	7.52	0.0	14264	0	0	0	662
Ocean			7.20	--	7.78	0.0	17410	0	20	0	776

April 2012

Site	Position	Depth	Dissolved O$_2$	Temp.	pH	ααd	Cl$^-$	NO$_2^-$-N	NO$_3^{2-}$-N	PO$_4^{3-}$-P	SO$_4^{2-}$-S
		cm	mg L^{-1}	^{o}C			--------------------- mg L^{-1} ---------------------				
BC1	High	100	1.47	15.5	6.65	2.5	93	0	0	0	11
	Mid	100	0.26	13.2	6.47	0.0	1461	0	3	0	41
	Low	Surface	--	--	--	--	--	--	--	--	--
	Low	25	1.38	13.5	6.17	1.0	316	0	3	0	12
	Low	50	0.58	13.4	6.33	0.0	432	0	3	0	79
	Low	100	0.19	13.3	6.33	0.0	1571	0	3	0	50
BC2	High	100	1.50	14.6	6.42	0.0	2272	0	0	5	57
	Mid	100	0.17	14.3	6.69	0.0	2092	0	0	5	43
	Low	Surface	--	--	--	--	--	--	--	--	--
	Low	25	2.78	14.7	7.14	0.0	376	0	0	5	8
	Low	50	0.47	15.3	7.02	0.0	728	0	0	5	13
	Low	100	0.06	14.6	6.46	0.0	3890	0	0	5	117
BC3	High	100	1.50	15.0	6.88	0.0	1287	0	3	0	112
	Mid	100	0.73	13.4	7.37	0.0	341	0	3	0	25
	Low	Surface	--	--	--	--	--	--	--	--	--
	Low	25	2.96	13.4	7.07	0.0	605	0	3	0	44
	Low	50	0.83	12.9	6.84	0.0	766	0	3	0	79
	Low	100	0.08	12.7	6.57	0.0	4499	0	4	0	200
BC4	High	100	2.45	15.7	6.33	0.5	85	0	0	5	7
	Mid	100	0.41	14.4	6.90	2.5	120	0	0	5	3
	Low	Surface	--	--	--	--	--	--	--	--	--
	Low	25	--	--	--	--	--	--	--	--	--
	Low	50	1.78	15.6	6.36	2.5	506	0	2	6	8
	Low	100	0.28	14.7	7.09	0.0	49	0	0	5	3
BC5	High	100	--	--	--	--	--	--	--	--	--
	Mid	100	0.59	13.2	4.62	5.0	1732	0	3	0	48
	Low	Surface	--	--	--	--	--	--	--	--	--
	Low	25	1.70	13.5	4.96	4.5	1914	0	3	0	65
	Low	50	0.80	12.7	5.50	1.0	2519	0	3	0	87
	Low	100	2.42	12.8	6.52	0.5	1086	0	3	6	6

Site	Position	Depth	Dissolved O_2	Temp.	pH	ααd	Cl^-	NO_2^--N	NO_3^{2-}-N	PO_4^{3-}-P	SO_4^{2-}-S
		cm	mg L^{-1}	°C			---------------------- mg L^{-1} ----------------------				
BC6	High	100	0.48	12.9	6.65	0.0	2363	0	0	6	39
	Mid	100	0.48	12.7	6.54	0.0	3146	0	0	6	75
	Low	Surface	--	--	--	--	--	--	--	--	--
	Low	25	1.46	13.3	6.48	1.0	1670	0	0	6	24
	Low	50	0.56	13.4	6.47	0.0	2031	0	0	6	84
	Low	100	0.11	12.9	6.60	0.0	2644	0	0	6	43
OW1	High	100	0.76	15.0	6.30	2.0	32	0	0	5	3
	Mid	100	0.38	15.5	6.18	3.0	56	0	0	5	4
	Low	Surface	--	--	--	--	--	--	--	--	--
	Low	25	--	--	--	--	--	--	--	--	--
	Low	50	2.10	15.8	6.11	3.0	136	0	0	0	3
	Low	100	0.27	15.7	7.23	0.5	44	0	0	5	3
OW2	High	100	0.65	15.4	6.82	1.0	156	0	0	0	4
	Mid	100	0.19	13.9	6.79	1.0	1365	0	3	0	34
	Low	Surface	--	--	--	--	--	--	--	--	--
	Low	25	1.94	15.4	6.63	0.0	2483	0	3	0	83
	Low	50	0.55	14.8	6.73	0.0	2473	0	3	0	68
	Low	100	0.18	14.0	7.09	0.5	2549	0	3	0	88
OW3	High	100	2.39	15.6	7.62	0.0	229	0	0	5	8
	Mid	100	0.07	15.0	7.47	0.0	1667	0	0	6	49
	Low	Surface	--	--	--	--	--	--	--	--	--
	Low	25	2.73	14.3	7.11	0.5	1953	0	0	5	100
	Low	50	0.64	14.2	7.37	0.0	1798	0	0	6	70
	Low	100	0.09	13.5	7.47	0.0	1874	0	0	6	81
OW4	High	100	0.15	13.6	6.96	0.5	1517	0	3	0	62
	Mid	100	0.21	13.8	6.71	0.0	2154	0	3	0	68
	Low	Surface	--	--	--	--	--	--	--	--	--
	Low	25	--	--	--	--	--	--	--	--	--
	Low	50	1.58	16.2	6.51	0.0	1878	0	3	0	36
	Low	100	0.37	14.2	6.73	0.0	2228	0	3	0	70
Bay			7.61	15.1	7.68	0.0	17911	0	20	0	802
Ocean			7.50	19.7	8.11	0.0	18089	0	0	27	838

May 2012

Site	Position	Depth	Dissolved O_2	Temp.	pH	ααd	Cl^-	NO_2^--N	NO_3^{2-}-N	PO_4^{3-}-P	SO_4^{2-}-S
		cm	mg L^{-1}	°C			---------------------- mg L^{-1} ----------------------				
BC1	High	100	1.00	16.7	6.32	3.5	76	0	0	0	10
	Mid	100	0.13	15.9	6.39	0.0	1392	0	2	0	29
	Low	Surface	--	--	--	--	--	--	--	--	--
	Low	25	0.67	18.9	5.74	0.5	204	0	2	0	8
	Low	50	0.26	18.2	6.03	0.0	400	0	2	0	29
	Low	100	0.08	17.7	6.20	0.0	730	0	2	0	67
BC2	High	100	0.30	18.2	6.05	0.0	2046	0	0	0	55
	Mid	100	0.09	18.3	6.25	0.0	--	--	--	--	--
	Low	Surface	2.46	24.2	6.58	0.0	118	0	0	0	5
	Low	25	0.22	21.4	6.30	0.0	334	0	0	0	9
	Low	50	0.10	20.0	6.29	0.0	469	0	0	0	12
	Low	100	0.02	18.1	6.12	0.0	2654	0	0	0	69
BC3	High	100	0.79	16.6	7.32	0.0	326	0	2	0	50
	Mid	100	0.25	15.8	7.05	0.0	625	0	2	0	41
	Low	Surface	--	--	--	--	--	--	--	--	--
	Low	25	0.84	17.5	6.53	0.0	730	0	2	0	36
	Low	50	0.31	16.9	6.52	0.0	737	0	2	0	58
	Low	100	0.11	16.0	6.47	0.0	3970	0	4	0	158
BC4	High	100	0.99	18.3	6.44	0.0	29	0	0	0	4
	Mid	100	0.21	17.0	6.24	3.0	354	0	0	0	3
	Low	Surface	--	--	--	--	--	--	--	--	--
	Low	25	1.96	21.0	6.46	1.0	331	0	0	0	3
	Low	50	0.70	19.7	6.15	0.5	581	0	0	0	6
	Low	100	0.08	17.4	6.78	0.5	42	0	0	0	2
BC5	High	100	--	--	--	--	--	--	--	--	--
	Mid	100	0.33	14.4	5.03	5.0	1950	0	3	0	46
	Low	Surface	--	--	--	--	--	--	--	--	--
	Low	25	0.88	15.6	5.16	0.0	897	0	2	0	30
	Low	50	0.33	14.9	5.75	0.0	2395	0	3	0	87
	Low	100	2.62	14.2	6.66	0.0	1081	0	2	6	8

Site	Position	Depth	Dissolved O_2	Temp.	pH	ααd	Cl^-	NO_2^--N	NO_3^{2-}-N	PO_4^{3-}-P	SO_4^{2-}-S
		cm	mg L^{-1}	°C			---------------------- mg L^{-1} ----------------------				
BC6	High	100	0.22	15.0	6.38	0.0	2314	0	0	5	38
	Mid	100	0.19	15.0	6.29	0.0	3016	0	0	5	66
	Low	Surface	1.17	18.7	6.11	0.0	472	0	0	0	7
	Low	25	0.49	17.7	6.15	0.0	1717	0	0	0	15
	Low	50	0.21	17.0	6.00	0.0	2080	0	0	0	88
	Low	100	0.07	15.5	6.44	0.0	2694	0	0	6	32
OW1	High	100	0.33	18.1	6.31	0.5	8	0	0	0	2
	Mid	100	0.22	18.6	6.50	0.0	8	0	0	0	2
	Low	Surface	--	--	--	--	--	--	--	--	--
	Low	25	--	--	--	--	--	--	--	--	--
	Low	50	0.63	20.4	5.82	1.0	89	0	0	0	2
	Low	100	0.12	18.7	7.17	0.0	25	0	0	0	2
OW2	High	100	0.66	17.1	6.86	0.0	85	0	0	0	4
	Mid	100	0.11	16.6	6.70	0.0	1266	0	2	0	27
	Low	Surface	--	--	--	--	--	--	--	--	--
	Low	25	1.65	19.7	6.51	0.0	2103	0	3	0	59
	Low	50	0.40	18.3	6.57	0.0	2114	0	3	0	51
	Low	100	0.12	17.5	6.99	0.0	2447	0	3	0	78
OW3	High	100	5.55	18.4	7.45	0.0	19	0	2	0	3
	Mid	100	0.09	18.6	7.20	0.0	1743	0	0	0	53
	Low	Surface	--	--	--	--	--	--	--	--	--
	Low	25	0.63	19.2	6.77	0.0	1726	0	0	0	71
	Low	50	0.31	18.2	7.10	0.0	1776	0	0	0	78
	Low	100	0.06	16.6	7.27	0.0	1871	0	0	0	80
OW4	High	100	0.12	16.0	6.88	0.0	834	0	2	0	32
	Mid	100	0.06	16.2	7.07	0.0	1161	0	2	0	34
	Low	Surface	--	--	--	--	--	--	--	--	--
	Low	25	--	--	--	--	--	--	--	--	--
	Low	50	0.57	19.3	6.96	0.0	626	0	2	0	64
	Low	100	0.15	17.0	7.16	0.0	2151	0	3	0	72
Bay			6.28	19.5	7.50	0.0	16073	0	16	0	735
Ocean			9.35	17.3	7.68	0.0	17908	0	0	0	815

June 2012

Site	Position	Depth	Dissolved O_2	Temp.	pH	ααd	Cl^-	NO_2^--N	NO_3^{2-}-N	PO_4^{3-}-P	SO_4^{2-}-S
		cm	mg L^{-1}	^oC			--------------------- mg L^{-1} ---------------------				
BC1	High	100	0.91	20.8	6.74	3.5	57	0	0	0	9
	Mid	100	0.09	19.7	7.77	0.0	1276	0	0	0	16
	Low	Surface	--	--	--	--	--	--	--	--	--
	Low	25	0.73	23.1	5.79	5.0	766	0	0	0	3
	Low	50	0.12	22.1	7.19	0.0	305	0	0	0	3
	Low	100	0.08	21.9	7.70	0.0	755	0	0	0	30
BC2	High	100	0.24	22.6	7.67	0.0	1765	0	0	0	45
	Mid	100	0.08	20.8	7.86	0.0	1889	0	0	0	52
	Low	Surface	--	--	--	--	--	--	--	--	--
	Low	25	0.66	22.2	6.93	0.0	368	0	0	0	5
	Low	50	0.06	21.7	7.90	0.0	351	0	0	0	4
	Low	100	0.02	20.9	7.96	0.0	2661	0	0	0	59
BC3	High	100	1.21	20.9	7.73	0.0	319	0	0	0	23
	Mid	100	0.19	20.1	7.75	0.0	280	0	0	0	4
	Low	Surface	--	--	--	--	--	--	--	--	--
	Low	25	0.76	21.3	7.83	0.0	840	0	0	0	13
	Low	50	0.10	20.7	7.94	0.0	653	0	0	0	3
	Low	100	0.07	20.6	7.83	0.0	2250	0	0	0	68
BC4	High	100	1.92	21.8	7.08	0.0	28	0	0	0	4
	Mid	100	0.22	19.1	7.64	3.5	526	0	0	0	6
	Low	Surface	--	--	--	--	--	--	--	--	--
	Low	25	--	--	--	--	--	--	--	--	--
	Low	50	1.03	20.7	7.51	0.0	407	0	0	0	2
	Low	100	0.11	19.2	7.99	0.5	46	0	0	0	0
BC5	High	100	--	--	--	--	--	--	--	--	--
	Mid	100	0.31	17.9	5.12	5.0	1680	0	0	0	44
	Low	Surface	--	--	--	--	--	--	--	--	--
	Low	25	0.90	18.1	4.55	2.0	880	0	0	0	13
	Low	50	0.25	17.8	6.56	1.0	2190	0	0	0	74
	Low	100	1.04	16.4	7.76	0.5	1074	0	0	6	6

Site	Position	Depth	Dissolved O_2	Temp.	pH	ααd	Cl^-	NO_2^--N	NO_3^{2-}-N	PO_4^{3-}-P	SO_4^{2-}-S
		cm	mg L^{-1}	^oC			---------------------- mg L^{-1} ----------------------				
BC6	High	100	0.29	17.3	7.92	0.0	2087	0	0	0	33
	Mid	100	0.30	16.6	7.90	0.0	2907	0	0	3	67
	Low	Surface	2.10	18.3	6.93	0.0	632	0	0	0	9
	Low	25	0.74	18.6	7.64	0.0	1533	0	0	0	5
	Low	50	0.17	18.5	7.48	0.0	2113	0	0	0	61
	Low	100	0.07	17.9	7.79	0.0	2794	0	0	6	52
OW1	High	100	0.46	21.4	7.63	0.0	15	0	0	0	2
	Mid	100	0.36	21.7	7.03	0.0	14	0	0	0	2
	Low	Surface	--	--	--	--	--	--	--	--	--
	Low	25	--	--	--	--	--	--	--	--	--
	Low	50	1.73	21.8	7.26	2.5	99	0	0	0	2
	Low	100	0.14	20.8	7.57	0.0	26	0	0	0	2
OW2	High	100	0.52	21.3	7.60	2.0	51	0	0	0	4
	Mid	100	0.08	20.4	8.09	1.0	1086	0	0	0	19
	Low	Surface	--	--	--	--	--	--	--	--	--
	Low	25	0.77	22.9	8.20	0.0	2720	0	0	0	82
	Low	50	0.25	21.6	8.23	0.0	2586	0	0	0	84
	Low	100	0.07	21.1	8.22	0.5	2240	0	0	0	72
OW3	High	100	5.22	21.5	7.95	0.0	25	0	0	0	3
	Mid	100	0.07	21.2	8.33	0.0	1606	0	0	0	51
	Low	Surface	--	--	--	--	--	--	--	--	--
	Low	25	2.01	21.0	8.34	0.0	1673	0	0	0	70
	Low	50	0.52	20.0	8.36	0.0	1741	0	0	0	80
	Low	100	0.10	19.1	8.33	0.0	1790	0	0	0	79
OW4	High	100	0.14	20.3	7.68	0.0	284	0	2	6	10
	Mid	100	0.05	20.4	7.91	0.0	906	0	0	0	26
	Low	Surface	--	--	--	--	--	--	--	--	--
	Low	25	--	--	--	--	--	--	--	--	--
	Low	50	0.44	22.5	7.74	0.0	510	0	0	0	9
	Low	100	0.06	20.8	7.93	0.0	1859	0	0	0	62
Bay			4.22	23.1	7.72	0.0	16966	0	0	0	770
Ocean			8.67	20.0	7.80	0.0	18206	0	0	0	828

July 2012

Site	Position	Depth	Dissolved O_2	Temp.	pH	ααd	Cl^-	NO_2^--N	NO_3^{2-}-N	PO_4^{3-}-P	SO_4^{2-}-S
		cm	mg L^{-1}	°C			---------------------- mg L^{-1} ----------------------				
BC1	High	100	3.17	25.4	7.97	5.0	43	0	0	0	13
	Mid	100	0.50	24.2	6.42	0.0	1389	0	0	0	27
	Low	Surface	--	--	--	--	--	--	--	--	--
	Low	25	--	--	--	--	--	--	--	--	--
	Low	50	0.53	28.4	6.58	0.5	1270	0	0	0	10
	Low	100	0.08	25.5	6.39	0.0	1566	0	0	0	28
BC2	High	100	--	--	--	--	1379	0	0	0	43
	Mid	100	--	--	--	--	1364	0	0	0	40
	Low	Surface	--	--	--	--	--	--	--	--	--
	Low	25	--	--	--	--	--	--	--	--	--
	Low	50	--	--	--	--	1616	0	0	0	20
	Low	100	--	--	--	--	2433	0	0	0	60
BC3	High	100	--	--	--	--	--	--	--	--	--
	Mid	100	0.77	24.7	6.92	0.0	415	0	0	0	16
	Low	Surface	--	--	--	--	--	--	--	--	--
	Low	25	--	--	--	--	--	--	--	--	--
	Low	50	1.69	26.5	6.73	0.0	1414	0	0	0	37
	Low	100	0.10	24.6	6.68	0.0	3762	0	0	0	143
BC4	High	100	1.38	25.6	7.63	0.0	0	0	0	0	5
	Mid	100	0.21	22.2	7.01	2.0	365	0	0	0	6
	Low	Surface	--	--	--	--	--	--	--	--	--
	Low	25	--	--	--	--	--	--	--	--	--
	Low	50	0.99	25.0	7.12	0.0	235	0	0	0	3
	Low	100	0.25	22.5	7.25	0.5	16	0	0	0	0
BC5	High	100	--	--	--	--	--	--	--	--	--
	Mid	100	0.95	20.0	5.06	5.0	1479	0	0	0	33
	Low	Surface	--	--	--	--	--	--	--	--	--
	Low	25	--	--	--	--	--	--	--	--	--
	Low	50	0.87	22.2	5.87	0.0	2926	0	0	0	102
	Low	100	1.74	20.1	6.65	0.0	1081	0	0	5	10

Site	Position	Depth	Dissolved O_2	Temp.	pH	ααd	Cl^-	NO_2^--N	NO_3^{2-}-N	PO_4^{3-}-P	SO_4^{2-}-S
		cm	mg L^{-1}	^oC			---------------------- mg L^{-1} ----------------------				
BC6	High	100	1.62	23.0	6.43	0.0	1710	0	0	0	29
	Mid	100	0.46	20.4	6.83	0.0	361	0	0	5	9
	Low	Surface	--	--	--	--	--	--	--	--	--
	Low	25	--	--	--	--	--	--	--	--	--
	Low	50	1.73	24.2	6.26	0.0	2555	0	0	0	63
	Low	100	0.03	22.1	6.50	0.0	2639	0	0	5	48
OW1	High	100	2.40	26.9	7.50	0.0	0	0	0	0	3
	Mid	100	1.68	26.1	7.45	2.0	0	0	0	0	3
	Low	Surface	--	--	--	--	--	--	--	--	--
	Low	25	--	--	--	--	--	--	--	--	--
	Low	50	--	--	--	--	--	--	--	--	--
	Low	100	0.38	25.3	7.12	0.0	0	0	0	0	3
OW2	High	100	3.28	28.6	7.41	0.0	33	0	0	0	4
	Mid	100	0.31	24.7	6.83	0.0	1308	0	0	0	27
	Low	Surface	--	--	--	--	--	--	--	--	--
	Low	25	--	--	--	--	--	--	--	--	--
	Low	50	1.66	26.9	6.82	0.0	2566	0	0	0	47
	Low	100	0.31	24.6	6.82	0.0	2294	0	0	0	81
OW3	High	100	--	--	--	--	--	--	--	--	--
	Mid	100	0.24	26.5	6.93	0.0	1587	0	0	0	60
	Low	Surface	--	--	--	--	--	--	--	--	--
	Low	25	--	--	--	--	--	--	--	--	--
	Low	50	1.49	25.9	6.85	0.0	2121	0	0	0	85
	Low	100	0.13	23.9	6.86	0.0	2160	0	0	0	82
OW4	High	100	0.41	26.1	7.57	0.0	0	0	0	0	5
	Mid	100	0.50	25.6	6.98	0.0	700	0	0	0	23
	Low	Surface	--	--	--	--	--	--	--	--	--
	Low	25	--	--	--	--	--	--	--	--	--
	Low	50	--	--	--	--	--	--	--	--	--
	Low	100	0.76	25.6	6.81	0.0	1625	0	0	0	59
Bay			2.03	29.6	7.64	0.0	17950	0	0	0	797
Ocean			6.70	26.9	6.71	0.0	17293	0	0	0	765

August 2012

Site	Position	Depth	Dissolved O$_2$	Temp.	pH	ααd	Cl$^-$	NO$_2^-$-N	NO$_3^{2-}$-N	PO$_4^{3-}$-P	SO$_4^{2-}$-S
		cm	mg L^{-1}	^{o}C			--------------------- mg L^{-1} ---------------------				
BC1	High	100	2.59	26.0	6.27	5.0	36	0	0	0	12
	Mid	100	0.35	24.8	6.98	0.0	1064	0	0	0	26
	Low	Surface	--	--	--	--	--	--	--	--	--
	Low	25	1.49	30.4	7.01	0.0	629	0	0	0	21
	Low	50	0.21	26.4	6.89	0.0	669	0	0	0	9
	Low	100	0.04	25.4	7.06	0.0	843	0	0	0	6
BC2	High	100	0.18	25.5	6.81	0.0	1411	0	0	0	43
	Mid	100	0.05	24.9	7.10	0.0	957	0	0	0	21
	Low	Surface	--	--	--	--	--	--	--	--	--
	Low	25	--	--	--	--	--	--	--	--	--
	Low	50	0.14	26.9	7.06	0.0	1239	0	0	0	5
	Low	100	0.02	25.4	6.93	0.0	1462	0	0	0	32
BC3	High	100	2.16	25.6	7.25	0.0	517	0	0	0	6
	Mid	100	0.28	25.1	7.31	0.0	647	0	0	0	34
	Low	Surface	--	--	--	--	--	--	--	--	--
	Low	25	--	--	--	--	--	--	--	--	--
	Low	50	0.59	25.8	7.25	0.0	1605	0	0	0	48
	Low	100	0.07	25.3	7.17	0.0	3189	0	0	0	118
BC4	High	100	1.13	25.3	6.82	0.0	0	0	0	0	4
	Mid	100	0.14	22.7	6.92	3.0	272	0	5	0	3
	Low	Surface	--	--	--	--	--	--	--	--	--
	Low	25	1.83	25.9	6.81	0.0	88	0	0	0	4
	Low	50	0.32	24.2	6.77	0.0	130	0	0	0	3
	Low	100	0.08	22.6	7.50	0.0	0	0	0	0	0
BC5	High	100	--	--	--	--	--	--	--	--	--
	Mid	100	0.63	20.8	5.51	5.0	1573	0	3	0	39
	Low	Surface	--	--	--	--	--	--	--	--	--
	Low	25	--	--	--	--	--	--	--	--	--
	Low	50	0.98	23.3	6.61	0.0	3143	0	0	0	101
	Low	100	1.17	20.3	7.06	0.0	1026	0	5	6	5

Site	Position	Depth	Dissolved O_2	Temp.	pH	ααd	Cl^-	NO_2^--N	NO_3^{2-}-N	PO_4^{3-}-P	SO_4^{2-}-S
		cm	mg L^{-1}	°C			---------------------- mg L^{-1} ----------------------				
BC6	High	100	0.37	21.9	7.35	0.0	794	0	2	6	6
	Mid	100	0.15	21.2	7.60	0.0	408	0	5	6	5
	Low	Surface	--	--	--	--	--	--	--	--	--
	Low	25	1.72	26.4	7.45	0.0	1381	0	0	0	16
	Low	50	0.30	24.1	7.06	0.0	2260	0	0	0	42
	Low	100	0.03	22.8	7.39	0.0	2709	0	6	6	47
OW1	High	100	0.33	25.4	6.84	2.5	0	0	0	0	0
	Mid	100	0.23	25.9	6.87	2.5	0	0	0	0	3
	Low	Surface	--	--	--	--	--	--	--	--	--
	Low	25	--	--	--	--	--	--	--	--	--
	Low	50	0.67	26.9	6.64	4.0	0	0	0	0	4
	Low	100	0.10	25.3	7.46	0.0	0	0	0	0	3
OW2	High	100	0.64	25.9	7.13	1.0	32	0	0	0	4
	Mid	100	0.11	24.7	7.58	1.0	1381	0	5	0	32
	Low	Surface	--	--	--	--	--	--	--	--	--
	Low	25	--	--	--	--	--	--	--	--	--
	Low	50	0.35	25.6	7.40	0.0	1738	0	5	0	43
	Low	100	0.07	25.4	7.80	0.5	2573	0	6	0	93
OW3	High	100	4.39	25.9	7.69	0.0	104	0	5	0	6
	Mid	100	0.13	25.1	8.01	0.0	1542	0	3	0	62
	Low	Surface	--	--	--	--	--	--	--	--	--
	Low	25	--	--	--	--	--	--	--	--	--
	Low	50	0.49	25.8	7.87	0.0	2281	0	5	0	90
	Low	100	0.80	24.1	7.94	0.0	2306	0	5	0	95
OW4	High	100	0.37	25.5	7.81	0.0	0	0	0	0	4
	Mid	100	0.26	25.6	7.64	0.0	185	0	5	0	6
	Low	Surface	--	--	--	--	--	--	--	--	--
	Low	25	--	--	--	--	--	--	--	--	--
	Low	50	1.73	27.5	7.23	0.0	220	0	5	0	9
	Low	100	0.19	25.5	7.66	0.0	1050	0	2	0	32
Bay			2.90	26.6	7.71	0.0	19550	0	0	0	858
Ocean			6.87	24.5	7.98	0.0	18646	0	0	0	815

September 2012

Site	Position	Depth	Dissolved O$_2$	Temp.	pH	ααd	Cl$^-$	NO$_2^-$-N	NO$_3^{2-}$-N	PO$_4^{3-}$-P	SO$_4^{2-}$-S
		cm	mg L^{-1}	°C			---------------------- mg L^{-1} ----------------------				
BC1	High	100	0.53	23.0	7.22	1.0	99	0	0	0	12
	Mid	100	0.04	21.9	7.30	0.0	981	0	0	0	26
	Low	Surface	0.32	22.1	6.55	0.5	215	0	0	0	13
	Low	25	0.12	20.6	6.46	0.0	137	0	0	0	10
	Low	50	0.05	21.0	6.68	0.0	576	0	0	0	26
	Low	100	0.04	21.7	7.02	0.0	678	0	0	0	43
BC2	High	100	0.04	21.8	6.55	0.0	804	0	0	0	25
	Mid	100	0.02	22.2	6.61	0.0	668	0	0	0	16
	Low	Surface	0.72	23.3	6.75	0.0	175	0	0	0	12
	Low	25	0.07	21.8	6.37	0.0	256	0	0	0	11
	Low	50	0.04	21.5	6.52	0.0	1352	0	0	0	27
	Low	100	0.01	21.7	6.39	0.0	1526	0	0	0	57
BC3	High	100	0.09	22.5	6.60	0.0	511	0	0	0	46
	Mid	100	0.06	21.8	6.39	0.0	126	0	0	0	10
	Low	Surface	0.26	19.7	6.77	0.0	157	0	0	0	13
	Low	25	0.15	20.3	6.04	1.0	185	0	0	0	10
	Low	50	0.04	20.8	6.40	0.0	576	0	0	0	44
	Low	100	0.03	21.6	6.66	0.0	2393	0	0	0	95
BC4	High	100	0.57	24.1	6.40	0.0	153	0	1	0	3
	Mid	100	0.14	22.1	6.20	3.0	448	0	3	0	6
	Low	Surface	--	--	--	--	--	--	--	--	--
	Low	25	--	--	--	--	--	--	--	--	--
	Low	50	0.59	22.8	6.40	0.0	327	0	0	0	2
	Low	100	0.06	21.7	7.17	0.5	182	0	0	0	0
BC5	High	100	6.91	21.0	6.37	0.0	174	0	0	0	4
	Mid	100	0.19	21.0	6.03	3.5	447	0	3	0	26
	Low	Surface	--	--	--	--	--	--	--	--	--
	Low	25	0.65	20.8	4.41	5.0	1726	0	3	0	51
	Low	50	0.11	21.1	5.85	0.0	3262	0	4	0	103
	Low	100	0.06	19.9	6.36	0.0	977	0	3	6	4

Site	Position	Depth	Dissolved O_2	Temp.	pH	ααd	Cl^-	NO_2^--N	NO_3^{2-}-N	PO_4^{3-}-P	SO_4^{2-}-S
		cm	mg L^{-1}	°C			---------------------- mg L^{-1} ----------------------				
BC6	High	100	0.09	21.6	7.12	0.0	447	0	0	7	11
	Mid	100	0.03	21.1	6.89	0.0	1803	0	0	7	15
	Low	Surface	1.68	20.5	6.02	0.0	391	0	0	0	15
	Low	25	0.21	21.2	6.51	0.0	1134	0	0	0	68
	Low	50	0.13	21.5	6.49	0.0	1827	0	0	0	54
	Low	100	0.00	21.6	6.80	0.0	2842	0	0	7	42
OW1	High	100	0.21	24.3	6.35	0.5	159	0	0	0	1
	Mid	100	0.23	23.7	6.25	1.0	158	0	0	0	1
	Low	Surface	--	--	--	--	--	--	--	--	--
	Low	25	--	--	--	--	--	--	--	--	--
	Low	50	0.32	23.1	6.67	0.5	169	0	0	0	1
	Low	100	0.18	24.4	8.63	0.0	159	0	0	0	1
OW2	High	100	0.46	24.8	6.76	0.5	160	0	0	0	3
	Mid	100	0.07	23.9	6.86	0.0	733	0	0	0	7
	Low	Surface	--	--	--	--	--	--	--	--	--
	Low	25	0.42	24.1	8.44	0.0	1878	0	2	0	25
	Low	50	0.07	22.7	8.68	0.0	1536	0	2	0	36
	Low	100	0.08	23.2	7.01	0.0	2195	0	4	0	82
OW3	High	100	5.85	24.1	7.91	0.0	161	0	3	0	2
	Mid	100	0.10	23.0	7.56	0.0	1351	0	3	0	59
	Low	Surface	--	--	--	--	--	--	--	--	--
	Low	25	0.42	21.5	7.05	0.0	2054	0	3	0	84
	Low	50	0.10	21.5	7.15	0.0	2564	0	0	0	109
	Low	100	0.10	22.1	7.43	0.0	1955	0	3	0	87
OW4	High	100	0.05	23.4	7.33	0.0	164	0	0	0	2
	Mid	100	0.05	23.6	7.03	0.0	318	0	0	0	3
	Low	Surface	--	--	--	--	--	--	--	--	--
	Low	25	--	--	--	--	--	--	--	--	--
	Low	50	0.13	23.5	6.52	0.0	257	0	0	0	3
	Low	100	0.16	24.5	7.56	0.0	258	0	0	6	6
Bay			3.44	22.0	7.42	0.0	13296	0	0	0	598
Ocean			8.50	23.8	8.10	0.0	16602	0	0	0	752

October 2012

Site	Position	Depth	Dissolved O_2	Temp.	pH	ααd	Cl^-	NO_2^--N	NO_3^{2-}-N	PO_4^{3-}-P	SO_4^{2-}-S
		cm	mg L^{-1}	°C			--------------------- mg L^{-1} ---------------------				
BC1	High	100	0.68	20.4	6.43	1.0	0	0	0	0	6
	Mid	100	0.03	19.5	7.30	0.0	811	0	2	0	26
	Low	Surface	2.63	20.9	7.27	0.0	324	0	2	0	7
	Low	25	0.33	18.2	6.27	5.0	461	0	0	0	3
	Low	50	0.09	18.4	6.80	0.0	179	0	0	0	3
	Low	100	0.04	19.4	7.15	0.0	413	0	0	0	17
BC2	High	100	0.05	18.9	7.34	0.0	508	0	0	0	12
	Mid	100	0.06	19.6	7.57	0.0	628	0	0	0	9
	Low	Surface	8.05	21.0	7.21	0.0	395	0	0	0	11
	Low	25	0.35	17.8	6.70	0.0	472	0	0	0	6
	Low	50	0.06	18.0	7.07	0.0	204	0	0	0	4
	Low	100	0.04	19.1	7.41	0.0	1356	0	0	0	24
BC3	High	100	0.30	20.1	7.27	0.0	56	0	0	0	6
	Mid	100	0.25	19.1	6.50	0.0	499	0	0	0	9
	Low	Surface	6.14	16.9	7.27	0.5	923	0	0	0	41
	Low	25	0.41	17.0	7.19	2.5	902	0	0	0	32
	Low	50	0.11	17.5	6.85	2.0	995	0	0	0	14
	Low	100	0.07	19.1	7.27	0.0	432	0	0	0	10
BC4	High	100	1.13	19.7	7.16	0.0	0	0	0	0	5
	Mid	100	0.27	18.2	7.14	0.0	192	0	0	0	4
	Low	Surface	--	--	--	--	--	--	--	--	--
	Low	25	--	--	--	--	--	--	--	--	--
	Low	50	1.27	16.0	7.17	0.0	167	0	0	0	4
	Low	100	0.25	17.5	7.66	0.0	19	0	0	0	0
BC5	High	100	--	--	--	--	--	--	--	--	--
	Mid	100	0.22	19.0	6.96	0.0	547	0	0	0	7
	Low	Surface	--	--	--	--	--	--	--	--	--
	Low	25	1.06	16.7	4.00	5.0	1325	0	0	0	20
	Low	50	0.27	17.6	5.97	2.5	1701	0	0	0	26
	Low	100	0.20	18.2	7.14	0.0	1089	0	0	7	7

Site	Position	Depth	Dissolved O_2	Temp.	pH	ααd	Cl^-	NO_2^--N	NO_3^{2-}-N	PO_4^{3-}-P	SO_4^{2-}-S
		cm	mg L^{-1}	°C			---------------------- mg L^{-1} ----------------------				
BC6	High	100	0.22	18.1	7.68	0.0	1147	0	0	0	8
	Mid	100	0.06	17.8	7.65	0.0	2556	0	0	0	16
	Low	Surface	7.69	13.6	6.92	0.0	416	0	0	0	5
	Low	25	0.68	15.1	7.31	0.0	902	0	0	0	56
	Low	50	0.18	15.9	7.38	0.0	1398	0	0	0	84
	Low	100	0.06	17.2	7.79	0.0	2785	0	0	7	26
OW1	High	100	0.35	20.5	7.18	0.0	0	0	0	0	3
	Mid	100	0.34	20.1	6.89	0.0	0	0	0	0	3
	Low	Surface	--	--	--	--	--	--	--	--	--
	Low	25	--	--	--	--	--	--	--	--	--
	Low	50	0.71	18.6	6.83	0.0	11	0	0	0	3
	Low	100	0.37	20.0	7.78	0.0	0	0	0	0	3
OW2	High	100	0.47	20.2	7.45	1.0	5	0	0	0	11
	Mid	100	0.05	19.8	7.82	0.0	650	0	0	0	11
	Low	Surface	--	--	--	--	--	--	--	--	--
	Low	25	0.36	19.3	7.88	0.0	1439	0	0	0	22
	Low	50	0.09	18.9	7.84	0.0	1228	0	0	0	13
	Low	100	0.08	19.6	8.00	0.0	2269	0	0	0	76
OW3	High	100	2.60	20.3	7.69	0.0	8	0	2	0	4
	Mid	100	0.09	18.9	8.07	0.0	1360	0	0	0	49
	Low	Surface	--	--	--	--	--	--	--	--	--
	Low	25	0.83	19.6	8.11	0.0	2996	0	0	0	104
	Low	50	0.23	18.1	8.01	0.0	2817	0	0	0	101
	Low	100	0.08	19.1	8.10	0.0	2597	0	0	0	99
OW4	High	100	0.08	20.1	7.52	0.0	0	0	0	0	3
	Mid	100	0.12	19.4	7.23	0.0	0	0	0	0	3
	Low	Surface	--	--	--	--	--	--	--	--	--
	Low	25	--	--	--	--	--	--	--	--	--
	Low	50	0.34	18.9	7.14	0.0	26	0	0	0	5
	Low	100	0.10	19.7	7.85	0.0	97	0	0	0	4
Bay			5.38	15.7	7.69	0.0	13801	0	0	0	595
Ocean			8.46	19.5	7.88	0.0	17994	0	0	0	785

November 2012

Site	Position	Depth	Dissolved O_2	Temp.	pH	ααd	Cl^-	NO_2^--N	NO_3^{2-}-N	PO_4^{3-}-P	SO_4^{2-}-S
		cm	mg L^{-1}	°C			---------------------- mg L^{-1} ----------------------				
BC1	High	100	0.35	13.4	5.14	1.0	2018	0	0	0	91
	Mid	100	0.11	14.3	6.51	1.0	2355	0	0	0	72
	Low	Surface	0.76	15.4	6.46	1.5	3839	0	0	0	155
	Low	25	0.36	15.9	6.18	5.0	1075	0	0	0	8
	Low	50	0.09	16.2	6.13	4.0	2121	0	0	0	48
	Low	100	0.13	16.4	6.31	3.0	2130	0	0	0	75
BC2	High	100	0.13	12.6	6.70	0.0	559	0	0	0	7
	Mid	100	0.04	15.0	6.38	3.0	3932	0	0	0	144
	Low	Surface	2.41	13.8	6.69	0.0	3329	0	0	0	125
	Low	25	0.18	15.1	6.01	3.5	4147	0	0	0	161
	Low	50	0.08	15.8	6.59	0.0	1771	0	0	0	49
	Low	100	0.04	16.3	6.47	0.0	2763	0	0	0	83
BC3	High	100	0.29	13.9	6.26	4.5	2252	0	0	0	99
	Mid	100	0.17	13.3	6.31	4.0	2346	0	0	0	76
	Low	Surface	8.87	13.5	6.90	0.0	2319	0	0	0	89
	Low	25	0.41	16.0	6.50	1.0	594	0	0	0	10
	Low	50	0.36	15.8	6.88	0.0	1265	0	0	0	63
	Low	100	0.09	16.7	6.71	0.0	1986	0	0	0	153
BC4	High	100	1.59	13.9	5.98	5.0	2007	0	0	0	90
	Mid	100	0.53	13.8	7.24	0.0	214	0	0	0	4
	Low	Surface	--	--	--	--	--	--	--	--	--
	Low	25	2.21	11.9	6.51	5.0	2899	0	1	0	124
	Low	50	0.92	12.3	6.94	0.0	306	0	0	0	7
	Low	100	0.58	13.5	7.82	0.0	0	0	0	0	0
BC5	High	100	--	--	--	--	--	--	--	--	--
	Mid	100	0.18	15.6	5.43	5.0	5818	0	0	0	254
	Low	Surface	--	--	--	--	--	--	--	--	--
	Low	25	0.88	13.5	4.87	5.0	2717	0	0	0	79
	Low	50	0.29	14.0	6.10	0.0	2998	0	0	0	64
	Low	100	1.62	15.2	7.17	0.0	1410	0	0	4	23

Site	Position	Depth	Dissolved O_2	Temp.	pH	ααd	Cl^-	NO_2^--N	NO_3^{2-}-N	PO_4^{3-}-P	SO_4^{2-}-S
		cm	mg L^{-1}	°C			---------------------- mg L^{-1} ----------------------				
BC6	High	100	0.17	13.7	6.69	1.0	3040	0	1	0	80
	Mid	100	0.15	13.6	6.35	5.0	7905	0	3	0	334
	Low	Surface	0.21	9.7	6.20	5.0	4114	0	2	0	150
	Low	25	0.82	11.3	6.73	6.7	678	0	0	0	23
	Low	50	0.25	12.2	6.56	5.6	1870	0	0	0	71
	Low	100	0.15	13.2	6.88	6.9	2536	0	1	4	16
OW1	High	100	0.44	13.8	6.87	2.0	807	0	0	0	31
	Mid	100	0.25	13.6	6.80	3.0	770	0	0	0	35
	Low	Surface	--	--	--	--	--	--	--	--	--
	Low	25	2.50	10.5	6.55	5.0	4308	0	2	0	190
	Low	50	0.94	11.9	6.71	0.5	0	0	0	0	1
	Low	100	0.44	13.5	8.59	0.0	0	0	0	0	0
OW2	High	100	0.40	13.2	7.53	4.0	992	0	0	0	38
	Mid	100	0.42	13.4	7.40	3.5	2560	0	1	0	103
	Low	Surface	--	--	--	--	--	--	--	--	--
	Low	25	1.33	11.4	7.07	0.0	980	0	0	0	8
	Low	50	0.53	12.3	7.35	0.0	1222	0	0	0	21
	Low	100	0.35	13.4	7.87	0.0	2317	0	1	0	80
OW3	High	100	0.95	13.7	7.37	0.0	1521	0	0	0	47
	Mid	100	0.24	12.8	7.76	0.0	1525	0	0	0	47
	Low	Surface	--	--	--	--	--	--	--	--	--
	Low	25	0.73	11.6	7.11	0.0	2212	0	1	0	89
	Low	50	0.34	12.2	7.32	0.0	2342	0	1	0	94
	Low	100	0.27	13.4	7.61	0.0	2059	0	1	0	85
OW4	High	100	0.56	14.8	8.65	2.0	2251	0	1	0	99
	Mid	100	0.42	14.3	8.88	0.0	37	0	0	0	2
	Low	Surface	--	--	--	--	--	--	--	--	--
	Low	25	2.78	11.7	7.48	3.5	11468	0	0	0	490
	Low	50	0.45	12.7	7.42	0.5	5534	0	2	0	212
	Low	100	0.46	14.0	8.65	0.0	18	0	0	3	2
Bay			8.09	13.2	7.44	0.0	15734	0	0	0	685
Ocean			8.04	11.0	7.63	0.0	18695	0	0	0	827

December 2012

Site	Position	Depth	Dissolved O_2	Temp.	pH	ααd	Cl^-	NO_2^--N	NO_3^{2-}-N	PO_4^{3-}-P	SO_4^{2-}-S
		cm	mg L^{-1}	°C			---------------------- mg L^{-1} ----------------------				
BC1	High	100	1.16	12.1	6.24	1.0	1510	0	0	0	59
	Mid	100	0.25	12.5	6.43	0.5	2883	0	0	0	99
	Low	Surface	5.62	14.3	6.98	0.5	1983	0	0	0	69
	Low	25	0.84	12.1	6.78	2.5	2218	0	0	0	70
	Low	50	0.46	12.2	6.50	2.0	1763	0	0	0	40
	Low	100	0.23	13.0	6.42	0.5	1974	0	0	0	44
BC2	High	100	0.27	11.6	7.42	0.0	911	0	0	0	14
	Mid	100	0.25	12.3	6.98	0.0	3194	0	0	0	118
	Low	Surface	--	--	--	--	--	--	--	--	--
	Low	25	1.09	12.0	6.56	0.0	3604	0	0	0	100
	Low	50	0.43	12.5	6.58	0.0	3752	0	0	0	121
	Low	100	0.04	12.9	6.92	0.0	4297	0	0	0	143
BC3	High	100	10.40	12.0	6.40	0.0	1946	0	0	0	68
	Mid	100	0.57	11.5	6.44	0.5	2679	0	0	0	92
	Low	Surface	--	--	--	--	--	--	--	--	--
	Low	25	1.23	11.4	6.83	1.0	2513	0	0	0	87
	Low	50	0.42	11.3	6.62	2.0	2638	0	0	0	94
	Low	100	0.16	12.0	6.48	0.0	2255	0	0	0	78
BC4	High	100	1.64	12.6	5.78	3.0	1064	0	0	0	48
	Mid	100	0.43	12.5	6.95	5.0	1008	0	0	0	35
	Low	Surface	--	--	--	--	--	--	--	--	--
	Low	25	3.15	10.1	6.20	5.0	3736	0	0	0	150
	Low	50	1.12	11.3	6.51	0.0	821	0	0	0	39
	Low	100	0.37	12.3	7.49	0.0	0	0	0	0	0
BC5	High	100	--	--	--	--	--	--	--	--	--
	Mid	100	0.91	14.4	4.39	5.0	4618	0	0	0	193
	Low	Surface	--	--	--	--	--	--	--	--	--
	Low	25	1.55	12.6	4.03	5.0	4627	0	0	0	176
	Low	50	0.44	12.4	5.81	1.0	2978	0	0	0	89
	Low	100	1.27	13.7	6.53	0.0	1041	0	0	0	10

Site	Position	Depth	Dissolved O_2	Temp.	pH	ααd	Cl^-	NO_2^--N	NO_3^{2-}-N	PO_4^{3-}-P	SO_4^{2-}-S
		cm	mg L^{-1}	^oC			---------------------- mg L^{-1} ----------------------				
BC6	High	100	0.19	12.3	6.42	2.0	4533	0	0	0	135
	Mid	100	0.26	12.6	6.19	3.5	6165	0	0	0	241
	Low	Surface	0.53	11.5	6.39	4.5	3315	0	0	0	106
	Low	25	1.04	11.5	6.76	0.0	1031	0	0	0	49
	Low	50	0.17	11.5	6.61	0.0	2234	0	1	0	79
	Low	100	0.04	11.6	6.84	0.0	3812	0	1	0	110
OW1	High	100	0.51	12.8	6.24	3.5	1088	0	0	0	36
	Mid	100	0.38	12.5	6.31	3.5	1120	0	0	0	42
	Low	Surface	--	--	--	--	--	--	--	--	--
	Low	25	--	--	--	--	--	--	--	--	--
	Low	50	0.94	12.1	6.61	1.5	0	0	0	0	0
	Low	100	0.29	12.4	7.57	0.5	56	0	0	0	5
OW2	High	100	0.89	12.2	7.02	4.0	1579	0	0	0	53
	Mid	100	0.40	12.3	7.26	2.0	1436	0	0	0	45
	Low	Surface	--	--	--	--	--	--	--	--	--
	Low	25	1.07	12.9	6.85	0.0	941	0	0	0	6
	Low	50	0.41	11.8	6.99	0.0	1298	0	0	0	30
	Low	100	0.15	12.2	7.37	0.0	2338	0	1	0	81
OW3	High	100	1.18	12.5	7.99	0.0	2306	0	1	0	85
	Mid	100	0.08	11.9	7.95	0.0	1802	0	0	0	55
	Low	Surface	--	--	--	--	--	--	--	--	--
	Low	25	0.98	11.9	7.88	0.0	2212	0	0	0	92
	Low	50	0.32	11.8	7.86	0.0	2048	0	0	0	80
	Low	100	0.12	12.1	8.04	0.0	2451	0	1	0	92
OW4	High	100	0.50	13.2	6.61	5.0	6951	0	3	0	300
	Mid	100	0.21	13.1	7.16	0.0	1598	0	0	0	68
	Low	Surface	--	--	--	--	--	--	--	--	--
	Low	25	4.12	12.9	6.84	3.5	11965	0	6	0	500
	Low	50	0.81	12.4	6.62	0.0	5283	0	2	0	200
	Low	100	0.10	12.9	7.64	0.0	333	0	0	0	13
Bay			9.17	11.2	7.65	0.0	14341	0	3	0	609
Ocean			10.32	8.3	7.87	0.0	17625	0	0	0	754

January 2013

Site	Position	Depth	Dissolved O$_2$	Temp.	pH	ααd	Cl$^-$	NO$_2^-$-N	NO$_3^{2-}$-N	PO$_4^{3-}$-P	SO$_4^{2-}$-S
		cm	mg L^{-1}	^{o}C			---------------------- mg L^{-1} ----------------------				
BC1	High	100	1.56	9.4	5.90	3.0	1661	0	0	0	67
	Mid	100	0.39	9.7	6.30	2.5	2466	0	0	0	57
	Low	Surface	4.12	8.9	6.64	0.5	899	0	0	0	26
	Low	25	0.57	10.3	6.80	1.0	1213	0	0	0	36
	Low	50	0.43	10.7	6.61	0.5	913	0	0	0	28
	Low	100	0.15	11.0	6.28	0.5	1534	0	0	0	25
BC2	High	100	0.42	9.1	6.65	0.0	1214	0	0	0	25
	Mid	100	0.14	9.8	6.38	0.0	2711	0	0	0	93
	Low	Surface	3.78	14.2	7.01	0.5	1351	0	0	0	41
	Low	25	1.01	12.0	6.59	0.0	2729	0	0	0	73
	Low	50	0.57	11.4	6.42	0.0	3814	0	0	0	92
	Low	100	0.09	11.3	6.35	0.0	4500	0	0	0	131
BC3	High	100	4.26	9.1	6.77	0.5	2497	0	0	0	81
	Mid	100	0.69	8.7	6.99	0.0	682	0	0	0	28
	Low	Surface	1.27	9.2	6.76	0.0	1156	0	0	0	43
	Low	25	1.15	10.0	6.74	0.0	1425	0	0	0	54
	Low	50	0.56	10.1	6.91	0.0	883	0	0	0	35
	Low	100	0.14	10.1	6.83	0.0	2110	0	0	0	74
BC4	High	100	1.73	10.2	5.62	4.0	754	0	0	0	32
	Mid	100	0.68	10.2	6.26	5.0	1728	0	0	0	55
	Low	Surface	--	--	--	--	--	--	--	--	--
	Low	25	2.03	10.5	5.38	3.0	3091	0	0	0	98
	Low	50	0.76	9.8	5.84	5.0	1763	0	0	0	71
	Low	100	0.35	10.2	6.79	0.0	79	0	0	0	0
BC5	High	100	--	--	--	--	--	--	--	--	--
	Mid	100	0.42	12.3	4.84	5.0	3436	0	0	0	130
	Low	Surface	--	--	--	--	--	--	--	--	--
	Low	25	1.92	10.2	4.97	4.0	3219	0	0	0	97
	Low	50	0.44	10.4	5.84	0.5	3718	0	0	0	126
	Low	100	2.33	11.7	6.49	0.0	1086	0	0	0	13

Site	Position	Depth	Dissolved O_2	Temp.	pH	ααd	Cl^-	NO_2^--N	NO_3^{2-}-N	PO_4^{3-}-P	SO_4^{2-}-S
		cm	mg L^{-1}	°C			---------------------- mg L^{-1} ----------------------				
BC6	High	100	0.36	9.8	6.08	5.0	4755	0	0	0	128
	Mid	100	0.54	10.0	6.11	0.5	5358	0	0	0	199
	Low	Surface	2.29	11.3	5.98	3.0	3076	0	0	0	103
	Low	25	1.00	9.8	6.48	0.0	1197	0	0	0	65
	Low	50	0.37	9.4	6.58	0.0	2508	0	0	0	44
	Low	100	0.07	9.8	6.65	0.0	5292	0	0	0	194
OW1	High	100	0.65	9.9	6.28	3.5	1915	0	0	0	70
	Mid	100	0.74	9.6	6.23	3.5	1478	0	0	0	57
	Low	Surface	--	--	--	--	--	--	--	--	--
	Low	25	--	--	--	--	--	--	--	--	--
	Low	50	0.97	9.9	5.92	0.5	0	0	0	0	1
	Low	100	0.22	9.7	8.11	0.0	734	0	0	0	28
OW2	High	100	1.30	8.9	6.79	4.0	1189	0	0	0	53
	Mid	100	0.36	9.3	7.62	1.0	1932	0	0	0	52
	Low	Surface	--	--	--	--	--	--	--	--	--
	Low	25	1.14	9.2	6.76	0.0	1271	0	0	0	27
	Low	50	0.60	8.7	6.92	0.0	2401	0	0	0	79
	Low	100	0.23	9.1	7.17	0.0	3031	0	0	0	99
OW3	High	100	1.78	10.1	7.33	0.0	2302	0	0	0	88
	Mid	100	0.20	9.2	7.53	0.0	1594	0	0	0	44
	Low	Surface	--	--	--	--	--	--	--	--	--
	Low	25	0.97	9.9	7.23	0.0	1918	0	0	0	72
	Low	50	0.35	9.2	7.53	0.0	2063	0	0	0	72
	Low	100	0.21	9.4	7.98	0.0	2497	0	0	0	94
OW4	High	100	0.85	10.3	6.68	2.5	5261	0	0	0	223
	Mid	100	0.35	10.0	7.11	0.5	1629	0	0	0	65
	Low	Surface	--	--	--	--	--	--	--	--	--
	Low	25	6.87	9.6	7.04	1.5	9756	0	0	0	363
	Low	50	1.54	9.4	6.38	0.0	3859	0	0	0	127
	Low	100	0.60	10.0	8.16	0.0	1158	0	0	0	45
Bay			7.80	9.7	7.35	0.0	12773	0	0	0	538
Ocean			10.76	7.7	7.75	0.0	17701	0	0	0	757

February 2013

Site	Position	Depth	Dissolved O_2	Temp.	pH	ααd	Cl^-	NO_2^--N	NO_3^{2-}-N	PO_4^{3-}-P	SO_4^{2-}-S
		cm	mg L^{-1}	°C			--------------------- mg L^{-1} ---------------------				
BC2	High	100	0.77	6.0	6.54	0.0	1551	0	3	0	44
	Mid	100	0.16	7.2	6.42	0.0	2582	0	2	0	93
	Low	Surface	8.00	7.6	6.86	0.0	978	0	2	0	34
	Low	25	0.73	8.2	6.60	0.0	1779	0	3	0	34
	Low	50	0.67	8.7	6.53	0.0	2276	0	4	0	47
	Low	100	0.11	9.8	6.36	0.0	5007	0	5	0	149
BC6	High	100	0.73	7.8	6.14	5.0	4636	0	5	0	148
	Mid	100	0.49	8.0	6.29	0.0	5377	0	5	0	198
	Low	Surface	9.30	4.6	5.94	4.0	1975	0	4	0	61
	Low	25	0.80	5.3	6.52	0.0	1648	0	3	0	76
	Low	50	0.33	6.0	6.80	0.0	2802	0	4	0	37
	Low	100	0.10	7.5	6.71	0.0	5655	0	5	0	216
OW3	High	100	3.81	6.8	7.68	0.0	1590	0	3	0	61
	Mid	100	0.26	6.5	7.50	0.0	1803	0	3	0	55
	Low	Surface	--	--	--	--	--	--	--	--	--
	Low	25	1.30	5.5	7.75	0.0	2331	0	4	0	88
	Low	50	0.46	5.5	8.05	0.0	2520	0	4	0	97
	Low	100	0.35	6.9	7.77	0.0	5856	0	5	0	228
Bay			10.69	2.9	7.54	0.0	12503	0	19	0	539
Ocean			10.40	5.9	8.11	0.0	18908	0	22	0	825

March 2013

Site	Position	Depth	Dissolved O_2	Temp.	pH	ααd	Cl^-	NO_2^--N	NO_3^{2-}-N	PO_4^{3-}-P	SO_4^{2-}-S
		cm	mg L^{-1}	°C			---------------------- mg L^{-1} ----------------------				
BC2	High	100	0.72	6.5	6.54	0.0	1819	0	0	0	59
	Mid	100	0.18	8.1	6.45	0.0	2660	0	0	0	105
	Low	Surface	9.86	5.9	7.41	0.0	812	0	0	0	29
	Low	25	1.00	7.6	6.65	0.0	1713	0	0	0	25
	Low	50	0.97	8.6	6.67	0.0	1894	0	0	0	34
	Low	100	0.08	9.8	6.42	0.0	4896	0	0	0	153
BC6	High	100	0.69	7.5	6.53	5.0	3942	0	0	0	124
	Mid	100	0.85	7.6	7.54	0.0	5331	0	0	0	200
	Low	Surface	4.54	2.9	6.29	0.0	1643	0	0	0	50
	Low	25	1.16	6.2	7.12	0.0	1961	0	0	0	71
	Low	50	0.34	4.7	7.38	0.0	2980	0	0	0	37
	Low	100	0.19	8.0	7.03	0.0	5533	0	0	7	217
OW3	High	100	4.79	7.1	8.23	0.0	120	0	4	0	7
	Mid	100	0.13	7.0	7.45	0.0	2149	0	0	0	74
	Low	Surface	--	--	--	--	--	--	--	--	--
	Low	25	1.35	6.3	7.30	0.0	2919	0	0	0	107
	Low	50	0.96	5.8	7.54	0.0	3252	0	0	0	125
	Low	100	0.44	7.2	7.69	0.0	3335	0	0	0	135
Bay			12.59	2.3	8.20	0.0	10522	0	0	0	461
Ocean			10.17	7.1	8.00	0.0	18112	0	0	0	813

April 2, 2013

Site	Position	Depth	Dissolved O_2	Temp.	pH	ααd	Cl^-	NO_2^--N	NO_3^{2-}-N	PO_4^{3-}-P	SO_4^{2-}-S
		cm	mg L^{-1}	^oC			---------------------- mg L^{-1} ----------------------				
BC2	High	100	0.76	8.6	6.58	0.0	1588	0	3	0	53
	Mid	100	0.07	10.0	6.47	0.0	2623	0	2	0	100
	Low	Surface	6.44	12.1	7.08	0.0	748	0	3	0	25
	Low	25	0.73	11.4	6.76	0.0	1261	0	0	0	9
	Low	50	0.86	11.4	6.71	0.0	1569	0	2	0	22
	Low	100	0.05	10.9	6.41	0.0	4707	0	0	0	143
BC6	High	100	0.99	8.4	6.23	0.0	2362	0	2	0	59
	Mid	100	0.16	8.5	6.40	0.0	4836	0	0	0	172
	Low	Surface	4.39	6.9	7.05	0.0	1639	0	2	0	55
	Low	25	0.57	9.8	6.36	0.0	2175	0	2	0	62
	Low	50	0.28	9.8	6.68	0.0	3134	0	2	0	43
	Low	100	0.13	9.6	6.66	0.0	5407	0	2	7	199
OW3	High	100	4.81	8.9	8.66	0.0	0	0	4	0	4
	Mid	100	0.11	8.8	7.65	0.0	2076	0	3	0	80
	Low	Surface	--	--	--	--	--	--	--	--	--
	Low	25	0.87	9.3	7.38	0.0	3281	0	0	0	127
	Low	50	0.29	8.7	7.59	0.0	3305	0	0	0	129
	Low	100	0.11	8.6	7.69	0.0	2897	0	0	0	115
Bay			7.50	9.2	7.93	0.0	11998	0	8	0	527
Ocean			9.18	8.7	8.07	0.0	17689	0	8	0	778

April 30, 2013

Site	Position	Depth	Dissolved O_2	Temp.	pH	ααd	Cl^-	NO_2^--N	NO_3^{2-}-N	PO_4^{3-}-P	SO_4^{2-}-S
		cm	mg L^{-1}	°C			---------------------- mg L^{-1} ----------------------				
BC2	High	100	0.46	13.6	6.57	0.0	1138	0	0	0	36
	Mid	100	0.18	13.9	6.40	0.0	2698	0	0	0	88
	Low	Surface	2.54	15.7	7.29	0.0	236	0	0	0	10
	Low	25	0.39	15.9	6.72	0.0	680	0	0	0	3
	Low	50	0.10	16.1	6.68	0.0	897	0	0	0	5
	Low	100	0.07	15.5	6.54	0.0	3473	0	0	0	81
BC6	High	100	0.14	12.1	6.29	0.0	1492	0	0	0	28
	Mid	100	0.11	12.0	6.38	0.0	4706	0	0	0	149
	Low	Surface	1.72	13.7	6.02	0.5	732	0	0	0	20
	Low	25	0.42	14.2	6.33	0.0	2090	0	0	0	47
	Low	50	0.07	14.4	6.64	0.0	3078	0	0	0	47
	Low	100	0.08	14.0	6.64	0.0	4782	0	0	0	152
OW3	High	100	2.90	13.4	8.76	0.0	0	0	0	0	2
	Mid	100	0.07	13.3	7.72	0.0	1862	0	0	0	62
	Low	Surface	--	--	--	--	--	--	--	--	--
	Low	25	0.65	13.4	7.52	0.0	2634	0	0	0	91
	Low	50	0.13	12.7	7.90	0.0	2425	0	0	0	88
	Low	100	0.08	12.3	7.77	0.0	2833	0	0	0	103
Bay			5.61	14.8	7.32	0.0	12106	0	0	0	489
Ocean			9.02	13.2	8.17	0.0	16482	0	0	0	658

May 2013

Site	Position	Depth	Dissolved O_2	Temp.	pH	ααd	Cl^-	NO_2^--N	NO_3^{2-}-N	PO_4^{3-}-P	SO_4^{2-}-S
		cm	mg L^{-1}	°C			--------------------- mg L^{-1} ---------------------				
BC2	High	100	0.14	15.5	6.70	0.0	1375	0	0	0	44
	Mid	100	0.06	16.0	6.58	0.0	2445	0	0	0	86
	Low	Surface	8.78	20.8	7.74	0.0	1038	0	0	0	27
	Low	25	0.16	17.6	6.76	0.0	946	0	0	0	3
	Low	50	0.05	17.6	6.82	0.0	1031	0	0	0	5
	Low	100	0.02	17.6	6.71	0.0	3365	0	0	0	89
BC6	High	100	0.07	13.7	7.01	0.0	1769	0	0	0	30
	Mid	100	0.06	13.5	6.63	0.0	4779	0	0	0	169
	Low	Surface	5.05	11.3	6.32	0.0	1030	0	0	0	19
	Low	25	0.16	15.0	6.87	0.0	2316	0	0	0	50
	Low	50	0.04	15.6	6.84	0.0	3392	0	0	0	69
	Low	100	0.04	15.5	6.86	0.0	4711	0	0	0	164
OW3	High	100	2.75	15.6	7.99	0.0	45	0	3	0	4
	Mid	100	0.11	15.4	7.64	0.0	1963	0	0	0	72
	Low	Surface	--	--	--	--	--	--	--	--	--
	Low	25	0.48	15.7	7.29	0.0	2624	0	0	0	101
	Low	50	0.10	14.7	7.54	0.0	2788	0	0	0	110
	Low	100	0.07	14.3	7.63	0.0	2908	0	0	0	115
Bay			5.67	15.8	7.69	0.0	15611	0	0	0	690
Ocean			7.55	14.7	7.97	0.0	18043	0	0	0	800

June 2013

Site	Position	Depth	Dissolved O_2	Temp.	pH	ααd	Cl^-	NO_2^--N	NO_3^{2-}-N	PO_4^{3-}-P	SO_4^{2-}-S
		cm	mg L^{-1}	^oC			----------------------	mg L^{-1}		----------------------	
BC2	High	100	0.16	21.4	6.54	0.0	1224	0	2	0	32
	Mid	100	0.04	21.4	6.47	0.0	1931	0	0	0	58
	Low	Surface	4.29	24.8	7.29	0.0	666	0	0	0	19
	Low	25	0.14	24.6	6.44	0.0	1259	0	0	0	4
	Low	50	0.04	24.2	6.60	0.0	1144	0	0	0	4
	Low	100	0.02	22.2	6.58	0.0	3367	0	0	0	99
BC6	High	100	0.06	18.0	6.33	0.0	2022	0	0	0	25
	Mid	100	0.04	17.8	6.37	0.0	4752	0	0	0	164
	Low	Surface	0.19	21.8	6.29	0.0	1034	0	0	0	9
	Low	25	0.13	21.6	6.36	0.0	2384	0	0	0	44
	Low	50	0.05	21.0	6.67	0.0	3538	0	0	0	102
	Low	100	0.05	19.2	6.70	0.0	4152	0	2	0	125
OW3	High	100	2.34	21.2	7.84	0.0	35	0	3	0	3
	Mid	100	0.04	20.9	7.51	0.0	1909	0	3	0	64
	Low	Surface	--	--	--	--	--	--	--	--	--
	Low	25	0.63	23.7	7.07	0.0	2678	0	4	0	104
	Low	50	0.10	21.1	7.54	0.0	2626	0	4	0	103
	Low	100	0.05	19.5	7.70	0.0	2501	0	4	0	98
Bay			7.62	29.4	8.22	0.0	15059	0	19	0	649
Ocean			6.56	22.2	8.18	0.0	18519	0	21	0	801

July 2013

Site	Position	Depth	Dissolved O_2	Temp.	pH	ααd	Cl^-	NO_2^--N	NO_3^{2-}-N	PO_4^{3-}-P	SO_4^{2-}-S
		cm	mg L^{-1}	^oC			---------------------- mg L^{-1} ----------------------				
BC2	High	100	0.15	25.8	6.62	0.0	2762	0	3	0	54
	Mid	100	0.06	24.6	6.80	0.0	1108	0	3	0	15
	Low	Surface	--	--	--	--	--	--	--	--	--
	Low	25	1.34	30.7	6.49	0.0	1405	0	3	0	8
	Low	50	0.11	27.9	6.53	0.0	1408	0	3	0	1
	Low	100	0.04	25.4	6.58	0.0	3476	0	0	0	94
BC6	High	100	0.08	21.6	6.75	0.0	1319	0	3	0	29
	Mid	100	0.05	21.4	6.60	0.0	4548	0	4	0	153
	Low	Surface	--	--	--	--	--	--	--	--	--
	Low	25	0.22	26.4	6.68	0.0	1854	0	3	0	2
	Low	50	0.06	25.3	6.48	0.0	3576	0	4	0	110
	Low	100	0.06	23.6	6.73	0.0	4710	0	4	0	136
OW3	High	100	2.90	25.0	7.75	0.0	70	0	2	0	1
	Mid	100	0.06	24.2	7.54	0.0	1808	0	3	0	58
	Low	Surface	--	--	--	--	--	--	--	--	--
	Low	25	--	--	--	--	--	--	--	--	--
	Low	50	0.39	24.8	7.44	0.0	2198	0	3	0	77
	Low	100	0.11	23.5	7.49	0.0	2272	0	3	0	81
Bay			7.80	33.5	8.54	0.0	18652	0	19	0	778
Ocean			6.82	25.9	8.47	0.0	15958	0	18	0	662

August 2013

Site	Position	Depth	Dissolved O$_2$	Temp.	pH	ααd	Cl$^-$	NO$_2^-$-N	NO$_3^{2-}$-N	PO$_4^{3-}$-P	SO$_4^{2-}$-S
		cm	mg L^{-1}	^{o}C			---------------------- mg L^{-1} ----------------------				
BC2	High	100	0.16	23.8	6.89	0.0	1262	0	3	0	28
	Mid	100	0.04	22.9	7.01	0.0	1147	0	0	0	12
	Low	Surface	--	--	--	--	--	--	--	--	--
	Low	25	0.51	23.8	6.50	0.0	2602	0	2	0	124
	Low	50	0.10	23.4	6.46	0.0	2155	0	0	0	68
	Low	100	0.04	23.3	6.84	0.0	2374	0	0	0	50
BC6	High	100	0.07	20.9	6.44	0.0	3249	0	0	0	79
	Mid	100	0.03	20.6	6.56	0.0	4596	0	0	0	149
	Low	Surface	--	--	--	--	--	--	--	--	--
	Low	25	0.26	21.6	6.84	0.0	1942	0	0	0	13
	Low	50	0.09	21.7	6.55	0.0	3675	0	0	0	75
	Low	100	0.04	21.5	6.66	0.0	4978	0	0	0	137
OW3	High	100	0.95	23.6	7.35	0.0	314	0	0	0	8
	Mid	100	1.20	22.6	7.77	0.0	1877	0	0	0	67
	Low	Surface	--	--	--	--	--	--	--	--	--
	Low	25	0.43	23.8	6.80	0.0	3128	0	0	0	131
	Low	50	0.14	22.2	7.03	0.0	2878	0	0	0	123
	Low	100	0.09	21.9	7.23	0.0	2621	0	0	0	103
Bay			2.79	23.0	8.17	0.0	18458	0	0	0	764
Ocean			6.47	24.8	8.05	0.0	17733	0	0	0	737

September 2013

Site	Position	Depth	Dissolved O_2	Temp.	pH	ααd	Cl^-	NO_2^--N	NO_3^{2-}-N	PO_4^{3-}-P	SO_4^{2-}-S
		cm	mg L^{-1}	^{o}C			---------------------- mg L^{-1} ----------------------				
BC2	High	100	0.74	23.2	6.68	0.0	1148	0	0	0	22
	Mid	100	0.10	22.2	6.70	0.0	1304	0	0	0	9
	Low	Surface	--	--	--	--	--	--	--	--	--
	Low	25	--	--	--	--	--	--	--	--	--
	Low	50	0.86	22.0	6.49	0.0	2081	0	0	0	41
	Low	100	0.06	22.8	6.63	0.0	1896	0	0	0	29
BC6	High	100	1.16	20.3	6.49	0.0	2678	0	0	0	70
	Mid	100	0.18	19.8	6.57	0.0	4474	0	0	0	136
	Low	Surface	--	--	--	--	--	--	--	--	--
	Low	25	--	--	--	--	--	--	--	--	--
	Low	50	1.13	20.7	6.34	0.0	3622	0	0	0	107
	Low	100	0.08	20.9	6.68	0.0	4187	0	0	0	95
OW3	High	100	--	--	--	--	--	--	--	--	--
	Mid	100	0.37	21.8	7.96	0.0	2295	0	0	0	85
	Low	Surface	--	--	--	--	--	--	--	--	--
	Low	25	--	--	--	--	--	--	--	--	--
	Low	50	0.78	21.3	7.31	0.0	2648	0	0	0	104
	Low	100	0.15	21.9	7.17	0.0	3012	0	0	0	120
Bay			3.55	19.4	7.53	0.0	21475	0	0	0	918
Ocean			7.34	19.8	8.32	0.0	18356	0	0	0	785

October 2013

Site	Position	Depth	Dissolved O_2	Temp.	pH	ααd	Cl^-	NO_2^--N	NO_3^{2-}-N	PO_4^{3-}-P	SO_4^{2-}-S
		cm	mg L^{-1}	°C			---------------------- mg L^{-1} ----------------------				
BC2	High	100	0.07	18.5	6.58	0.0	1166	0	0	0	13
	Mid	100	0.04	18.3	6.59	0.0	1216	0	0	1	5
	Low	Surface	4.48	15.7	7.38	0.0	253	0	0	1	9
	Low	25	0.25	16.0	6.50	0.0	959	0	0	2	75
	Low	50	0.07	16.7	6.58	0.0	2792	0	0	2	149
	Low	100	0.04	18.1	6.56	0.0	1336	0	0	3	13
BC6	High	100	0.08	18.0	6.64	0.0	2028	0	0	3	26
	Mid	100	0.04	17.6	6.61	0.0	4143	0	0	4	122
	Low	Surface	5.29	14.9	5.70	5.0	1193	0	0	4	47
	Low	25	0.62	16.1	6.37	3.5	2408	0	0	5	106
	Low	50	0.06	16.6	6.51	0.0	2848	0	0	5	69
	Low	100	0.06	17.4	6.72	0.0	958	0	0	6	30
OW3	High	100	1.07	19.2	7.17	0.0	961	0	0	6	30
	Mid	100	0.05	18.0	7.52	0.0	1814	0	2	7	60
	Low	Surface	--	--	--	--	--	--	--	--	--
	Low	25	0.49	17.1	6.95	0.0	2759	0	2	7	116
	Low	50	0.07	16.9	7.38	0.0	2449	0	3	8	97
	Low	100	0.07	17.9	7.36	0.0	2533	0	3	8	102
Bay			5.67	16.2	7.56	0.0	17442	0	0	0	718
Ocean			7.98	18.5	8.11	0.0	18166	0	0	0	751

November 2013

Site	Position	Depth	Dissolved O_2	Temp.	pH	ααd	Cl^-	NO_2^--N	NO_3^{2-}-N	PO_4^{3-}-P	SO_4^{2-}-S
		cm	mg L^{-1}	^oC			---------------------- mg L^{-1} ----------------------				
BC2	High	100	0.46	14.1	6.55	0.0	1103	0	0	0	10
	Mid	100	0.14	14.0	6.56	0.0	1278	0	0	0	5
	Low	Surface	--	--	--	--	--	--	--	--	--
	Low	25	0.77	12.8	6.31	0.0	584	0	0	0	6
	Low	50	0.12	12.6	6.44	0.0	1352	0	0	0	85
	Low	100	0.29	13.4	6.46	0.0	2432	0	0	0	46
BC6	High	100	0.20	14.2	7.24	0.0	1222	0	0	0	12
	Mid	100	0.06	14.2	6.66	0.0	4225	0	0	0	118
	Low	Surface	--	--	--	--	--	--	--	--	--
	Low	25	1.21	10.9	6.49	0.0	1551	0	0	0	65
	Low	50	0.22	11.5	6.69	0.0	2257	0	0	0	139
	Low	100	0.11	12.1	6.75	0.0	3508	0	0	0	52
OW3	High	100	0.98	14.4	7.28	0.0	1357	0	0	0	45
	Mid	100	0.10	13.3	7.56	0.0	1764	0	0	0	59
	Low	Surface	--	--	--	--	--	--	--	--	--
	Low	25	1.01	13.3	6.97	0.0	2654	0	0	0	120
	Low	50	0.13	12.6	7.16	0.0	2540	0	0	0	110
	Low	100	0.29	13.5	7.13	0.0	3008	0	0	0	131
Bay			8.35	11.0	7.45	0.0	18128	0	0	0	775
Ocean			8.40	12.1	8.04	0.0	18113	0	0	0	770

December 2013

Site	Position	Depth	Dissolved O_2	Temp.	pH	ααd	Cl^-	NO_2^--N	NO_3^{2-}-N	PO_4^{3-}-P	SO_4^{2-}-S
		cm	mg L^{-1}	°C			--------------------- mg L^{-1} ---------------------				
BC2	High	100	0.95	8.5	6.62	0.0	1000	0	0	0	7
	Mid	100	0.21	8.7	6.63	0.0	1026	0	0	0	5
	Low	Surface	6.44	8.1	6.81	0.0	149	0	0	0	10
	Low	25	0.56	8.2	6.27	0.0	426	0	0	0	17
	Low	50	0.39	8.6	6.42	0.0	635	0	0	0	9
	Low	100	0.25	9.5	6.55	0.0	1889	0	0	0	34
BC6	High	100	0.10	10.3	7.34	0.0	1451	0	0	3	15
	Mid	100	0.09	10.1	6.62	0.0	3994	0	0	0	111
	Low	Surface	0.65	6.2	6.11	5.0	1101	0	0	0	37
	Low	25	0.96	7.3	6.27	1.5	1513	0	0	0	43
	Low	50	0.46	7.9	7.29	0.0	1997	0	0	0	143
	Low	100	0.10	9.1	6.88	0.0	3468	0	0	0	50
OW3	High	100	2.47	9.3	7.65	0.0	523	0	0	0	21
	Mid	100	0.20	8.8	7.73	0.0	1697	0	0	0	54
	Low	Surface	--	--	--	--	--	--	--	--	--
	Low	25	1.17	7.7	7.09	0.0	2569	0	0	0	114
	Low	50	0.22	7.7	7.43	0.0	2367	0	0	0	98
	Low	100	0.24	9.0	7.53	0.0	2338	0	0	0	96
Bay			11.51	5.7	8.05	0.0	15311	0	0	0	649
Ocean			10.70	7.9	7.99	0.0	17961	0	0	0	755

January 2014

Site	Position	Depth	Dissolved O_2	Temp.	pH	ααd	Cl^-	NO_2^--N	NO_3^{2-}-N	PO_4^{3-}-P	SO_4^{2-}-S
		cm	mg L^{-1}	°C			---------------------- mg L^{-1} ----------------------				
BC2	High	100	0.86	7.5	6.60	0.0	940	0	0	0	18
	Mid	100	0.14	7.9	6.62	0.0	963	0	0	0	6
	Low	Surface	6.04	8.9	6.91	0.0	116	0	0	0	4
	Low	25	0.41	8.6	6.39	0.0	258	0	0	0	3
	Low	50	0.27	8.6	6.41	0.0	424	0	0	0	2
	Low	100	0.44	8.8	6.57	0.0	1455	0	0	0	63
BC6	High	100	0.27	8.9	6.98	0.0	1351	0	0	0	11
	Mid	100	0.20	8.8	6.66	0.0	3643	0	0	0	102
	Low	Surface	1.96	5.8	6.06	0.0	763	0	0	0	22
	Low	25	0.83	6.9	6.16	0.0	1520	0	0	0	44
	Low	50	0.32	7.2	6.45	0.0	1972	0	0	0	113
	Low	100	0.22	7.9	6.82	0.0	3365	0	0	0	49
OW3	High	100	5.29	7.7	7.25	0.0	30	0	0	0	2
	Mid	100	0.13	7.4	7.47	0.0	1819	0	0	0	57
	Low	Surface	--	--	--	--	--	--	--	--	--
	Low	25	1.04	7.5	7.25	0.0	2239	0	0	0	87
	Low	50	0.31	7.1	7.36	0.0	2304	0	0	0	91
	Low	100	0.41	7.7	7.56	0.0	2171	0	0	0	86
Bay			7.84	7.8	7.03	0.0	7225	0	0	0	292
Ocean			10.13	7.3	8.08	0.0	17950	0	0	0	775

APPENDIX N: SOIL TEMPERATURE

Site	Depth	Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Average
	cm		--- °C ---												
BC1L	10	2011			10.1	14.7	20.6	25.5	27.3	26.7	25.0	18.0			
BC1M	10	2011			9.5	14.0	19.4	24.0	26.4	26.2	23.9	17.9			
	50	2012	8.3	8.3	11.6	14.2	18.5	22.4	25.7	25.3	23.1	19.1	12.9	10.3	16.7
		2013	7.2	6.5	8.1	13.0	17.0	22.2	25.1	24.3	23.0	19.4	13.5	9.1	15.7
BC1H	10	2011			9.4	14.7	21.0	26.4	29.1	27.7	24.0	18.5			
BC2L	10	2011			10.5	15.3	20.6	24.9	26.7	26.3	25.1	18.7		9.6	
		2012	6.8	7.5	12.4	14.8	20.9	25.0	28.4	26.6	22.9	18.7	14.6	10.1	17.4
		2013	10.2	9.3	9.5	15.5			26.9	25.2	24.1		12.3	9.3	
	30	2012	7.4	8.6	13.1	16.0	21.3	25.7	28.8	27.2	23.7	19.7	15.4	11.1	17.5
		2013	10.4	9.6	9.7	15.0	19.3	24.2	26.3	24.8	22.9	18.9	12.8	9.3	16.9
	50	2012	8.0	8.2	11.9	14.6	19.5	23.6	26.8	26.0	23.2	19.3	15.6	10.8	17.3
		2013	10.5	9.6	9.7	14.8	19.1	23.9	26.2	24.7	22.9	19.0	13.0	9.4	16.9
BC2M	10	2011			9.6	14.2	20.3	25.1	26.9	26.2	24.3	18.4		9.7	
		2012	7.0	7.6	12.4	15.1	20.9	24.9	27.9	26.5	23.6	18.9	12.2	8.9	17.2
		2013	6.3	6.3	8.5	14.8	19.6	25.4	27.4	25.2	22.7	18.4	11.6	7.6	16.1
	30	2012	7.8	8.1	12.0	14.8	19.9	24.0	27.0	26.1	23.6	19.3	12.9	9.8	17.1
		2013	7.0	6.7	8.6	14.0	18.4	24.0	26.4	24.7	22.9	18.9	12.8	8.5	16.1
	50	2012	8.4	8.4	11.8	14.6	19.1	23.1	26.2	25.7	23.6	19.6	13.6	10.5	17.0
		2013	7.7	7.1	8.7	13.4	17.5	22.8	25.5	24.3	22.8	19.9			
BC2H	10	2011			8.5	14.1	20.5	25.9	28.7	27.4	23.2	17.5		8.7	
		2012	6.3	6.9	12.0	15.6	21.0	26.1	29.4	27.3	22.9	17.9	9.3	7.9	16.9
		2013	4.8	4.4	6.3	13.8	19.6	25.5	28.8	26.6	24.4	18.5	11.2	6.6	15.9
	30	2012	7.2	7.3	11.6	15.1	19.8	24.7	28.1	26.6	23.1	18.4	10.4	8.6	16.7
		2013	5.4	4.9	6.5	13.3	18.6	24.5	27.9	26.1	24.3	19.0	12.4	7.5	15.9
	50	2012	7.8	7.7	11.3	14.7	18.9	23.7	27.0	26.2	23.1	18.8	11.4	9.3	16.7
		2013	6.2	5.4	6.8	12.7	17.7	23.4	26.9	25.6	24.1	19.4	13.3	8.3	15.8
BC3L	10	2011			10.2	15.9	22.0	27.2	29.6	28.3	24.2	18.9			
BC3M	10	2011			9.6	14.9	21.4	26.1	28.7	27.5	23.7	17.4			

Site	Depth	Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Average
	cm								-- °C --						
BC3H	10	2011			9.9	14.0	19.5	24.5	26.6	26.0	24.2	18.1			
BC4L	10	2011			8.1	13.8	19.9	24.6	25.7	24.8	22.5	16.8			
BC4M	10	2011			8.9	13.5	18.7	23.3	25.3	24.7	22.6	18.0			
BC4H	10	2011			9.7	15.1	21.0	26.3	28.6	27.3	24.8	19.2			
BC5L	10	2011			8.9	12.3	16.0	19.6	21.4	21.8	21.0	17.3			
BC5M	10	2011			10.3	12.5	15.5	18.7	21.1	21.9	21.3	18.8			
	50	2012	12.3	11.5	12.4	13.7	15.7	18.1	20.4	21.3	21.1	19.1	15.2	13.6	16.2
		2013	11.4	10.0	9.8	11.8	14.3	17.6	20.1	20.4	20.1	18.8	16.0	13.0	15.3
BC5H	10	2011			8.7	12.5	17.2	21.3	23.7	23.4	21.6	17.6			
BC6L	10	2011			8.4	11.9	15.9	20.5	23.1	23.1	21.2	17.6		9.4	
		2012	6.6	6.9	10.8	12.2	16.9	20.2	23.8	23.5	20.9				
		2013							24.7	23.3	21.1	17.6	11.1	8.6	
	30	2012	6.9	7.0	10.5	12.0	16.2	19.6	23.1	23.0	20.7	16.9	11.8	9.4	14.8
		2013	7.0	6.2	7.7	12.8	17.2	21.7	24.7	23.2	20.9				
	50	2012	7.9	7.7	10.6	12.2	15.8	19.3	22.5	22.7	20.9	17.4	12.8	10.2	15.0
		2013	8.0	6.9	8.1	12.4	16.4	20.7	23.9	22.8	21.1	17.8	12.0	9.0	14.9
BC6M	10	2011			8.4	11.4	14.7	17.8	20.7	21.6	20.5	17.3		11.0	
		2012	8.5	8.2	10.8	12.6	16.2	19.3	22.2	22.6	21.0	17.5	11.8	10.4	15.1
		2013	7.5	6.4	7.0	11.3	15.5	20.3	23.2	22.5	20.8	17.9	13.2	9.3	14.6
	30	2012	9.4	8.9	10.8	12.6	15.6	18.5	21.1	22.0	21.0	18.0	13.0	11.0	15.2
		2013	8.1	6.9	7.4	11.0	15.1	19.6	22.6	22.2	20.8	18.2	13.9	9.9	14.6
	50	2012	9.8	9.1	10.7	12.5	15.2	18.0	20.4	21.5	20.9	18.1	13.5	11.6	15.1
		2013	8.8	7.4	7.7	10.7	14.4	18.7	21.7	21.7	20.4	18.2	14.5	10.6	14.5
BC6H	10	2011			8.5	12.0	15.8	20.1	22.8	22.9	21.3	17.3		10.5	
		2012	7.8	7.9	11.2	13.1	16.6	19.9	23.6	23.3	21.2	17.4	11.3	9.6	15.2
		2013	6.7	5.8	6.8	12.0	16.1	21.2	24.0	22.9	21.1	17.8	12.2	8.7	14.6
	30	2012	8.8	8.5	11.1	12.9	15.9	19.2	22.4	22.6	21.2	17.9	12.3	10.5	15.3
		2013	7.7	6.6	7.3	11.4	15.3	20.0	22.9	22.3	20.9	18.2	13.5	9.8	14.6
	50	2012	9.3	8.8	10.9	12.7	15.3	18.5	21.4	22.0	21.0	18.1	12.9	11.0	15.2
		2013	8.3	7.0	7.5	10.9	14.6	19.0	22.0	21.7	20.7	18.3	14.0	10.3	14.5

Site	Depth	Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Average
	cm		-- °C --												
OW1L	10	2011			8.6	13.8	20.1	25.7	27.7	26.2	23.2	17.9			
OW1M	10	2011			9.4	14.3	20.4	25.7	28.5	27.5	23.9	18.8			
OW1H	10	2011			9.6	14.7	20.4	25.9	28.1	27.0	24.3	19.3			
OW2L	10	2011			10.3	15.3	21.3	26.1	28.2	27.0	24.1	18.4			
OW2M	10	2011			10.3	14.7	19.9	24.3	26.1	25.4	24.1	19.3			
	50	2012	8.1	8.2	11.6	14.3	18.5	22.4	25.3	25.0	23.0	19.1	12.7	10.2	16.5
		2013	7.4	6.5	7.6	12.5	16.8	21.5	24.3	23.5	22.3	19.0	13.7	9.3	15.4
OW2H	10	2011			10.1	15.4	21.6	26.8	29.7	28.4	24.9	19.5			
OW3L	10	2011			9.4	14.1	20.0	25.3	26.9	25.3	22.7	18.0		9.8	
		2012	7.0	7.0	10.9	13.3	18.2	22.1	25.6	24.7	22.0	17.9	11.2	9.1	15.8
		2013	6.3	5.5	7.0	12.7	17.2	22.5	25.5	23.9	22.1	18.1	11.8	7.8	15.0
	30	2012	7.2	7.1	10.8	13.1	17.9	21.8	25.3	24.6	22.0	18.0	11.5	9.7	15.7
		2013	6.9	5.9	7.1	11.8	16.1	21.2	24.5	23.4	21.9	18.4	12.7	8.5	14.9
	50	2012	8.0	7.6	10.6	12.9	17.0	21.0	24.4	24.1	22.0	18.4	12.5	10.1	15.7
		2013	7.4	6.2	7.2	11.4	15.5	20.5	23.8	23.0	21.8	18.5	13.2	9.0	14.8
OW3M	10	2011			9.6	15.0	21.3	26.3	28.3	26.8	23.9	18.0		8.7	
		2012	6.0	7.1	12.4	14.9	21.1	25.1	28.3	26.5	23.1	18.1	10.2	8.2	16.8
		2013	5.4	5.0	6.8	13.8	18.7	24.6	27.0	24.6	22.3	18.0	11.3	7.3	15.4
	30	2012	6.5	7.3	12.1	14.6	20.3	24.3	27.4	26.1	23.1	18.4	11.0	9.1	16.7
		2013	6.2	5.5	7.0	13.0	17.6	23.3	25.9	24.1	22.2	18.4	12.3	8.0	15.3
	50	2012	6.9	7.3	11.6	14.2	19.3	23.5	26.6	25.6	22.9	18.5	11.6	9.6	16.5
		2013	6.7	5.8	7.0	12.3	16.6	22.0	24.9	23.6	22.0	18.5	12.9	8.5	15.1
OW3H	10	2011			9.9	15.1	21.1	26.4	29.1	28.0	24.7	19.3		9.0	
		2012	6.5	7.3	12.7	15.6	21.3	25.7	29.6	27.6	24.4	18.7	10.2	8.9	17.4
		2013	5.8	5.2	7.0	14.0	19.0	24.8	27.7	26.1	24.2	19.0	11.5	7.0	16.0
	30	2012	7.7	7.9	12.2	15.1	20.0	24.5	28.3	27.0	24.5	19.5	11.9	10.0	17.4
		2013	6.9	6.0	7.4	13.3	17.9	23.5	26.6	25.5	24.2	19.8	13.3	8.3	16.0
	50	2012	8.4	8.2	11.8	14.7	18.9	23.3	27.0	26.4	24.4	20.0	12.8	10.8	17.2
		2013	7.5	6.5	7.6	12.7	17.1	22.3	25.5	24.9	23.9	20.0	14.2	9.1	15.9

Site	Depth	Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Average
	cm		---						°C			---			
OW4L	10	2011			10.2	15.1	20.9	27.4	28.9	26.8	23.6	17.9			
OW4M	10	2011			9.7	14.5	20.9	27.3	29.5	27.2	23.6	17.8			
OW4H	10	2011			8.8	14.1	20.6	27.5	29.5	27.3	24.3	19.0			

APPENDIX O: AIR TEMPERATURE

Year		Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Average
		----------------------						°C					----------------------	
2011	Daily Average			7.2	13.2	18.1	23.6	25.9	24.3	21.7	15.5	11.7	7.9	
	Average High			8.8	14.6	18.9	24.6	26.9	25.1	22.3	16.7	13.1	9.7	
	Average Low			5.8	12.0	17.4	22.8	25.0	23.6	21.1	14.5	10.5	6.2	
2012	Daily Average	5.4	6.4	11.2	13.5	18.9	22.8	27.1	24.8	21.4	16.5	8.2	7.9	15.3
	Average High	7.2	8.0	12.9	14.9	19.9	23.9	28.1	25.5	22.5	17.7	9.4	9.2	16.6
	Average Low	3.7	5.0	9.7	12.3	18.0	22.0	26.2	24.2	20.4	15.4	7.2	6.6	14.2
2013	Daily Average	4.0	3.7	5.2	12.0	17.2	22.6	25.3	23.7	21.0	17.0	8.8	5.8	13.9
	Average High	5.4	5.4	6.3	13.2	18.4	23.6	26.2	24.7	22.0	18.0	10.8	7.3	15.1
	Average Low	2.6	2.2	4.3	11.1	16.2	21.8	24.6	22.8	20.1	16.2	7.0	4.3	12.8
2014	Daily Average	0.6	2.5											
	Average High	3.1	3.8											
	Average Low	-1.6	1.3											

Average of three temperature data loggers located at 38°08’23.10” N, 75°10’50.52” W (BC6 transect).

APPENDIX P: Precipitation

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
							mm						
2010											20.1	43.9	
2011	86.9	42.4	87.4	45.3	30.7	47.7	83.9	264.4	94.0	56.3	56.8	26.2	921.9
2012	49.9	78.5	36.4	64.1	99.8	48.5	50.9	116.8	163.3	228.7	12.9	100.3	1050.2
2013	66.6	88.9	118.6										

Average of three tipping bucket rain gauges located at 38°09’08.70” N, 75°10’32.88” W (OW2 transect).

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