LINKING RIVER, FLOODPLAIN, AND VADOSE ZONE HYDROLOGY IN A COASTAL WETLAND IMPACTED BY SALTWATER INTRUSION: THE LOXAHATCHEE RIVER (FLORIDA, USA)

By

DAVID ANDREW KAPLAN

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To my father, whose generosity, sense of humor, and creative spirit were indomitable.
And to my grandfather, who quietly championed fairness and moderation; respected education above material success; and coined the term “pixel.”

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LINKING RIVER, FLOODPLAIN, AND VADOSE ZONE HYDROLOGY IN A COASTAL WETLAND IMPACTED BY SALTWATER INTRUSION: THE LOXAHATCHEE RIVER (FLORIDA, USA)

By

David Andrew Kaplan

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Floodplain forests provide unique ecological structure and function, which are often degraded or lost when watershed hydrology is modified. Restoration of impacted ecosystems requires an understanding of surface water, groundwater, and vadose (unsaturated) zone hydrology in the floodplain. However, finding direct relationships between basic hydrological inputs and floodplain hydrology is hindered by complex interactions between surface water, groundwater, and atmospheric fluxes in a variably saturated matrix with heterogeneous soils, vegetation, and topography. Soil moisture and porewater salinity are of particular importance for seed germination and seedling survival in systems impacted by saltwater intrusion, but are difficult to monitor and often overlooked. This study contributes to the understanding of floodplain hydrology in one of the last bald cypress (*Taxodium distichum* [L.] Rich.) floodplain swamps in southeast Florida (USA) by investigating hydrology in the floodplain of the Loxahatchee River, where reduced freshwater flow has led to inadequate hydroperiod and saltwater intrusion into historically freshwater wetlands.

Twenty-four dielectric probes measuring soil moisture and porewater salinity every 30 minutes were installed along two transects—one in an upstream, freshwater location; the other in a downstream tidal area. Data collected over four years quantified the spatial variability and temporal dynamics of vadose zone hydrology, showed that soil moisture can be closely predicted based on river stage and topographic elevation, and helped to explain observed vegetation patterns. Groundwater elevation and salinity were measured in a network of twelve wells along a gradient from fresh to saline conditions. Dynamic Factor Analysis (DFA), a time series dimension reduction technique, was used to model temporal variation in groundwater and soil moisture datasets as linear combinations of common trends (which represent unexplained common variability) and appropriate explanatory variables. The resulting dynamic factor models (DFMs) were useful for assessing the effects of ecosystem restoration and management scenarios on floodplain hydrology. These relationships were coupled with ecological performance measures to predict floodplain vegetation dynamics using a spatially distributed ecohydrological model. This study offers a methodological and analytical framework for floodplain monitoring in locations where restoration success depends on vadose zone hydrology and provides relationships for evaluating proposed management scenarios for the Loxahatchee River.

CHAPTER 1
INTRODUCTION

Saltwater Intrusion in Coastal Wetlands

Coastal wetlands perform a unique suite of physical, biological, and chemical functions. They protect coastal areas from storm damage and erosion; filter, transform, and store sediments, nutrients, and other contaminants; and provide habitats that support huge numbers of commercially and ecologically important fish, birds, and other wildlife (e.g., Mitsch and Gosselink, 2000). Coastal zones, including wetlands, estuaries, and bays provide at least half of all global ecological services (Costanza et al., 1997) and generate billions of dollars annually from fisheries, recreation, and tourism (Hanson and Stedman, 1995; Niemi et al., 2004).

Environmental pressures facing coastal wetlands have both natural and anthropogenic sources, and these stressors often overlap and can have synergistic effects (McCarthy et al., 2001). Increasing human population and development in coastal areas has led to increased point source and non-point source pollution, habitat destruction, and significant alteration of watershed hydrology (Niemi et al., 2004). Coastal areas are also very dynamic and subject to changing environmental conditions caused by natural, climatic, and oceanographic processes such as flooding, drought, long-term wet/dry cycles, storm surges, hurricanes, winds, herbivory, and changes in sea level elevation (Winn et al., 2004). Sea level rise, groundwater pumping for coastal cities, and watershed modifications have led to saltwater intrusion in many coastal areas around the world.

Operating separately or in tandem, natural and anthropogenic saltwater intrusion can have severe adverse impacts on coastal wetlands including the loss of freshwater,

brackish, and estuarine systems; increased erosion; and the expansion of marine or open water systems. While saltwater contamination and resultant abandonment of drinking water wells and aquifers has garnered considerable attention (e.g., Universidad de Granada, 2001), the impacts of conversion or loss of coastal wetland ecosystems as surface and groundwater salinities increase are less well documented. This review summarizes the drivers of saltwater intrusion generally and discusses the resulting fresh water/brackish water/saltwater dynamics and ecosystem responses in impacted coastal wetlands. Case studies demonstrate the effects of saltwater intrusion in wetlands from selected areas around the world and the potential for restoration of these impacted ecosystems. Finally, the life cycle requirements and flooding and salinity tolerances of bald cypress (*Taxodium distichum* [L.] Rich.), a major component of coastal floodplain forests in the southeastern United States, are reviewed in depth.

Drivers of Saltwater Intrusion

Saltwater intrusion has been described as the "landward and upward displacement of the freshwater-saltwater interface in coastal aquifers, and increased saline water penetration in deltaic and estuarine areas" (Knighton et al., 1991) and as the invasion of fresh or brackish surface water or groundwater by water with higher salinity (Barlow, 2003). The dynamics of saltwater intrusion are controlled by the interactive effects of tidal activity, the timing and volume of freshwater discharge from rivers, wind speed and direction, and density gradients caused by salinity. With diurnal tidal cycles, stochastic weather processes, and decadal climate cycles, the dynamic behavior of saltwater intrusion is non-linear and complex (Wang, 1988).

Natural drivers of saltwater intrusion include storm surges, hurricanes, climatic fluctuations that alter freshwater outflows, and sea level rise. Anthropogenic drivers of

saltwater intrusion include land drainage; pumping of coastal freshwater aquifers; reduction in freshwater discharge from dam construction, water withdrawals, or other water diversions; and hydrologic/hydraulic structures and land use changes within watersheds. For the purpose of this review, sea level rise will be considered a "natural" driver of saltwater intrusion with the recognition that anthropogenic climate change exacerbates the effect of sea level rise and may also alter the timing and magnitude of climatic cycles and extreme events such as hurricanes.

Natural drivers

Sea level and global climate are inextricably coupled. At the end of the most recent glacial period, sea level was between 100 and 125 m below current levels (Larsen, 1998; USGS, 2000a). Sea levels have consistently risen during the current interglacial period (USGS, 2000a) and particularly during the mid- to late-Holocene era (6500 years before present [YBP] to the present), though not always at the same rate (Wanless et al., 1989). In Florida, sea level rose quickly (2 to 5 mm yr^{-1}) between 3200 and 6500 YBP. This rate generally slowed to approximately 0.4 mm yr^{-1} over the next 3200 years, allowing for the development of broad coastal wetlands around the continents, but has increased rapidly in the past decade to between 2 and 4 mm yr^{-1} (Wanless et al., 1994). In addition to the direct addition of glacial meltwater to the oceans, rising global temperatures have led to a sea level rise of 10 to 20 cm due to thermal expansion of the water in the ocean (Lovgren, 2004).

Put simply, sea level rise causes inland migration of the marine environment into estuaries and freshwater systems by increasing salinity and/or increasing the frequency, duration, and depth of inundation. However, relative sea level rise is a function of global and local factors (DeLaune, 1987). Temporal and spatial variability in the rates of

relative sea level rise result in highly variable effects on coastal wetlands (Burkett et al., 2001). Many coastal wetlands have developed such that the rate of vertical accretion of deposited sediment and peat formation are sufficient to keep up with sea level rise (Erwin, 2003). Accelerated sea level rise, combined with local conditions such as subsurface subsidence, changing tidal and freshwater flow regime, and reduced sediment availability, has led to local relative sea level rise, submergence, and loss of coastal wetlands (Moorhead and Brinson, 1995; Burkett et al., 2001). Estimated sea level rise alone has the potential to eliminate as much as 22% of the world's coastal wetlands by 2100 (Nicholls et al., 1999), though regional impacts would vary (Michener et al., 1997).

In addition to sea level rise, other natural drivers of saltwater intrusion include climatic cycles and weather events. Hurricanes and other large storm events can cause tidal surges much greater than average high tides, and saline storm surges can infiltrate into wetland soils and form areas of ponded saline water (Gardner, 1992). Long-term drought can also be a major factor affecting saltwater intrusion. With diminished freshwater outflows of surface and groundwater, the tidally-driven saltwater wedge encroaches further inland (Thomson et al., 2001). Drought can also lead to "acute environmental conditions" that lead to plant mortality and subsequent land loss (Thomson et al., 2001). Wind can also drive saltwater inland and can affect salinity profiles by mixing the water column. Even short-term inundations of seawater from these natural drivers can have major impacts on freshwater wetlands, though their recovery ability is variable (Flynn et al., 1995).

Anthropogenic drivers

More than 50% of the world's population lives within 100 km of the coast, with increasing populations expected (Niemi et al., 2004). The development of the world's coastlines has had major impacts on the coastal environment, many of which have resulted in or intensified saltwater intrusion. Bathymetric modifications to facilitate transport of people and goods (Wang, 1988; Liu et al., 2001); land drainage for agriculture or urban development (Holman and Hiscock, 1998); reduction in fresh surface water discharge from dams or water withdrawals (Johnson, 1997); and reduction in groundwater discharge from pumping of the aquifer (Sadeg and Karahanogulu, 2001) have led to saltwater intrusion in many coastal cities. Often, several of these anthropogenic drivers are at work simultaneously; however they can be split into two major causal groups: structural/morphological modifications and reduced freshwater flows.

The development of deep-water ports and oil and natural gas infrastructure has required extensive channel deepening, widening, and maintenance in and around many major cities worldwide. In general, wider, deeper, straighter river cross-sections result in increased extent of saltwater intrusion. Liu et al. (2001) found that, under similar environmental conditions, saltwater intruded significantly further upstream in large, deep channels, than in smaller, shallow channels. In computer simulations, Wang (1988) found that doubling the dimensions of a navigation channel in New Orleans, LA (USA) would increase the extent of the 5 parts per thousand (ppt) isohaline from 45 to 80 km inland. In addition, many rivers have been straightened to improve transport and provide flood control (e.g., Bechtol and Laurian, 2005), facilitating the inland intrusion of saline waters. Fast, deep canals confined within the river channel, combined with river

control structures such as levees and floodwalls, also reduce sediment transport into coastal wetlands by acting as large local sinks and/or causing sediment-laden water to bypass wetlands. This increases local relative sea level rise and can lead to land submergence and wetland loss (DeLaune et al., 1994).

River control structures can also reduce or completely eliminate freshwater flows to coastal wetlands, directly increasing salinity (Thomson et al., 2002). Drainage of large wetland areas for agricultural and urban development in some coastal areas has lowered groundwater elevation to below sea level, leading to saline intrusion of the aquifer and surface waters, especially in areas with highly conductive aquifers (Holman and Hiscock, 1998) Groundwater pumping for drinking water supply has had similar effects (Sadeg and Karahanogulu, 2001). In both cases, groundwater pumping can cause land subsidence and result in relative sea level rise (USGS, 1999a). Dam construction and water withdrawals can also cause major reduction or elimination of freshwater, increasing saltwater intrusion. The construction of the Aswan High Dam on the Nile River in Egypt has reduced freshwater outflows to the Mediterranean from 42 to 10 $km^3\ yr^{-1}$ leading to increased salinities in the delta wetlands and the Mediterranean Sea (Johnson, 1997). Currently, greater than 90% of the Nile flow is diverted for agricultural use.

Synergistic effects

In many cases, several natural and/or anthropogenic drivers act simultaneously. For example, deep-water canals and structural flood protection measures can increase the inland extent of saltwater inflow and cut off freshwater wetlands from freshwater flow and sediment loads, preventing accretion. When combined with accelerated sea level rise, hurricanes, or severe drought, saltwater intrusion can lead to quick and

catastrophic loss of coastal wetlands (Wanless et al., 1989). For example, in a study on the gulf coast of Florida, DeSantis et al. (2007) found the interactive effects of drought and sea-level rise to accelerate the loss of coastal forest.

Impacts on Coastal Wetlands: Case Studies

While sea level has cycled up and down over millennia, the coastal ecosystems currently ringing the continents have developed over a relative stable period of sea level rise (Wanless et al., 1989). Relatively fast-acting natural and anthropogenic drivers are overwhelming coastal wetlands with more frequent, longer, deeper, and more saline inundation in many places (Burkett et al., 2001). The effects of saltwater intrusion on coastal wetlands include plant stress or mortality from prolonged submergence and/or high salinities, erosion of wetland substrate, conversion of freshwater habitats to brackish or saltwater habitats, and the transition of coastal saltwater habitats to open water (DeLaune et al., 1987; DeLaune et al., 1994). Once initiated, these effects can lead to positive feedbacks, with plant mortality leading to peat subsidence and erosion, leading to further intrusion of saline floodwaters, etc. Globally, lower primary productivity caused by wetland loss also has the potential to further accelerate warming-induced sea level rise, as these ecosystems cease sequestering carbon dioxide (Thomson et al., 2002).

Flooding changes the chemical, physical, and biological properties of soils, and wetland species have different anatomical, morphological, and biochemical adaptations to flooded conditions (Pezeshki et al., 1990). Effects of flooding and salt stress include decreased stomatal response and reduced photosynthetic rates, though the magnitude of the effect is species-specific (Pezeshki et al., 1990). McKee and Mendelssohn (1989) found that the response of plants to saltwater intrusion is variable and depends

on species composition; level, duration and abruptness of exposure to saline water; and flooding depth. Lin et al. (2003) found that of all abiotic factors, "salinity was the primary determining factor for discriminating habitat types in the wetlands" but that different wetland communities differ in their sensitivity to salinity. After inundation, wetland recovery depends on several factors including post-intrusion salinity and flooding level (Flynn et al., 1995). Also vital is the location and connectivity of a source of propagules to re-populate the wetland (if significant plant mortality occurred) or the location of a source of more salt-tolerant propagules (if the ecosystem transitions to another wetland type) (McKee and Mendelssohn, 1989). The effects of saltwater intrusion on selected coastal wetlands (and associated wetland plant species) from around the world are explored in case studies in the following section.

The Mississippi River delta

Exposure to increasingly deep and saline floodwaters has been recognized as a major problem in the forested coastal wetlands of the Mississippi River delta (USA) since at least the mid-1970s (Earles, 1975). Both natural and anthropogenic causes are considered to be drivers of saltwater intrusion in the delta (Salinas et al., 1986; DeLaune et al., 1987), and major impacts, including heavy tree mortality, are apparent in the area's ghost forests (coastal wetlands with standing dead trees, primarily bald cypress). A study by DeLaune et al. (1987) found sedimentation rates to be less than 25% of submergence rates in the Lake Verret swamp forest, as determined by Cesium-137 (^{137}Cs) dating. In a study by Pezeshki et al. (1990), increases in salinity and flooding resulting from inland encroachment of saltwater into Louisiana's coastal forests were shown to impact tree morphology and carbon assimilation rates. Salinities greater than 3 ppt were correlated with leaf burning and reductions in carbon assimilation rates

of up to 84% in seedlings. Long-term exposure at even these sub-lethal levels can lead to reduced seedling survival, initiating a long-term habitat change in these wetlands (Pezeshki et al., 1990).

A study by Thomson et al. (2002) focused on the effects of drought-induced saltwater intrusion in the Mississippi River deltaic plain, which increased salinities to record levels in the Lake Pontchartrain basin. Effects included large diebacks of coastal cordgrass (*Spartina* spp.) salt marshes due to hypersaline conditions. The authors associated this decrease in primary productivity with a decrease in coastal stability, reduced accretion, and the conversion of vegetated marshes into unvegetated mudflats—all leading to increased relative sea level rise.

Accretion is achieved through the accumulation of both mineral sediments (necessary to maintain soil bulk density for salt marshes) and peat accumulation (DeLaune et al., 1994). Increased submergence stresses plant communities and reduces primary productivity, which in turn reduces peat accumulation and sediment baffling. In the highly modified Mississippi delta, many marshes are cut off from historic freshwater and sediment flows, preventing accretion from keeping up with local sea level rise. DeLaune et al. (1994) proposed that marsh elevation decreases rapidly after saltwater intrusion-induced plant mortality because of the collapse of the root structure, suggesting that peat collapse, not erosion, causes local subsidence, which then spreads via erosion. After a sufficient amount of time with no vertical accretion, total plant mortality and peat collapse mark the transition of an area from coastal marsh to open water.

Other studies in the Mississippi River Delta have shown the varying effects of saltwater intrusion on coastal wetlands. Holm and Sasser (2001) found differing salinity responses in two neighboring Mississippi River subdeltas (Atchafalaya and Wax Lake) based on presence or absence of salinity incursions. Strong winds associated with cold fronts and tropical storms caused salinity incursions into the Atchafalaya Delta, but not the Wax Lake Delta. The authors hypothesized that the presence of a wide and deep navigation channel near the Atchafalaya Delta allowed for saline intrusion while the proximity of the Wax Lake Delta to the freshwater plume of the Atchafalaya River prevented saltwater intrusion. These differences caused a divergence in vegetation communities in the sub-delta's wetlands. Whereas the Wax Lake delta continued to support the freshwater herbaceous marsh species broadleaf arrowhead (*Sagittaria latifolia* Willd.) and delta arrowhead (*Sagittaria platyphylla* [Engelm.] J.G. Sm.), the abundance of *S. latifolia* in the Atchafalaya Delta declined by 90%. In greenhouse studies, the authors found that *S. latifolia* growth was impaired by salinity concentrations of 6 ppt within 13 days, and that flooding and simulated herbivory further impaired growth. The resultant changes in wetland composition have the potential to affect the Atchafalaya Bay as a wintering ground for approximately 150,000 migratory waterfowl.

Pezeshki et al. (1987) investigated the effects of salt stress from storm surges, brine surges associated with oil recovery, and general saltwater intrusion on maidencane (*Panicum hemitomon* Schult.), another dominant herbaceous species in the Mississippi River delta's freshwater marshes. The authors found that flooding with 5 to 12 ppt saltwater reduced stomatal conductance by 55% to 80% and decreased photosynthesis by 20% to 67%, with higher salinities resulting in plant mortality after

four days. Flynn et al. (1995) found that flooding freshwater marsh sods with salinities of 14 to 15 ppt resulted in nearly complete dieback of aboveground biomass and that recovery varied by species. *P. hemitomon* did not recover at all, while *S. lancifolia* and rice cutgrass (*Leersia oryzoides* [L.] Sw.) exhibited some ability to recover, depending on post-intrusion salinity and flooding level. McKee and Mendelssohn (1989) found that *S. lancifolia* and *L. oryzoides* could survive for longer periods than found by Pezeshki et al. (1987) if salinities were increased gradually, however neither species survived at salinities greater than 15 ppt.

Grace and Ford (1996) also investigated the potential for recovery of *S. lancifolia* after saltwater intrusion. In field experiments, the authors subjected *S. lancifolia* to salinity of 15 ppt for a duration of 1 week, with some plants also exposed to flooding of 20 cm and simulated herbivory, after which plants were allowed to recover. The authors found no long-term effects from any one, or combination of any two treatments, but found reduced growth and plant death when herbivory, saltwater, and flooding were combined. This suggests that grazing by both birds and mammals can increase the potential impact of saltwater intrusion on coastal wetlands. This is especially true in the Mississippi River Delta, which is home to a very large population of vertebrate herbivores including nutria (*Myocaster coypus*), which are estimated to affect nearly 100,000 acres of coastal wetlands (USGS, 2000b).

Northern Australia

Two case studies from northern Australia illustrate the potential for rapid wetland effects from naturally-induced saltwater intrusion. Knighton et al. (1991) investigated tidal creek extension and saltwater intrusion in northern Australia. Tidal creek extension occurs in areas with large tidal ranges and small land elevation differences. In the

coastal plains of the Mary River, tidal creek systems have extended more than 30 km over the past 50 years, destroying freshwater wetland vegetation over an area greater than 17,000 ha. Salt-tolerant mangroves have slowly expanded along the new creek systems. Tidal creeks have also rapidly expanded in the Alligator Rivers region in northern Australia, turning freshwater wetlands saline. Winn et al. (2004) associated the loss of freshwater vegetation with the destruction of crocodile breeding grounds, magpie geese habitat, and overall decrease in diversity of flora and fauna.

Both systems have changed rapidly over the past 50 years. In 1943, the Mary River coastal plain had two main creeks, which extended less than 5 km inland. The tidal networks developed by (natural) extension and widening of the main channels and tributary growth. By 1989, drainage density was as high as 10 km^2 km^{-1} and formerly freshwater billabongs had become part of the saline creek system (Knighton et al., 1991). Similarly, the Alligator Rivers region extended only 1 km in 1950, with beach ridges, vegetation, and alluvium deposits blocking saltwater inflow. Above average wet seasons in the 1970s increased flooding, which cut through alluvium barriers and allowed saline water to extend inland. Storm surges from cyclones, coupled with weak wet season flooding led to further intrusion of saline waters into the freshwater basin, a process compounded by rising sea levels.

Further synergistic effects include drying and erosion of the denuded Alligator Rivers mudflats during the dry season. Loss of elevation as soil eroded increased the depth of the basin, further exacerbating saltwater intrusion. In one section of the Alligator Rivers coastal plain, in Kakadu National Park, a barrage was constructed across a tidal creek in an attempt to halt the tidal creek extension, but the creek

breached the structure. By 1997, more than half of the freshwater vegetation had died, bare saline mudflats covered more than 10 times their original extent, and the tidal creek had extended 4 km inland (Winn et al., 2004).

United Kingdom

Holman and Hiscock (1998) found saline intrusion in the coastal marshes of the River Thurne in northeast Norfolk (United Kingdom) to have been caused by historic and current land drainage for agriculture. Land drainage has been occurring in the River Thurne catchment over several centuries, and the salinization of surface waters has been recorded since 1911. Increased salinity in several broads (lowland lakes) has led to blooms of the algae *Prymnesium parvum*, which produces a toxin that is fatal to fish and some gilled invertebrates. Higher salinities have also caused changes in wetland plant communities from freshwater to brackish water, affecting nationally rare species. Several of the affected broads are designated under the 1971 Ramsar Convention as internationally important, which has led to efforts to ameliorate the situation. The authors conclude that management of drainage levels (transitioning from arable farming to wet pasture) has the potential to increase fresh groundwater resources, reducing the salinity of water draining into the broads.

Management and Restoration Potential

Sea level rise is a difficult driver to overcome—its effects are beyond the scope of local or regional management. However, when saltwater intrusion is caused by anthropogenic drivers, or a combination of both natural and anthropogenic effects, some amount of restoration and management is likely achievable (Scruton, 1998). Reestablishing hydrological regimes and connections can ameliorate the salinity effects of saltwater intrusion by increasing (well-timed) freshwater flows and supplying the

sediment required for accretion. In other cases, recharging or reducing groundwater withdrawals from coastal aquifers could push back an encroaching saltwater wedge. One important consideration when considering increasing freshwater flows is the "complex temporal and spatial relationship between flooding and its effects on seed delivery via dispersal, germination and seedling recruitment" (Middleton, 1999). In other words, simply supplying more fresh water, without a robust understanding of the natural hydrological and ecological dynamics of an impacted system, may not achieve restoration goals. However, in places where restoration methods are successful in maintaining or increasing accretion rates (i.e., more sediment delivery and maintenance or increase in primary productivity and peat formation) and/or restoring historic hydrological and salinity regimes, the effects of saltwater intrusion may be halted or delayed. Where relative sea level rise continues to outpace accretion and in areas where over-developed freshwater resources cannot be redirected, however, restoration and management efforts may be impossible.

The Loxahatchee River in southeastern Florida (USA) is an example of a coastal floodplain wetland ecosystem impacted by saltwater intrusion with primarily anthropogenic drivers where restoration methods are being developed and tested. Of primary concern in the Loxahatchee River are: 1) the loss of old-growth bald cypress and transition to mangrove-dominated communities in the tidal floodplain as salinity increased and 2) inadequate hydroperiod in the upstream riverine floodplain, which has shifted the system towards drier plant communities. Thus, the specific life cycle requirements and flooding and salinity tolerances of bald cypress are reviewed in the following section.

Bald Cypress Life Cycle Requirements and Environmental Tolerances

Bald cypress is a flood-tolerant canopy tree species that grows in forested wetlands (Elcan and Pezeshki, 2002) and is the most flood-tolerant tree species in Florida. Bald cypress is found in 23 U.S. states (USGS, 1999b; Fig. 1-1), and along with water tupelo (*Nyssa aquatic* L.) and swamp tupelo (*Nyssa sylvatica* Marshall var. *biflora* [Walter] Sarg.), is a dominant tree species in the riverine and coastal wetlands of the southeast (Allen et al., 1994; Day et al., 2006). Though bald cypress is the dominant canopy species in southeastern floodplain forests, the ecosystem as a whole is species-rich, with as many as 48 to 62 additional woody species found in bald cypress-dominated forests (Nixon et al., 1977; Robertson et al., 1978).

Early European settlers found large tracts of bald cypress/tupelo floodplain forests in the southeastern coastal plain, and the French explorer Bienville is quoted as remarking, “It is almost impossible to conceive the abundance of the forest…there are hundreds of miles of cypress trees…as thick as hairs on the head…and it is wonderful” (Mancil, 1980). While small areas of cypress forest were cleared as early as 1722 (Myers et al., 1995), massive logging in the early 19th century greatly reduced the extent and inventory of bald cypress severely. Williston et al. (1980) estimated that cypress forests covered between 1.2 and 2 million ha (at the time of their inventory), with over half of the population in Louisiana and Florida. In the southeastern United States, the combined effects of saltwater intrusion, land subsidence, canal and levee construction, competition, and nutria herbivory have stressed many remnant bald cypress populations and prevented natural regeneration of logged areas (Allen et al., 1994; Souther and Shaffer, 2000). The following sections focus on the bald cypress life cycle and habitat

requirements and examine the literature on the salinity and flooding tolerance of seeds, seedlings, and mature trees.

Seeds

Bald cypress is a deciduous conifer, which produces a seed-bearing female cone. Seeds are produced yearly, with larger seed crops occurring at 3- to 5-year intervals (Burns and Honkala, 1990). Bald cypress seeds are resin-coated and attach to cone scales. Seeds drop to the ground or into water either singly or by entire cone. Squirrels feeding on bald cypress seeds may accelerate this drop as they feed (Burns and Honkala, 1990). Bald cypress seeds are dispersed primarily by water (Schneider and Sharitz, 1988; Middleton, 1999), and are relatively short-lived. Thus, the maintenance of viable seed banks is dependent on a regular flood pulse for distribution. Seeds settle along drift lines after floodwaters recede and require moist, but not saturated conditions to germinate (Middleton, 2000). Due to this requirement, Middleton (2000) found that the zone of germination is limited to areas that draw down during the growing season.

In a study of seed longevity and germination requirements, Middleton (2000) found that bald cypress seeds had a short window for germination, with less than 40% of seeds remaining viable after 100 days and less than 5% remaining viable after 1 year. Other studies have found that seeds can remain viable for up to 30 months if they are under water (Fowells, 1965). Under saturated conditions, seed germination may occur on sphagnum moss or a wet, muck seedbed, but seeds will not germinate under water (Fowells, 1965). At the other end of the moisture regime, seeds will not germinate on well-drained soils due to lack of surface moisture. Thus, a prolonged drawdown (1 to 3 months) of flooded soils to a saturated condition is required for germination (Burns and Honkala, 1990; Middleton 1999, 2002). In spite of these rather rigid environmental

requirements, bald cypress forests can survive even with infrequent regeneration events as long as mature populations remain healthy and continue to produce seeds. Since seed germination of other swamp species is similarly restricted by the extent and timing of flooding, bald cypress is not out-competed by other long-lived tree species (Middleton, 2000).

Germination rates under natural conditions are variable and highly dependent on timing and extent of flooding. Three laboratory studies of bald cypress in freshwater conditions found germination rates of 15.5%, 25 to 75%, and 74% (Faulkner, 1982; Beilman, 1947; Bonner, 1974). In contrast, Gunderson (1984) achieved only 2.1% germination in a field experiment in the Corkscrew Swamp Sanctuary in Florida. A survey of commercial nursery growers found germination rates ranging from 10% to 90%, with an average germination rate of 57% (University of Florida Institute of Food and Agricultural Sciences [UF IFAS], 2004). Conner and Inabinette (2004) found variable germination rates ranging from 24% to 58% (average values) for seeds collected from nine southern U.S. coastal sites with saltwater influence, but germinated under freshwater conditions. The authors did not specify the range of salinities in the wetlands from which the seeds were collected.

In a study to test methods for improving bald cypress seed germination, Liu et al. (2009), examined methods to overcome dormancy (stratification, fire, and plant hormones); mechanical obstacles (cutting the seed in half), chemical inhibitors (soaking in acidic, alkaline, and alcohol solutions), and hypoxic stress (adding hydrogen peroxide, H_2O_2). The authors concluded that soaking seeds in 0.5% to 1.0% sodium hydroxide (NaOH) for five minutes greatly improved germination, while soaking seeds in

1% NaOH also improved growth of bald cypress seedlings. Soaking seeds in hydrochloric acid (HCl), H_2O_2, gibberellic acid (GA3), and alcohol did not affect germination rates.

While many studies have examined the effect of salinity on bald cypress seedlings (see following section), fewer have investigated salinity effects on seed germination. Krauss et al. (1998) examined the germination capacity of seeds from both freshwater and brackish water locations in an attempt to identify salt tolerant bald cypress genotypes for use in large-scale forest restoration projects in areas affected by saltwater intrusion. Seed germination decreased with increasing salinities, with mean germination rates of 26.3%, 22.9%, 15.4%, and 10.2% based on salinity treatments of 0, 2, 4, and 6 ppt, respectively. The authors found superior germination in three of the eight families used in the experiment. The more successful families were all from brackish sources.

Seedlings

Bald cypress seedlings reach heights of 20 to 75 cm their first year of growth (Bull, 1949), although their growth and survival is highly dependent on hydroperiod and salinity. Seedlings must grow fast enough to keep their crowns above floodwaters for most of the growing season in order to survive (Conner, 1988; Conner et al., 1986; Conner et al., 1987). Growth is reduced when seedlings are submerged and prolonged submergence causes seedling mortality (Fowells, 1965). This may explain why many cypress stands are of the same age, with regeneration commonly occurring during extended periods of low water levels (Matoon, 1915; Putnam et al., 1960). Middleton (2000) found that the seedling establishment zone was much narrower than the

germination zone and was restricted to higher (relative) elevations with prolonged summer drawdown and less overtopping of seedlings with floodwaters.

Allen et al. (1996) reviewed the effects of flooding, salinity, and the combination of both on bald cypress seedlings and made the following general conclusions:

- Seedlings can tolerate shallow flooding, but it causes a period of stress and adaptation during the first year.
- Shallow flooding causes physiological impairment, including inhibited root elongation, reduced net photosynthesis, and reduced stomatal conductance.
- Seedlings are “moderately salt tolerant.”
- Effects of combined flooding and salinity are greater than either alone, and these effects are more pronounced at higher salinities.
- Seedlings show an intraspecific variation in flood and salinity tolerance with more tolerant genotypes found in brackish or freshwater areas.

Regarding the effects of flooding alone, Shankin and Kozlowski (1985) found flooding bald cypress seedlings with 2 cm of water for 14 weeks reduced height growth by 30%, leaf area by 56%, and total dry weight by 51%. Megonigal and Day (1992) found a two-thirds reduction in biomass of continuously flooded versus periodically flooded seedlings. For the continuously flooded seedlings, morphological changes in the second and third years (including the development of adventitious roots) improved growth, with no significant differences between flooded and non-flooded seedlings by the end of the third year. In a controlled greenhouse experiment, Allen et al. (1994) found the survival, height growth, leaf area, and total biomass of seedlings from five fresh and ten brackish water sources to decline with increasing salinity, but with less dramatic effects than other studies. Mean survival of seedlings from all fifteen sources was 100% at a salinity of 0 ppt, 99% at 2 ppt, 95% at 4 ppt, 83.5% for 6 ppt, and 72.5% for 8 ppt. The authors also found three of the fifteen families to perform better overall

under high salinities, indicating intraspecific variation in salt tolerance. Pezeshki (1990) found no differences in height growth, stomatal conductance, or net photosynthesis between seedlings watered (but not flooded) with 0 ppt and 3 ppt salinities. Connor (1994) found little difference in survival between treatments of 0 and 2 ppt, but 100% mortality after 10 weeks of flooding with water at a salinity of 10 ppt.

In a field experiment, Connor and Inabinette (2004) investigated the survival of seedlings grown from seeds collected from eight estuarine areas, planted in the field, and observed for two years. Salinity varied during the study period, with severe droughts reducing freshwater flow and causing a salinity spike of 18.5 ppt in the study's second year. Seedling mortality was highly variable, with one study site losing 100% of seedlings after two intrusion events raised salinity concentrations to 7.5 and 12.1 ppt. In the second study site, mortality was also severe, with only seedlings from Alabama, Florida, and Louisiana surviving. By the end of the study, overall morality was 27%, 78%, and 85% for seedlings from Louisiana, Alabama, and Florida, respectively. The seeds from Louisiana were collected from areas of degraded coastal forests where salinities ranged from 3.5 to 12 ppt.

Krauss et al. (1998) also performed field experiments to investigate the growth and health of bald cypress seedlings from different families (i.e., individuals more closely related to each other than other individuals in a population [Zobel and Talbert, 1984]), under varying salinity regimes. The authors found seedling growth to be limited by a combination of vegetation, salinity, and hydrologic regime. Despite these interacting factors, seedling height and diameter were far greater where salinity was lowest. The authors also found higher foliar concentrations of sodium (Na^+) and chloride (Cl^-) in

trees from higher salinity sites, indicating a considerable stress, since both ions can cause direct ion toxicity at high concentrations. Certain genotypes maintained superior growth in this field experiment, agreeing with results from early greenhouse studies (e.g., Allen et al., 1994), and indicating the potential for selection of salt-tolerant genotypes.

In a study involving bald cypress seeds and seedlings collected in the Loxahatchee River floodplain, Liu et al. (2006) measured seedling survival, height, stem diameter, growth rates, biomass, water potential, and Na^{+}, Potassium (K^{+}), and Calcium (Ca^{2+}) content under four salinities (0, 2, 4, and 8 ppt) and three flooding levels (0%, 50%, and 100% root submergence). The authors found that seedlings tolerated 100% root submergence for 30 days with a salinity of 0 ppt, as well as 50% and 100% flooding with a salinity of 2 ppt. However, 25 to 75% of seedlings died under 100% root submergence with salinities of 4 and 8 ppt. The authors concluded that a general threshold of 2 ppt is required to maintain seedling health and, in turn, a healthy bald cypress ecosystem.

Mature trees

Mature bald cypress can grow to be very large and very old. The largest specimens can reach 40 to 45 m and have diameters at breast height (DBH) of 200 – 375 cm (Fowells, 1965). In the United States, the champion bald cypress grows in Louisiana, has a DBH of 521 cm, is 25 m tall, and is estimated to be over 3000 years old (American Forestry Association [AFA], 1982). As the dominant canopy tree species, bald cypress is a major component of overall wetland function, controlling light availability, productivity, trophic dynamics, and nutrient cycling (Middleton, 1999). In the dense shade of a healthy forest, bald cypress trees cease growing taller after about 200

years, but may continue to add diameter (Burns and Honkala, 1990). Most bald cypress seedlings that germinate in highly shaded conditions do not reach maturity. The species grows slowly in partial shade, and does best in full sun (i.e., in a canopy gap or at the edge of a stand). Thus, the species is classified as having intermediate shade tolerance (Burns and Honkala, 1990). Bald cypress is one of the few conifer species that can sprout from the stumps of trees up to 60 years old (though younger trees are more likely to sprout). Sprout survival is often poor, however, and those that survive are more subject to wind damage as the stump decays (Fowells, 1965).

Hydroperiod is an important factor determining the survival of seeds and seedlings, but as trees mature, their flooding tolerance increases. Hydroperiods in bald cypress swamps have been found to range between 280.5 and 365 days, with an average of 330 days of inundation (Wetzel, 2001). Floodwaters also input significant amounts of nutrients, making floodplain bald cypress forests highly productive ecosystems compared to terrestrial forests. Stillwater bald cypress forests do not receive this yearly subsidy, and are thus equally or less productive than terrestrial systems (Ewel, 1990).

Regarding salinity tolerance, Penfound and Hathaway (1938) found a maximum tolerance of 8.9 ppt for mature bald cypress in southern Louisiana, although it is unclear how long these trees were inundated. Chabrek (1972) found that bald cypress stands rarely occur naturally in areas with salinity exceeding 1.98±1.40 ppt (mean ± std). Wicker et al. (1981) concluded that bald cypress forests are limited to areas where salinity does not exceed 2 ppt more than 50% of the time that trees are inundated. In a study of environmental stress to mature bald cypress trees at 21 sites along the

Northwest Fork of the Loxahatchee River between 1979 and 1982, all sampled trees showed signs of stress (indicated by poor growth rings) at some point in their lives, however, the proportion of stressed trees 14.5 km or less from the river mouth increased from 30% in 1940 to 80% in 1982. During the same time period, the proportion of stressed trees 14.5 km or more upstream of the river mouth decreased from 11% to 3% (South Florida Water Management District [SFWMD], 2006).

In summary, although mature trees may be able to withstand high salinity events from acute environmental impacts such as hurricanes, prolonged increases in the duration, depth, and salinity of inundation can kill even mature trees. Consequences are already apparent in many coastal areas, with heavy tree mortality seen from the Mississippi River delta to the Loxahatchee River in southeast Florida, the location of our field study.

Study Site: The Loxahatchee River

The Loxahatchee River is located on the lower eastern coast of Florida, USA (26° 59' N, 80° 9' E), and its watershed drains approximately 544 km^2 in Palm Beach and Martin counties. The Loxahatchee River has three main tributaries: the North Fork, the Northwest Fork, and the Southwest Fork. These three tributaries join at the Loxahatchee Estuary Central Embayment, which connects to the Atlantic Ocean via Jupiter Inlet (Fig. 1-2). The watershed includes several protected, publicly owned areas including Jonathan Dickinson State Park (JDSP), Loxahatchee Slough Preserve, Jupiter Ridge Natural Area, and J.W. Corbett Wildlife Management Area. The Loxahatchee River is often referred to as the "last free-flowing river in southeast Florida" (SFWMD,

2006), and in 1985, a 15.3-km stretch of the Northwest Fork was designated as Florida's first National Wild and Scenic River (NPS, 2004).

The Northwest Fork of the Loxahatchee River (NW Fork) and its watershed are unique in that they contain a diverse array of terrestrial and aquatic ecosystems including sandhill, scrub, hydric hammock (a plant community characterized by 30 to 60 days of inundation yearly and mixed, facultative hardwood species), wet prairie, floodplain swamp, estuarine swamps (primarily red mangrove, *Rhizophora mangle* L., and white mangrove, *Laguncularia racemosa* [L.] Gaertn.f.), seagrass beds, tidal flats, oyster beds, and coastal dunes (Roberts et al., 2006; Treasure Coast Regional Planning Council [TCRPC], 1999) in an increasingly urbanized area. Within the river channel itself, there are four distinct aquatic environments: freshwater, oligohaline, mesohaline, and polyhaline. Since much of the NW Fork's watershed is protected, many of these ecosystems remain intact and support a diversity of protected animal and plant species including the endangered West Indian manatee (*Trichechus manatus latirostris*) and four-petal pawpaw (*Asimina tetramera* Small). The upper watershed of the NW Fork is also home to one of the last remnants of bald cypress swamp in southeast Florida. However, changing hydrology and salinity regimes in the river and its floodplain over the past century have been linked to undesired vegetative changes in the floodplain forest (SFMWD, 2006). Of primary concern are: 1) the transition from bald cypress floodplain swamp to mangrove-dominated communities in the tidal floodplain as saltwater moves further upriver and into the floodplain, and 2) inadequate hydroperiod in the upstream riverine floodplain, which has shifted the system towards drier plant communities (SFWMD, 2009).

Altered hydroperiods and encroaching salinity in the NW Fork have been linked to four major factors: 1) construction of major and minor canals that direct water away from the historic watershed; 2) the permanent opening of Jupiter Inlet (Fig. 1-2), historically an intermittent barrier to saltwater intrusion, in 1947; 3) construction of the C-18 canal (Fig. 1-2) in 1958, which transferred a majority of flow from the NW Fork to the Southwest Fork (Fig. 1-2); and 4) lowering of the regional groundwater table by community consumption (SFWMD, 2002). These hydrologic changes have, in turn, been linked to changes in the composition of floodplain vegetation, where studies have documented the retreat of bald cypress upriver since at least the turn of the twentieth century (General Land Office [GLO], 1855; Alexander and Crook, 1975; McPherson, 1981; Ward and Roberts, 1996, SFWMD, 2002, 2005).

The health of the Loxahatchee River and its adjacent ecosystems is a priority for many residents, visitors, agencies, and political leaders. As such, a number of protection and restoration planning efforts have been initiated over the past twenty years, including the Loxahatchee River National Wild and Scenic River Management Plan and the North Palm Beach County Comprehensive Everglades Restoration Plan (CERP) Project (among others) (SFWMD, 2006). As in many other U.S. states (e.g., Johnson, 2008), Florida requires its water management agencies to make a priority list of rivers and schedule for their establishment of minimum flows and levels (Chapter 40E-8 of the Florida Administrative Code). In Florida, this task falls to the five Water Management Districts. Minimum Flows and Levels (MFLs) are designed to protect the ecology and water resources of a river from “temporary loss of water resource functions which result from a change in surface or groundwater hydrology that takes more than

two years to recover" (Section 373.042[1], Florida Statues). Chapter 373 protects water resource functions such as flood control, water quality, water supply and storage, fish and wildlife protection, and navigation and recreation (Mortl, 2006).

The proposed minimum flow criteria are linked to the concept of protecting valued ecosystem components (VECs) from "significant harm," and the MFL for the NW Fork was adopted in 2003 (SFWMD, 2002). Specifically, the MFL mandated that a violation would occur if an exceedance of the MFL criteria was met more than once every six years. In this case, an exceedance was defined as a reduction of flow at Lainhart Dam (Fig. 1-2) below ~1 $m^3 s^{-1}$ (nominally 35 $ft^3 s^{-1}$) for more than 20 consecutive days within any given calendar year (SFWMD, 2002). Due to reduced freshwater flows in the NW Fork, it was recognized that low dry-season flows would immediately trigger exceedances of the MFL. Under the MFL legislation, this mandated the development and implementation of a recovery plan to achieve the MFL.

The proposed recovery plan includes "structural, operational, and regulatory components that when implemented will provide sufficient additional water to the Northwest Fork to meet the proposed MFL…" (SFWMD, 2002). A draft, "Evaluation of Restoration Alternatives for the Northwest Fork of the Loxahatchee River" (SFWMD, 2005), was released in March 2005, and the final "Restoration Plan for the Northwest Fork of the Loxahatchee River" (Restoration Plan) was released in April 2006 with the goal of protecting the river's remaining cypress swamp and hydric hammock communities, as well as estuarine resources including oysters (*Crassostrea virginica*), fish larvae, and sea grasses—all identified as VECs (SFWMD, 2006). Both MFL targets and restoration scenarios rely primarily on increased freshwater flow over Lainhart Dam,

which was found to be the most important driver of upstream hydroperiod and downstream surface water salinity. In spite of the Loxahatchee's "free-flowing" appellation, flow over Lainhart dam is controlled by managing conveyance through the G-92 water control structure (Fig. 1-2). Conclusions and recommendations of the MFL and Restoration Plan, and reviewed in the following sections.

Historic and Current Hydrology

In the NW Fork, encroaching salinity has been linked to reduced freshwater flows, increased tidal connection, sea level rise, and lowering of the regional water table (Mortl, 2006). Historically, the NW Fork received flow from the Loxahatchee Marsh (Slough) and Hungryland Slough. Currently, the slough receives discharges from C-18 Canal (Fig. 1-2) and runoff and groundwater inflow from adjacent uplands. The NW Fork also receives input from three major tributaries: Cypress Creek, Hobe Grove Ditch, and Kitching Creek (Fig. 1-2). Beginning in the early 20th century, major land conversion for agricultural and urban development drastically altered drainage patterns in the watershed. Canals, levees, and drainage ditches lowered the water table and increased the speed of drainage. The Masten and Lainhart Dams (Fig. 1-2) were constructed in the 1930s to maintain higher water levels in the NW Fork (SFWMD, 2006). Road construction, dredging, and canal construction for irrigation of citrus and sod farms in the 1940s and 1950s further reduced flows to the NW Fork via the Federation and Hobe Grove ditches and Kitching Creek. The construction of water conveyance infrastructure has also effectively reduced the size of the watershed from approximately 700 km^2, as defined topographically, to 544 km^2, as defined by topography and hydraulic structures (canals, levees, etc.) that direct water away from the historic watershed (Mortl, 2006). The Masten and Lainhart dams were

reconstructed in the 1980s to help reduce over-drainage of the watershed, especially during the dry season (SFWMD, 2006).

Most significantly, the C-18 canal was constructed in 1957-1958 to provide drainage and flood protection to the region. The canal redirects a significant portion of the freshwater flow from the NW Fork to the channelized Southwest Fork, where it discharges to the Loxahatchee Estuary Central Embayment though the S-46 control structure (Fig. 1-2). This severely reduced freshwater flows to the NW Fork. In 1974, the C-14 canal and the G-92 structure (Fig. 1-2) were built to reconnect the C-18 canal and the Loxahatchee Slough with the NW Fork with flows of 1.4 to 2.8 $m^3 s^{-1}$ (nominally 50 to 100 $ft^3 s^{-1}$; SFWMD, 2006). A consent decree, brought about by a lawsuit filed by the Florida Wildlife Federation (FWF) mandated that the SFWMD provide 1.4 $m^3 s^{-1}$ (nominally 50 $ft^3 s^{-1}$) of flow to the NW Fork "subject to the presence of available water supplies" (SFWMD, 2002).

Hydrology at the mouth of the Loxahatchee Estuary has also been modified. Historically, the Jupiter Inlet (Fig. 1-2) opened and closed due to variation in flow from the Loxahatchee River, the Jupiter River, Jupiter Sound, and Lake Worth Creek. During the dry season (November-April), silt and debris filled the inlet, preventing saltwater flow into the estuary and river. In the wet season (May-October), high freshwater flows opened the inlet to the Atlantic Ocean, but prevented or minimized the intrusion of saltwater. From the late 1800s through 1912, construction of the Intracoastal Waterway and the St. Lucie and Lake Worth inlets reduced flow to the Jupiter inlet, causing it to close. In 1947, the US Army Corps of Engineers (USACE) permanently stabilized

Jupiter Inlet for navigation (SFWMD, 2002) and it has remained permanently open since that time.

Historic and Current Vegetation

Wetlands are very sensitive to changes in hydrology. Modifications of wetland hydrology have a cascading effect on nearly all biogeochemical processes in an ecosystem and can affect oxygen and nutrient availability, pH, salinity, and sediment deposition. Wetland hydrology and physiochemical environment are directly related to wetland plant species composition and richness, primary productivity, and organic matter accumulation (e.g., Mitsch and Gosselink, 2000). As expected, wetland communities in the floodplain of the NW Fork have undergone significant changes as hydroperiod and salinity have changed over the past century.

The earliest documented vegetative survey comes from the 1855 General Land Office (GLO) Township Plats and Field Survey Notes (GLO, 1855). This early report indicated that mangroves were present in the floodplain only up to the confluence of the North, Northwest, and Southwest Forks, about 9.7 km upstream of the river mouth (denoted as river kilometer 9.7, RK 9.7). Freshwater species, including bald cypress, cabbage palm (*Sabal palmetto* [Walter] Lodd. Ex Schult. & Schult. f.), wax myrtle (*Myrica cerifera* L.), pop ash (*Fraxinus caroliniana* Mill.), and bay trees (*Persea* spp.), were identified as the major trees in the riverine swamp upstream of RK 9.7. By 1967, a vegetation transect located near RK 12.1 (i.e., upstream of RK 9.7) was found to contain a mix of salt-tolerant and non-salt-tolerant species that included healthy, stressed, and dead bald cypress (SFWMD, 2002), and in 2003 the Florida Park Service (FPS) and SFWMD re-surveyed the transect and found only one living bald cypress remaining (SFWMD, 2005).

Alexander and Crook (1975) used aerial photography from 1940 and ground-truthing to examine changes in the riverine swamp community of the Loxahatchee River and Kitching Creek. The authors concluded that areas of wet prairie and swamp hardwood communities had been converted to pinelands and mangrove communities since 1940 due to lowered groundwater table and saltwater encroachment between RK 9.7 and RK 12.9. Their study also identified logging, fire, hurricanes, and heavy frost as possible impacts on plant communities. Based on analysis of peat soils, the authors also concluded that the historical reach of bald cypress forest was downstream to approximately RK 9.7, which is in agreement with GLO (1855). McPherson (1981) studied the transitional area between bald cypress and mangrove forests and found higher surface salinities near dead and stressed bald cypress (20 to 30 ppt) than near intermediately stressed trees (15 to 20 ppt). McPherson found that salinities decreased with depth below the ground and distance from the river channel, especially where freshwater seepage was observed and concluded that the bald cypress forest extended no further downstream from than approximately RK 8.9.

In 1983-1984, six 10-m-wide vegetation transects were established along the NW Fork as part of the SFWMD's Loxahatchee River Restoration Plan (Fig. 1-3). Ward and Roberts (1996) re-surveyed the transects between October 1993 and January 1994 and found that bald cypress density (stems ha^{-1}) increased from Transect 6 (denoted as T6; near Kitching Creek at RK 13.5) upstream to T1 (RK 23.3), though density was lower on T3 (RK 19.5), which had large populations of pop ash, red maple (*Acer rubrum* L.), and cabbage palm. These six transects were resurveyed in 2003, and four additional

transects were added, including transects in the lower segments of Kitching and Cypress Creeks and in the North Fork of the Loxahatchee River (Fig. 1-3).

The most thorough examination of changes in the floodplain communities of the Northwest Fork is SFWMD's interpretation and analysis of aerial photography from 1940, 1985, and 1995 (SFWMD, 2002; Fig. 1-4). In 1940, mangroves were dominant between RK 7.2 and RK 9.7 and extended upstream to RK 12.6, representing 23% of the vegetative coverage of the floodplain in the NW Fork (Fig. 1-4a). Freshwater communities were present upstream from RK 10.5 and were dominant above RK 12.9, representing 73% of the floodplain's vegetative coverage. In 1940, development and disturbance in the watershed was very minor; the 1940 U.S. Census lists 215 residents in the Town of Jupiter (SFWMD, 2002).

By 1985, a large portion of the watershed had been developed, with the exception of Jonathan Dickinson State Park. Large areas of mangroves in the NW Fork were destroyed due to urbanization between RK 7.2 and RK 8.9 (Fig. 1-4b). However, mangroves had become dominant between RK 8.9 and RK 14.0 and extended as far upstream as RK 16.9. Despite losses from development, mangroves represented 25% of the NW Fork's vegetative coverage in 1985, while the freshwater community coverage had been reduced to 61%. The majority of vegetative changes occurred in the lower and middle segments of the Northwest Fork, with mangroves representing over 75% of the plant community downstream of RK 14.8 by 1985 (SFWMD, 2002). Analysis of aerial photography from 1995 revealed only minor changes in vegetative coverage, likely due to increased freshwater flows resulting from the construction and improved operation of the G-92 structure. Finally, aerial photographs and additional

resources indicate that the majority of mangrove encroachment occurred between 1953 and 1979 (SFWMD, 2002).

Surface Water Monitoring and Modeling

Several models have been developed to support the development of the MFL and Restoration Plan for the NW Fork. These include a watershed-scale model of freshwater inflows (the Watershed, or WaSh, model), a hydrodynamic/salinity model (RMA-2 and RMA-4), and a Long-Term Salinity Management Model (LSMM). These models were used in combination to evaluate alternative scenarios in the Restoration Plan (Fig. 1-5). Zahina (2004) also developed a vegetation model (SAVELOX) that used empirical data to estimate changes in vegetation based on extrapolated changes in salinity. The structure, assumptions, and results of these modeling efforts are summarized in the following sections to place into context the conclusions of the MFL and Restoration Plan. Further details are available in SFWMD (2002, 2006).

The Watershed (WaSh) model

Staff from the SFWMD used a restructured version of the Hydrologic Simulation Program-Fortran model (HSPF) (Donigian et al., 1984) to simulate freshwater inflows to the Northwest Fork. The WaSh model uses a cell-based system, includes groundwater and dynamic channel-routing components (Wan et al., 2003), and is capable of modeling watersheds with shallow water tables and dense drainage networks. The four major components of the WaSh model for the Loxahatchee River were: 1) a cell-based representation of the watershed basin land surface; 2) a groundwater component consistent with the basin cell structure; 3) a surface water drainage system; and 4) water management practices (SFWMD, 2006).

WaSh uses the PWATER and IWATER routines from HSPF to route rainfall in each cell to one of three fates: 1) infiltration into the groundwater; 2) evaporation into the atmosphere; or 3) drainage to surface water. Infiltrated water is transferred to the groundwater model, which exchanges groundwater between cells as well as between groundwater and surface water. Groundwater flow is modeled using a two-dimensional (2-D) unconfined groundwater flow model. The surface water drainage component is made up of both cells and reaches. Reaches represent river and stream reaches as well as major canals and hydraulic structures. Channel flow is modeled using a 1-D fully dynamic shallow wave model (SFWMD, 2006).

WaSh uses equally sized grid cells with associated attributes (land use, soil type, elevation, impervious area, and slope) to describe the watershed. Routing of precipitation to infiltration, evaporation, and runoff is based on the hydrological parameters associated with grid cell attributes, particularly land use. WaSh uses three types of cells: free cells, canal cells, and reach cells. Free cells contain no canals. Reach cells contain a river or stream reach or a primary (large) canal. Canal cells contain tertiary (small) canals that are not included as a reach cell. Each cell has an associated attribute that specifies where runoff from that cell is routed. The HSPF routines run on 1 hr time steps, 24 hours at a time. A water balance is calculated for each cell (including rainfall, evaporation, storage in the soil, surface runoff, and infiltration) every day, after which accumulated surface runoff and infiltration are routed to groundwater or surface water, as appropriate.

WaSh was implemented on the Northwest Fork by dividing the watershed into four regions: the Jonathan Dickinson State Park region (which includes the North Fork, Kitch

Gauge, Park River, and Loxahatchee Estuary basins); the Pal-Mar and Grove region (which includes the Pal-Mar, Historic Cypress Creek, Grove West, and Grove East basins); the Jupiter Farms region (which includes Jupiter Farms and the Wild and Scenic basins); and the C-18 region (which includes the C-18 and Corbett basins, along with flow diversions from the L-8/Grassy Basin (Fig. 1-6). Grid cells were populated with hydrography, 2000 land use, soil, and LIDAR elevation data or the 0.30-m (nominally 1-ft contour where LIDAR was unavailable. Rainfall and evapotranspiration (ET) data from 1965 to 2004 were used to calibrate and validate the model. A complete description of the calibration and validation process is found in Chapter 6 of SFWMD (2006).

After calibration and validation, the model was used to create a long-term simulation of freshwater flows from 1965 to 2003. Simulated flows were then used as inputs to a hydrodynamic/salinity model (see following section). Daily flows were averaged to estimate the average contribution of freshwater flow delivered to the NW Fork from each individual basin (Table 1-1). Calibrated model results indicated that nearly half (45%) of the flow in the NW Fork flows over Lainhart Dam (via the C-18/Corbett, G-92, and Jupiter Farm basins). Cypress Creek (Pal-Mar and Grove West basins) provides the next largest flow contribution (33%). It is important to note that these values describe daily averages over the 39-year simulation; actual flow volumes and relative contributions vary widely according to climate, season, and water management practices (SFWMD, 2006).

Hydrodynamic and salinity model

With freshwater inflows from the WaSh model as inputs, staff from the SFWMD developed a hydrodynamic/salinity model to determine the role of freshwater flows from

the NW Fork and S-46 structure on salinities in the Loxahatchee River and Estuary. To calibrate and validate the model, a series of surface water elevation (SWE) and surface water electrical conductivity (SWEC; used to calculate salinity) monitoring stations were established from the Coast Guard station, near Jupiter Inlet, upstream to RK (Fig. 1-2). The hydrodynamic/ salinity model used the RMA-2 and RMA-4 models (USACE, 1996). RMA-2 is a 2-D, depth-averaged hydrodynamic model that computes water surface elevations and horizontal velocity components. It uses a finite element solution of the Reynolds form of the Navier-Stokes equations for turbulent flows. The Mannings or Chezy equations are used to calculate friction and turbulence characteristics are defined using eddy viscosity coefficients. RMA-4 simulates depth-averaged advection-diffusion processes and is used to determine mixing processes. RMA-4 was used to analyze the effects of different restoration scenarios on salinity distributions in the Loxahatchee River using depth-averaged hydrodynamics from the RMA-2 model.

The RMA models used a model mesh consisting of approximately 5,000 nodes, resulting that retains the oxbows and meandering channel of the Northwest Fork and extends 4.8 km into the Atlantic Ocean to create a stable boundary condition for salinity. Since the RMA model makes explicit use of basin bathymetry, it had the capability of simulating the geography of the NW Fork before and after implementation of a restoration project that restored several previously bisected oxbows in the Northwest Fork to reduce the upstream extent of saltwater intrusion (Dent, 1997a). The RMA model was set up using a bathymetric survey performed by the United States Geological survey (USGS) in 2003 and verified using measured field data from a series of tide and salinity monitoring stations installed by the USGS, SFWMD, and the

Loxahatchee River District (LRD). Three of the five sampling locations recorded salinity and temperature at two depths to detect temperature and salinity stratification. The model's only driving forces were tide and freshwater inflow, and thus the effects of wind, precipitation, evaporation, and exchange with groundwater were not considered. The RMA model was verified using field data from May through August 2003.

According to SFWMD (2005), the model "was able to predict the tide regimen rather accurately and predict the trend of salinity changes over the 3-month simulation period." Since RMA-2 and RMA-4 both output depth-averaged salinities, model output matched measured data better where the system was well-mixed (i.e., at the Jupiter Inlet) than in more stratified areas. Field sampling stations measured salinity at fixed points (while the tide goes up and down), and are thus measured bottom salinities at high tide and top salinities at low tide. Measured differences between high and low tide salinities can thus be much greater than the modeled differences. SFWMD identified unaccounted for freshwater flows from both surface and groundwater as another possible reason for differences between modeled and measured data.

After verification, the RMA model was used to simulate salinities in the NW Fork and Central Embayment of the Loxahatchee River under twelve different freshwater flow scenarios ranging from 1.13 to 198.21 $m^3 s^{-1}$ (nominally 40 to 7000 $ft^3 s^{-1}$), based on simulations from the WaSh model. Salinities under each flow scenario were then calculated at fifteen sites where salinity values were required for ecological assessment. RMA output was averaged over a complete lunar moth to account for the full tidal cycle. Regression of the freshwater flow versus salinity relationship revealed a strong exponential function of the form:

$$Y = Y_0 + ae^{-bx} \quad (1\text{-}1)$$

where Y is salinity in ppt, X is freshwater flow in $ft^3\ s^{-1}$, and Y_0, *a*, and *b* are regression coefficients. As expected, salinity deceases with increasing flow. Although there are deviations between field data and modeled flow versus salinity curves attributable to tide, wind, groundwater flow, precipitation, and evaporation, the "overall trend" (SFWMD, 2005) indicates a strong relationship between freshwater inflow and salinity (this relationship was tested with four years of field data and results are presented in Chapter 2). Analysis of modeled and field data indicate strong tidal mixing in the NW Fork, leading the authors to make two important conclusions: 1) restoration flow scenarios can be modeled using cumulative flow to the NW Fork as opposed to individual flows from form all tributaries, simplifying the analysis of restoration alternatives; and 2) any addition of freshwater flows will help achieve lower salinities in the NW Fork, whether they come from the G-92 structure (and over Lainhart Dam) or from another basin.

Long-term salinity management model

The RMA model described above uses constant freshwater inflows to estimate salinity conditions in the NW Fork and Central Embayment of the Loxahatchee River. Since freshwater flows are rarely consistent enough to be assumed constant, SFWMD developed the Long-Term Salinity Management Model (LSSM). LSSM predicts tidally averaged salinities under different restoration scenarios considering the dynamic nature of the natural system. LSSM uses a simple exponential function to simulate the transition from one "quasi-equilibrium" state to another, simulating the lag time between changes in freshwater flow and salinity. The model can also be used to calculate

required freshwater flow volumes required to achieve salinity management goals (SFWMD, 2006).

LSSM uses the amount of freshwater inflow to set a “target” or equilibrium salinity value then transitions the system to the target value on daily time steps according to the relationship:

$$SAL_2 = SAL_1 + (SAL_1 - SAL_{EQ}) * e^{-ct} \quad (1\text{-}2)$$

where SAL_1 is the salinity at the beginning of the time step, SAL_2 is the salinity at the end of the time step, SAL_{EQ} is the equilibrium salinity at a specific point under a specific freshwater inflow volume, t is time, and c is a constant that control the speed of transition between states. If the freshwater inflow volume changes before salinity reaches equilibrium, the program calculates a new equilibrium salinity and re-initiates the procedure (SFWMD, 2006).

Comparison of LSSM’s output with field data indicate that the mean salinity estimated by the model is approximately 0.1 to 0.6 ppt greater than measured data. However, the authors concluded that “the simulated daily salinity matches well with the observed salinities statistically” (SFWMD, 2005) and output from LSSM was used to simulate salinity conditions in the Northwest For and Central Embayment of a 39-year period of record from 1965 to 2003. This long-term simulation was then used to analyze the effectiveness of six proposed restoration flow scenarios, based on estimations of ecosystem responses (i.e., performance measures) to modeled salinities.

SAVELOX model

The Salinity-Vegetation model for the Northwest Fork of the Loxahatchee River (SAVELOX) model (Zahina, 2004) was developed within the Ecological Evaluation

Group of the SFWMD's Water Supply Planning and Development Division. The purpose of the SAVELOX model was to evaluate the potential vegetative impacts of different restoration flow scenarios based on currently observed vegetation and hydrology. SAVELOX is an empirical model based on vegetation surveys conducted from 2000 to 2002 and a 30-year salinity time series, which was simulated based on the models summarized in the previous sections. Using these data and simulations, empirical relationships between vegetation parameters (species abundance, canopy diameter, tree height, and tree DBH) and long-term salinity conditions were developed.

30-year salinity time series were simulated for seven sites along the NW Fork spanning from RK 12.6 to RK 16.4 and these time series were used to calculate summary statistics (daily mean, mode, standard deviation, and maximum salinity concentrations) and to calculate the amount of time that a site experienced salinity above certain threshold levels (1, 2, 3, and 4 ppt). Using these threshold values, "salinity events" were defined as the number of consecutive days that the site met or exceeded the threshold value, and the mean (average) of these events was defined as D_s (mean duration of salinity event). The mean number of days between each salinity event was also calculated and defined as D_b. D_s and D_b were calculated for each threshold value. The ratio of Ds:Db was then used to describe the salinity characteristics of each site when relating salinity conditions to measured vegetation parameters.

Field vegetation surveys included both quantitative and "semi-quantitative" surveys. The semi-quantitative survey was used to identify general vegetative trends related to salinity and to identify key species for further investigation during the

quantitative survey. A total of 23 sites on the Northwest Fork and ten sites on Kitching Creek were surveyed using the semi-quantitative method in 2000 and 2001. Survey sites were intentionally located greater than 30 m (nominally 100 ft) from river bends, oxbows, and the floodplain-upland transition to reduce the potential effects of river flow and freshwater seeps on vegetation community response. Abundance of all macrophytes within a 122 x 7.5 m (nominally 400 x 25 ft) area along each riverbank was recorded at each site. Abundance was measured using a modified version of the Braun-Blanquet cover-abundance scale.

Results of the semi-quantitative survey were used to select key species based on salinity tolerance, physiological characteristics, and ecosystem function and to meet specific criteria including: species that make up a significant component of the riverine swamp community (i.e., no rare species); long-lived species (to reflect long-term salinity conditions); and species that represent a range of saltwater tolerances. The ten species that met all criteria were bald cypress, cabbage palm, laurel oak (*Quercus laurifolia* Michx.), Virginia willow (*Itea virginica* L.), dahoon holly (*Ilex cassine* L.), pop ash, pond apple (*Annona glabra* L.), swamp bay (*Persea palustris* [Raf.] Sarg.), red mangrove, and red maple.

Nine sites from the semi-quantitative surveying effort were the resurveyed in January 2002. At each site, two 30 x 7.5 m (nominally 100 x 25 ft) belt transects were established and data was collected for adult trees, saplings (juvenile trees taller than breast height but shorter than canopy height), seedlings (juveniles shorter than breast height), and stump sprouts of key species. For each key species, the number of individuals, canopy diameter, tree height, and trunk circumference (to calculate DBH)

were recorded. Vegetation data and long-term salinity conditions were used to create salinity-vegetation relationships based on regressions correlating a measured vegetation parameter and the D_s:D_b ratio. The model was verified by comparing model output with data from field surveys at locations not used in model development.

SAVELOX was used to model three distinct hydrological periods: from 1971 to 1981 (below-average rainfall, reduced freshwater flow); from 1981 to 1991 (average rainfall and improvements to the G-92 structure, leading to increased freshwater flow); and from 1991 to 2001 (above-average rainfall operational improvements, leading to further increases in freshwater flow). Study and model results are lengthy and are discussed in detail in Zahina (2004). In general, the study found a high level of correlation between D_s:D_b ration and river kilometer (as expected), as well as a trend of decreasing species abundance with increasing D_s:D_b ratio (or river kilometer). The authors found model output for vegetation parameters to agree with measured field data well enough to use the relationships to assess the effects of different restoration scenarios. For example, the model predicted little vegetation change over the 30-year period at RK 13.2 (where higher salinity dominated throughout the simulation period) and RK 16.4 (where freshwater conditions prevailed). However, at RK 15.6, the freshwater swamp appeared to be reproductively healthy and in a state of recovery (as noted in SFWMD, 2006).

Evaluation of Restoration Scenarios

Results from the WASH, RMA, LSSM, and SAVELOX models were integrated to develop five constant-flow restoration scenarios for comparison with base flow conditions (as simulated by the 39-year period of record from 1965 to 2003). The five scenarios include flow augmentation over Lainhart dam, flow augmentation from other

tributaries (Cypress Creek, Hobe Grove Ditch, and Kitching Creek), and a combination of both. Table 1-2 summarizes the base condition and five flow scenarios, with "LD" scenarios signifying flow over Lainhart Dam and "LD/TB" scenarios signifying flow from Lainhart Dam and other tributaries to the NW Fork. The LSSM was then used to determine movement of the saltwater front (defined as the upstream extent of the 2 ppt isohaline) and to recalculate average daily salinity values at 15 salinity study sites under each of the flow scenarios. As expected, increased freshwater flows lower salinity throughout the entire river and estuary. Evaluation of the ecological impacts of each flow scenario considered impacts to each of the following zones and associated VEC species: riverine floodplain (bald cypress swamp and hydric hammock); tidal floodplain (mangrove swamp); low salinity zone (fish larvae); mesohaline zone (oysters); and polyhaline zone (sea grasses). To evaluate impacts to the riverine floodplain, river flow and SWE relationships, and the range and average floodplain elevations for hydric hammock and swamp forest, were used to assess the potential impacts of restoration flows at T1 and T3.

Monthly average flow conditions over the 39-year POR were used to assess restoration impacts on the floodplain swamp and hydric hammock. For the wet season, the total number of days for which the 20-day rolling average flows exceeded 3.1 $m^3 s^{-1}$ (nominally 110 $ft^3 s^{-1}$) was chosen as a metric to assess the impact on the floodplain swamp. This measure was used to reflect the fact that after storms, many areas of the floodplain swamp may remain inundated even after flow decreases below 3.1 $m^3 s^{-1}$. For the hydric hammock in the wet season, the number of days of inundation was used as a metric (i.e., the number of days when flow was greater than 5.1, 6.8, and 9.6 $m^3 s^{-1}$

[nominally 180, 240, and 340 $ft^3\ s^{-1}$], corresponding to the low, median, and high elevation occurrences of hydric hammock at T1).

The LD65, LD65TB65, and LD90TB110 scenarios provided higher flows than the base condition, with the most significant flow augmentations occurring in the dry season. Only LD90TB110 provided significantly greater flows in the wet season. The LD65, LD65TB65, and LD90TB110 scenarios did not appear to affect the hydroperiod of the hydric hammock, however, the LD200 and LD200TB200 scenarios would cause significant negative impacts on both the floodplain swamp and the hydric hammock due to consistently inundated conditions that would preclude seedling recruitment (SFWMD, 2006).

In the tidal floodplain, the D_s:D_b ratio (see previous section) for each of the flow scenarios was calculated and corresponding species abundance estimations were made. Using 1 ppt as the critical salinity threshold for freshwater floodplain swamp, restoration flows in the range of 3.7 to 5.7 $m^3\ s^{-1}$ (nominally 130 to 200 $ft^3\ s^{-1}$; i.e., between the LD65TB65 and LD90TB110 scenarios) would be required to allow recovery of a healthy freshwater floodplain swamp community downstream to the mouth of Kitching Creek (RK 13.1). To re-establish freshwater conditions all the way to the boundary of JDSP would require flows in excess of 11.3 $m^3\ s^{-1}$ (nominally 400 $ft^3\ s^{-1}$), however this would result in constant floodplain inundation upstream, hindering the ability of seeds to germinate.

In addition to these analyses, the effects of restoration flow scenarios on fish larvae, oysters, and sea grasses were evaluated. The results of these analyses are summarized in Table 1-3, but methods are not discussed in detail here (see SFWMD,

2006). Generally, the overall impacts of restoration flows on the VECs of the Fork were assessed using a semi-quantitative plus/minus scoring system, and no single restoration scenario had solely positive impacts on all VECs in the ecosystem. Additionally, since many of the VECs in the Northwest Fork require a naturally varying range of flow (and salinity) conditions, constant flow scenarios would likely be insufficient to meet restoration goals. To address this issue, a series of preferred restoration flow scenario (PRFS) were developed that incorporated flows that were allowed to vary both seasonally and yearly to maintain healthy, functioning ecosystems.

Four elements of a variable flow regime were considered when developing the PRFS: base flow, seasonal high flows, monthly and short-term flow variations, and frequent and rare flood events during the wet season. Under the PRFS, flow augmentation still occurs at low flows of 3.7, 2.0, and 2.3 $m^3 s^{-1}$ (nominally 30, 70, and 80 $ft^3 s^{-1}$) during wet, dry, and transitional seasons, respectively, however the amount of flow augmentation is calculated using a set of logic-based rules and is determined using one of two methods. The first method is based on monthly median flows and is calculated by:

$$\text{additional flow} = 130 - (\text{monthly median flow}) * \frac{\text{monthly median flow}}{\text{October median flow}} \quad (1\text{-}3)$$

where all flows are in $ft^3 s^{-1}$. The ratio of monthly median/October median flows is used to scale the augmentation by the natural proportionality of median flows. The term (130- monthly median flow) is intended to represent the monthly variability of flows. This method of flow augmentation provides variable transitions around breakpoint flows and eliminates the tendency to create constant flow conditions. The second method uses a flood pulse intended to simulate flow conditions after a rainfall event. During the

wet season the pulse has a mean daily flow of 3.3 $m^3 s^{-1}$ (nominally 115 $ft^3 s^{-1}$) and a range of 3.1 to 3.7 $m^3 s^{-1}$ (nominally 110 to 130 $ft^3 s^{-1}$). During the dry season the pulse is smaller, with a mean daily flow of 1.9 $m^3 s^{-1}$ (nominally 68 $ft^3 s^{-1}$) and a range of 1.4 to 2.6 $m^3 s^{-1}$ (nominally 50 to 90 $ft^3 s^{-1}$). Under the variable flow scenario, the amount of flow augmentation required over Lainhart Dam is similar to the constant flow scenario LD90TB110, and is thus referred to as LV90 (with L signifying Lainhart Dam and V signifying variable flow scenario).

For the portion of flow contributed by Cypress Creek, Hobe Grove Ditch, and Kitching Creek, three possible variable flow situations were considered: augmentation of the average tributary base flow of 0.85 $m^3 s^{-1}$ (nominally 30 $ft^3 s^{-1}$) with an additional 0.85, 1.70m or 2.55 $m^3 s^{-1}$ (nominally 30, 60, or 90 $ft^3 s^{-1}$) whenever total flow of the Northwest Fork under LV90 is below 8.50 $m^3 s^{-1}$ (nominally 300 $ft^3 s^{-1}$). As applied to the constant-flow scenarios, the three variable flow scenarios (LV90TV60, LV90TV90, and LV90TV120) were evaluated for their effect on daily salinity and corresponding ecological impact on all VECs.

Finally, the effects of salinity and tidal amplitude led to the choice of the LV90TV60 scenario as the preferred restoration scenario for reestablishment of the freshwater floodplain forest downstream approximately to the mouth of Kitching Creek (RK 13.1). This PRFS is expected to have minimal negative impacts to fish larvae, oysters, and sea grasses, with the exception of the potential loss of oyster habitat currently located at RK 9.7. The SFWMD aims to mitigate for this potential loss by providing additional oyster substrate for colonization downstream. Additional freshwater flow would not be effective to restore freshwater vegetation below this point due to tidal SWE and low

floodplain elevations (SFWMD, 2006) and would be more deleterious to estuarine VECs. In summary, the Preferred Restoration Flow Scenario includes both seasonal and short-term flow variability, with supplemental flows added during the wet season to achieve 120 days of inundation in the freshwater, riverine floodplain. Supplemental flows during the dry season aim to maintain average flow of 1.95 $m^3 s^{-1}$ (nominally 69 $ft^3 s^{-1}$) in the riverine floodplain to discourage saltwater intrusion. When total flow in the NW Fork is less than 8.5 $m^3 s^{-1}$ (nominally 300 $ft^3 s^{-1}$), 0.85 $m^3 s^{-1}$ (nominally 30 $ft^3 s^{-1}$) of supplemental flow is added from the tributaries. Fig. 1-7 shows the expected vegetation changes in the Northwest Fork under the LV90TV60 Preferred Restoration Flow Scenario.

Research Objectives

Description and modeling of hydroperiod, surface water salinity, groundwater elevation and salinity, soil moisture, and soil porewater salinity are essential to understanding the hydrological and ecological functioning of coastal floodplain wetlands (e.g., Benke et al., 2000, Glamore and Indraratna, 2009; Nyman et al., 2009). Given the specific life cycle requirements of bald cypress, vadose zone hydrology is crucial to the maintenance and restoration of the bald cypress-dominated floodplain swamp ecosystem. Groundwater also plays a vital role in the water balance of many wetlands and is increasingly recognized as an important driver of ecological processes (Hancock et al., 2009) and the development of particular ecological communities in wetlands from Florida, USA (Harvey and McCormick, 2009) to Australia (Hatton et al., 1998). This is particularly true in coastal wetlands, where the effect of groundwater on salinity gradients can largely dictate habitat conditions in the estuary (Jassby et al., 1995).

While the development of the MFL and Restoration Plan for the NW Fork of the Loxahatchee River initiated the intensive monitoring and watershed and hydrodynamic modeling summarized in previous sections (also see SFWMD, 2002, 2006, 2009), these efforts focused primarily on surface water and did not address the linkage with the vadose (unsaturated) zone. Except for one study of biogeochemical transport and submarine groundwater discharge (Swarzenski et al., 2006), the role of groundwater in the Loxahatchee River and its floodplain is also largely uninvestigated. This is consistent with most hydrological monitoring and modeling efforts performed in support of ecological restoration projects, which tend to focus on surface water (e.g., Wang, 1997). Even those studies that explicitly address the role of groundwater in wetland hydrology (e.g., Jung et al., 2004) usually overlook hydrological conditions in the vadose zone, which largely dictate seed germination and seedling survival of many floodplain wetland species (Middleton, 1999).

To fill these gaps in our understanding of the hydrological and ecological functioning of coastal floodplain wetlands, and improve restoration planning efforts for the Loxahatchee River, the research objectives of our study were to:

- Experimentally characterize soil moisture and porewater salinity dynamics in the floodplain wetlands of the NW Fork of the Loxahatchee River at several depths and distances from the river over multiple wet and dry seasons.
- Develop relationships between surface water, groundwater, and vadose zone hydrology to better predict the effects of proposed restoration and management scenarios on the vadose zone and floodplain vegetation.
- Apply advanced time series analysis methods to investigate the interactions between shallow groundwater elevation and salinity and other hydrological variables in the watershed to identify important common trends among the series and the external hydrological factors (local and/or regional) that most fully explain their observed variation.

- Integrate these physically-based and empirical relationships into a management-based modeling tool that will be useful for stakeholders.

Materials and methods used to meet these objectives, and the results and conclusions of each, are described separately in the following chapters. A final conclusion chapter summarizes the findings and significance of the overall study.

Table 1-1. Flow contributions to the NW Fork from each sub-basin in the watershed (adapted from SFWMD, 2006).

Basin	Average Daily Flow ($m^3 s^{-1}$)	NW Flow Contribution (%)
1. Kitching Gauge	0.49	8.4
2. North Fork	0.57	*
3. Park River	0.14	2.5
4. Lox Estuarine	0.41	*
5. C-18/Corbett G-92	1.97	33.6
5. C-18/Corbett S46	1.45	*
6. Historic Cypress Creek	0.20	3.4
7. Pal-Mar	1.63	27.8
8. Grove West	0.31	5.4
9. Grove East	0.30	5.1
10. Jupiter Farms	0.62	10.6
11. Wild and Scenic	0.20	3.3
Total:	9.15	100

*This basin does not drain to the Northwest Fork

Table 1-2. Constant flow restoration scenarios (adapted from SFWMD, 2006). Flow in $m^3 s^{-1}$ ($ft^3 s^{-1}$). POR indicates modeled flow over period of record.

Source of Flow	Base condition	LD65	LD65TB65	LD90TB110	LD200	LD200TB200
Lainhart Dam (LD)	POR	1.84 (65)	1.84 (65)	2.55 (90)	5.66 (200)	5.66 (200)
Other tributaries (TB)	POR	POR	1.84 (65)	3.11 (110)	POR	5.66 (200)
Total Flow	1.42 (50)	2.69 (95)	3.68 (130)	5.66 (200)	6.51 (230)	11.33 (400)
Approximate saltwater front position (RK)	15.3	13.7	12.9	12.1	11.3	9.7

Table 1-3. Summary of the evaluation of restoration flow scenarios on valued ecosystem components (VECs) of the NW Fork of the Loxahatchee River (adapted from SFWMD, 2006).

Eco-Zone	VEC Component	BASE	LD65	LD65TB65	LD90TB110	LD200	LD200TB200
Riverine Floodplain	Cypress swamp	0	+	+	++	---	---
	Hydric hammock	0	0	0	0	---	---
Tidal Floodplain	Swamp upstream of RK 14.5	0	++	++	++	-	--
	Swamp upstream of RK 12.9	0	0	++	++	++	--
	Swamp upstream of RK 9.9	0	0	0	0	+	--
	Swamp upstream of RK 9.5	0	0	0	0	0	--
Low Salinity Zone	Fish larvae	0	0	0	-	-	--
Mesohaline Zone	Oysters upstream of RK 9.5	0	-	--	---	---	---
	Oysters upstream of RK 8.8	0	0	-	--	---	---
	Oysters upstream of RK 7.9	0	0	0	--	--	---
	Oysters upstream of RK 6.6	0	0	0	-	--	---
Polyhaline Zone	Seagrass upstream of RK 5.2	0	0	0	--	--	---
	Seagrass upstream of RK 3.9	0	0	0	-	-	--
	Seagrass upstream of RK 2.8	0	0	0	0	0	0
	Seagrass upstream of RK 2.4	0	0	0	0	0	0
	Seagrass upstream of RK 1.1	0	0	0	0	0	0

0 = No change; +, ++ = Beneficial impact; -, - - , - - - = Negative impact+

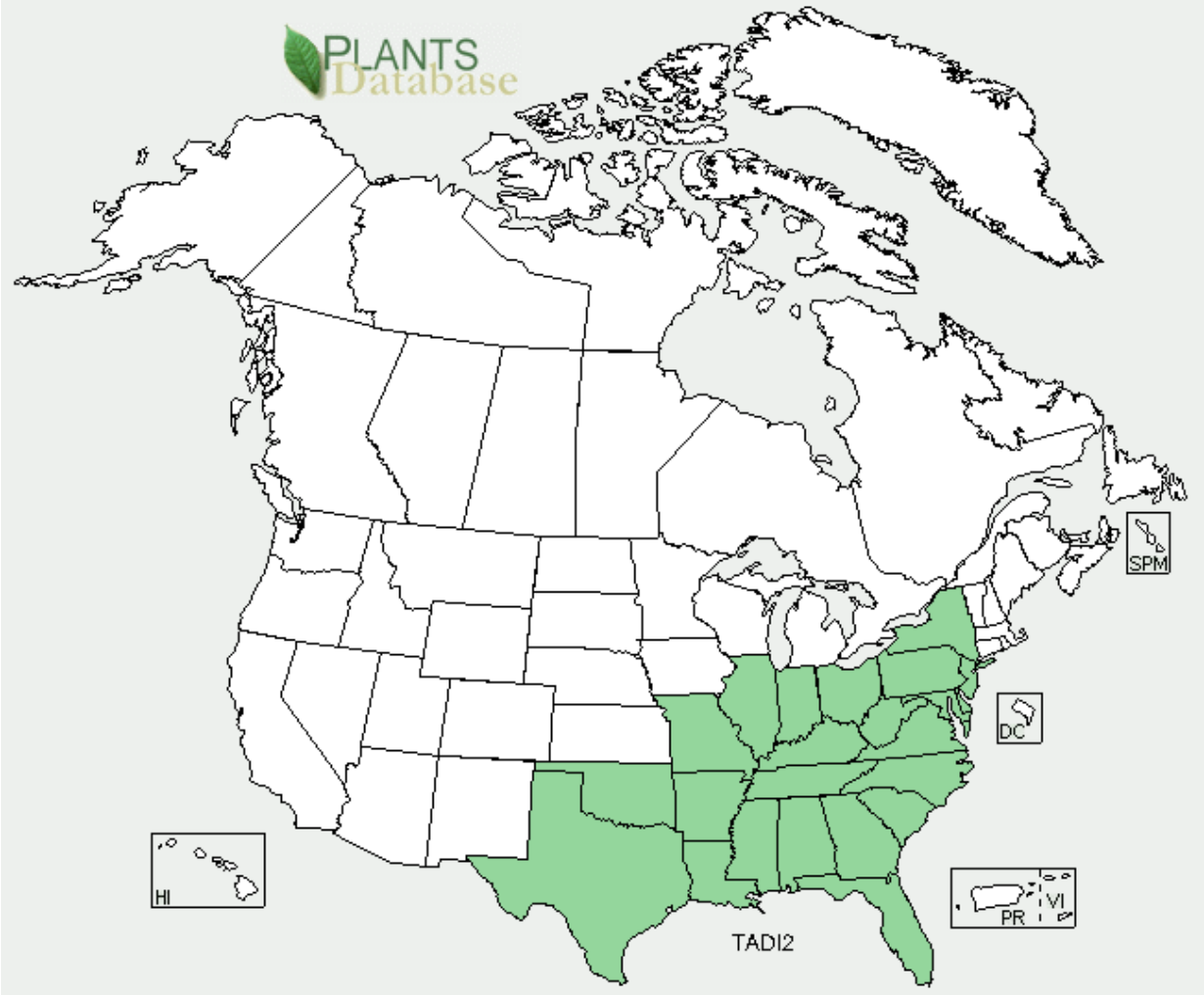

Figure 1-1. Bald cypress (*Taxodium distichum* [L.] Rich.) distribution in the United States (source: USDA, 2002).

Figure 1-2. The Loxahatchee River and Estuary with meteorological measurement locations (S46 and JDWX weather stations) and major hydraulic infrastructure. Transect notation is followed by distance from river mouth (river kilometer, RK).

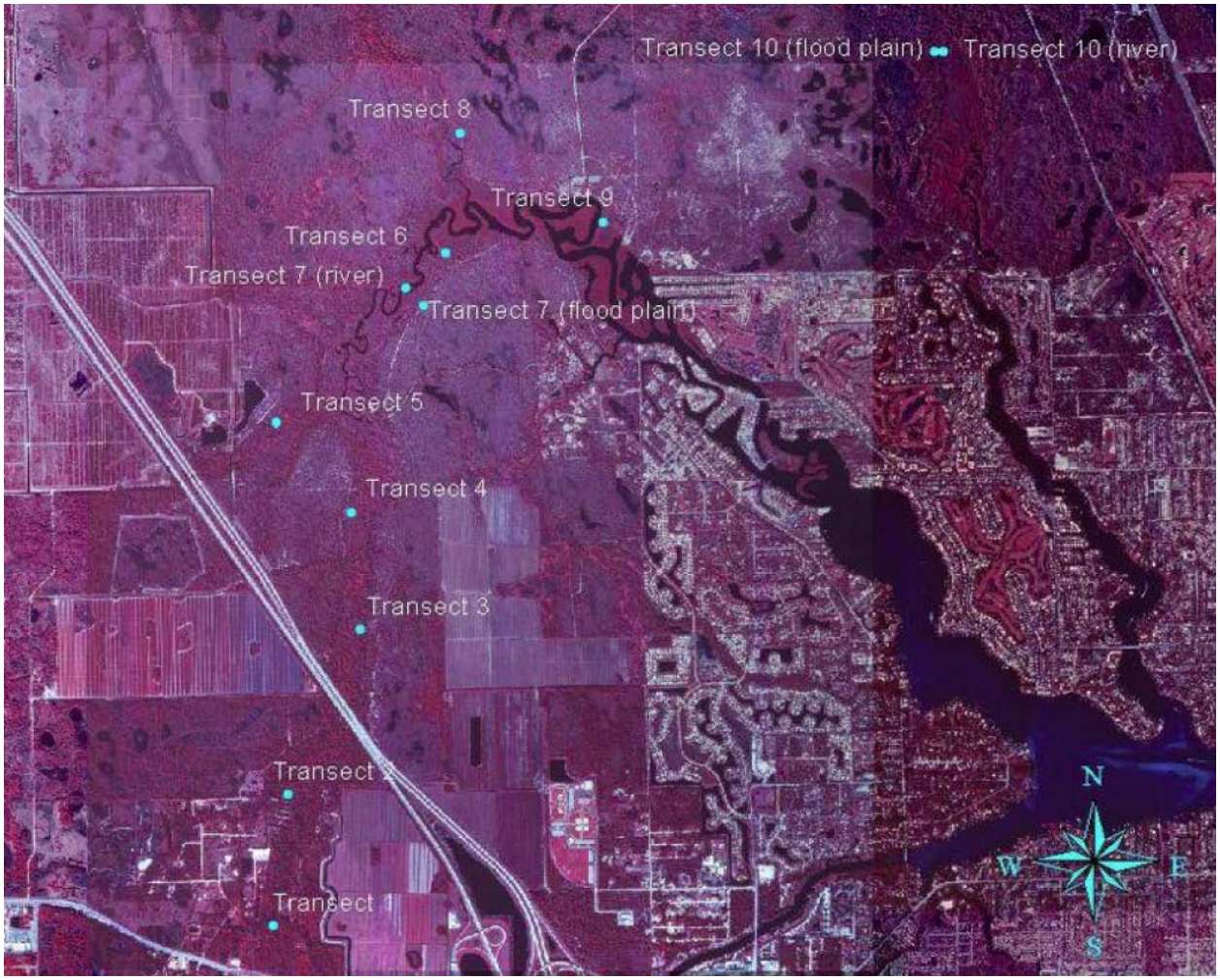

Figure 1-3. Location of the ten floodplain vegetation transects on the Loxahatchee River (source: SFWMD, 2006).

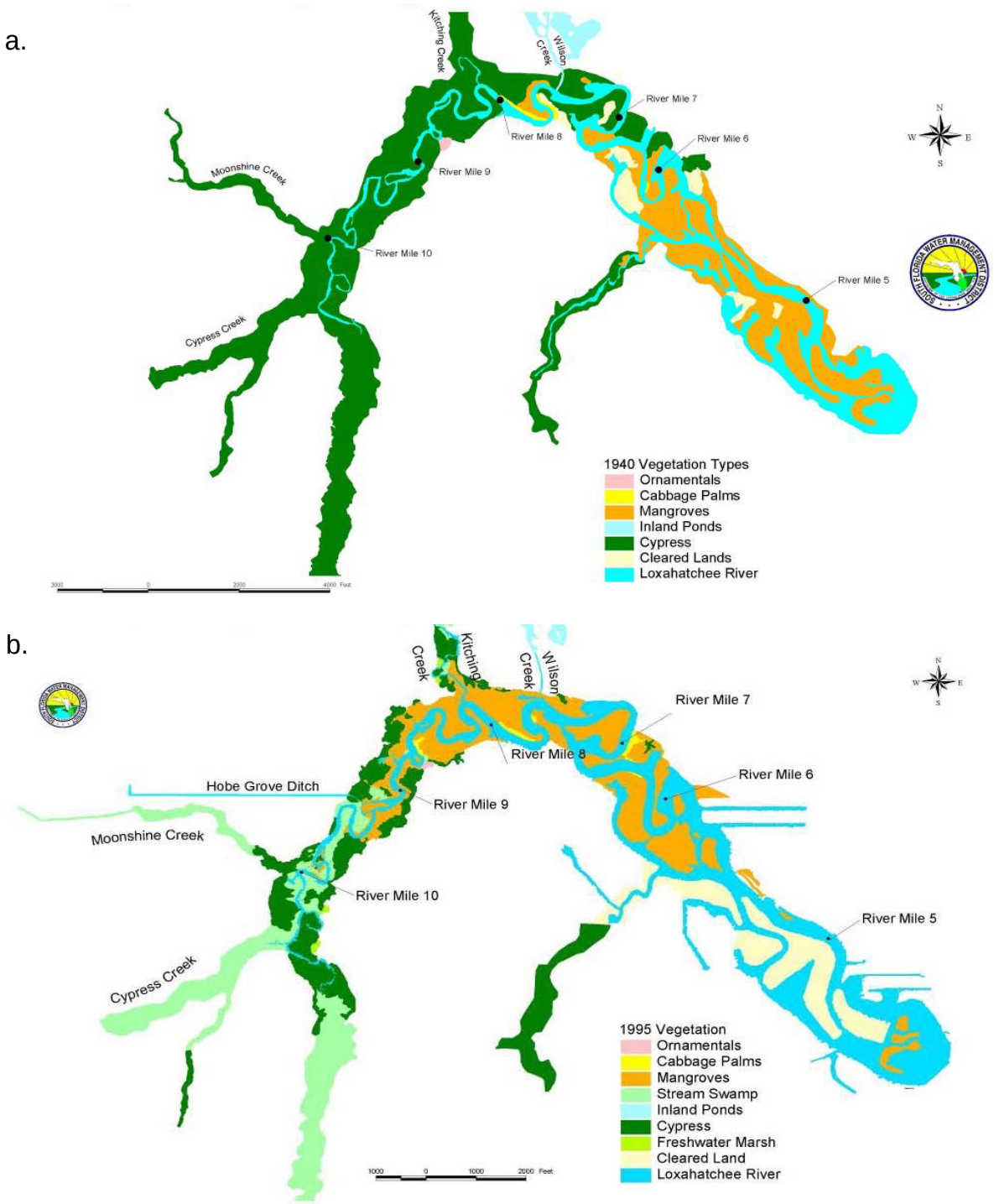

Figure 1-4. Interpretation of aerial photography of vegetation communities in the floodplain of the NW Fork of the Loxahatchee River in (a) 1940 and (b) 1995. River Miles 5 to 10 correspond to River Kilometers (RK) 9.7, 11.3, 12.9, 14.5, 16.1, and 17.7. By 1995, mangroves had displaced large areas of bald cypress in the lower and middle sections of the river due to saltwater intrusion, and bald cypress were present, but declining, in upstream freshwater areas due to reduced hydroperiod (source: SFWMD, 2006).

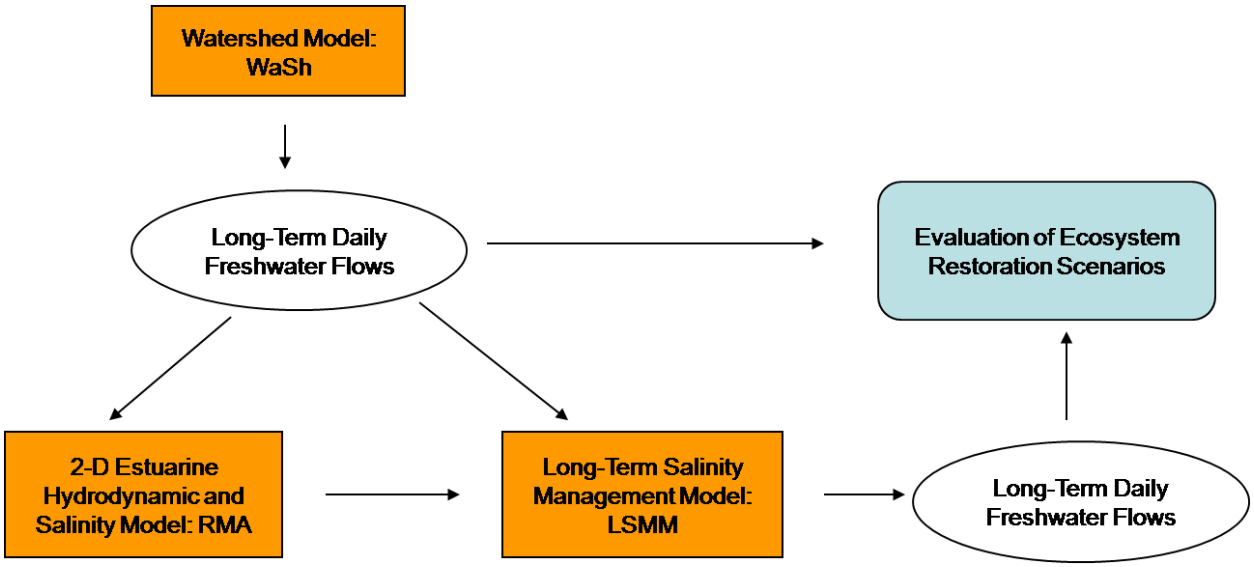

Figure 1-5. Relationship between the three hydrological models used to evaluate restoration scenarios for the NW Fork (source: SFWMD, 2006).

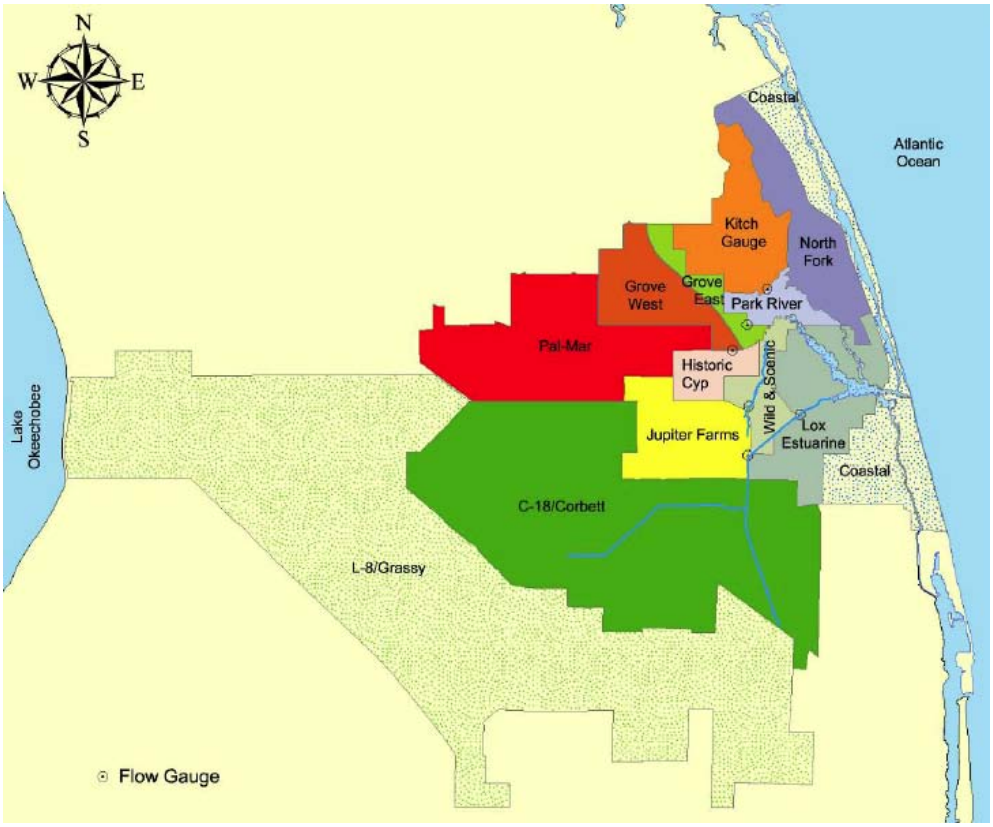

Figure 1-6. Major drainage basins of the Loxahatchee River watershed (source: SFWMD, 2006).

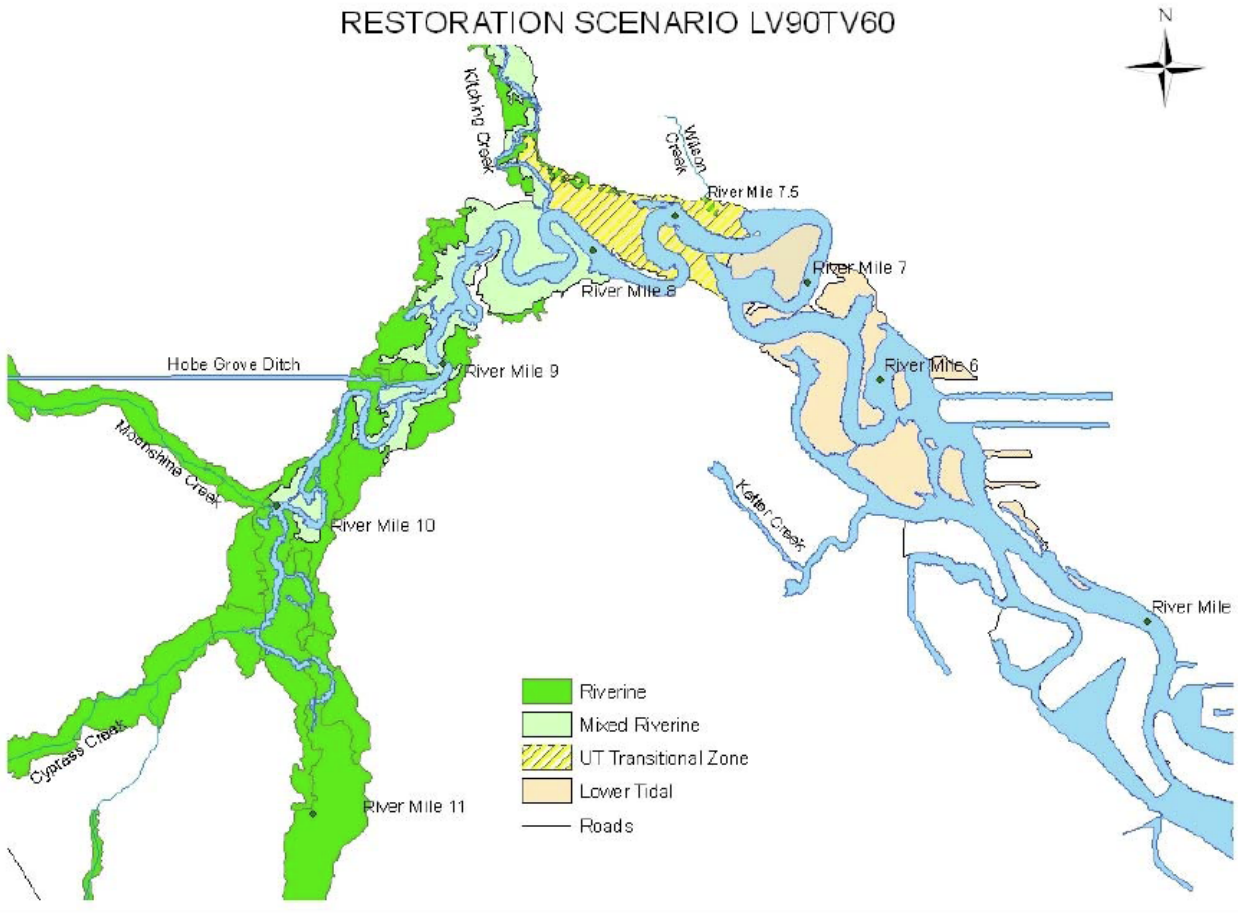

Figure 1-7. Expected floodplain vegetation under the Preferred Restoration Flow Scenario (source: SFWMD, 2006). River Miles 6 to 11 correspond to River Kilometers (RK) 9.7, 11.3, 12.9, 14.5, 16.1, and 17.7

CHAPTER 2
LINKING RIVER, FLOODPLAIN, AND VADOSE ZONE HYDROLOGY TO IMPROVE RESTORATION OF A COASTAL RIVER IMPACTED BY SALTWATER INTRUSION

Introduction

Coastal wetlands perform a unique suite of physical, biological, and chemical functions. They protect coastal areas from storm damage; filter, transform, and store sediments, nutrients, and other contaminants; and provide habitats that support huge numbers of commercially and ecologically important fish, birds, and other wildlife (e.g., Mitsch and Gosselink, 2000). Coastal zones also provide at least half of all global ecological services (Costanza et al., 1997) and generate billions of dollars annually from fisheries, recreation, and tourism (Niemi et al., 2004). Environmental pressures facing coastal wetlands come from both natural and anthropogenic sources, and these stressors often overlap and have synergistic effects (McCarthy et al., 2001).

Saltwater intrusion is an example of such a pressure. Natural drivers of saltwater intrusion include climatic fluctuations that alter freshwater outflows (Thomson et al., 2002); storm surges and hurricanes (Flynn et al., 1995); and sea level rise (Moorhead and Brinson, 1995; Burkett et al., 2001). Estimated sea level rise alone has the potential to eliminate as much as 22% of the world's coastal wetlands by 2100 (Nicholls et al., 1999), though regional impacts would vary (Michener et al., 1997). Anthropogenic drivers of saltwater intrusion include land drainage (e.g., Holman and Hiscock, 1998); pumping of coastal freshwater aquifers (e.g., Sadeg and Karahanogulu, 2001); reduction in freshwater discharge from dam construction, water withdrawals, and other water diversions (e.g., Johnson, 1997); and hydraulic structures and land use changes within watersheds (e.g., Wang, 1988; Liu et al., 2001; Bechtol and Laurian,

2005). When anthropogenic and natural drivers act together, saltwater intrusion can lead to rapid and catastrophic loss of coastal wetlands (Wanless et al., 1989).

Saltwater intrusion in coastal wetlands causes plant stress or mortality from prolonged submergence and/or high salinities; erosion of wetland substrate; conversion of freshwater habitats to brackish or saltwater habitats; and the transition of coastal saltwater habitats to open water (DeLaune et al., 1994). These effects have been observed in coastal wetlands around the globe, including the floodplain forests of the Mississippi River delta (USA) (Earles, 1975; Salinas et al., 1986); the coastal plains of the Mary and Alligator Rivers in northern Australia (Winn et al., 2004; Knighton et al., 1991); and the coastal marshes of the River Thurne in northeast Norfolk (UK) (Holman and Hiscock, 1998).

When saltwater intrusion is caused by anthropogenic drivers, or a combination of natural and anthropogenic drivers, some amount of restoration and management is likely achievable (Scruton, 1998). Re-establishing hydrological regimes and connections can ameliorate the effects of saltwater intrusion by increasing well-timed freshwater flows (Middleton, 2002) and, where appropriate, supplying the sediment required for accretion (DeLaune et al., 1994). Hydrological monitoring and modeling efforts in support of these restoration efforts usually focus on surface water (e.g., Wang, 1997) or groundwater (e.g., Jung et al., 2004), but overlook hydrological conditions in the vadose (unsaturated) zone, which largely dictate seed germination and seedling survival (Middleton, 1999).

For example, the timing and duration of flooding and drawdown in the floodplain play a critical role in the reproduction of bald cypress (*Taxodium distichum* [L.] Rich.), a

major component of floodplain swamps in sixteen U.S. states (Thompson et al., 1999). Along with water tupelo (*Nyssa aquatica* L.) and swamp tupelo (*Nyssa biflora* Walter), bald cypress is a dominant tree species in the riverine and coastal floodplains of the southeast (Day et al., 2006; Allen et al. 1994). Cypress seeds settle along drift lines after floodwaters recede and require moist but not flooded conditions to germinate (Middleton, 2000). Under saturated conditions, seeds may germinate on moss or wet muck, but will not germinate under water—though they can remain viable for up to 30 months if inundated (Fowells, 1965). At the other end of the moisture regime, seeds will not germinate on well-drained soils due to lack of surface moisture. Thus, a drawdown of inundated soils to saturated or moist conditions is required for germination (Burns and Honkala, 1990; Middleton 1999, 2002). Seedlings must also grow fast enough to keep their crowns above floodwaters for most of the growing season to survive (Conner, 1988; Conner et al., 1986, 1987).

Bald cypress seeds and seedlings also have limited salt tolerance (Allen et al., 1996). The combined negative effects of flooding and salinity are greater than either alone, and are more pronounced at higher salinities. In general, Chabrek (1972) found that bald cypress stands rarely occur naturally in areas with salinity exceeding 1.98±1.40 ppt (mean± std) and Wicker et al. (1981) concluded that bald cypress forests are limited to areas where salinity does not exceed 2 ppt greater than 50% of the time that trees are inundated. This is in agreement with Liu et al. (2006) who established a bald cypress seedling salinity tolerance threshold of 2 parts per thousand (ppt) using seedlings collected from the area studied in this paper. Given its specific life-cycle

requirements, vadose zone hydrology is crucial to the maintenance and restoration of bald cypress floodplain swamp ecosystems

Like in many other U.S. states (e.g., Johnson, 2008), Florida law requires its water management agencies to establish Minimum Flows and Levels (MFLs) to protect water resources and valued ecosystem components (VECs) from “significant harm” (Section 373.042[1], Florida Statutes). Bald cypress swamp has been identified as a VEC in the floodplain of the Loxahatchee River, a southeastern (USA) coastal river where restoration efforts to ameliorate saltwater intrusion are being developed and tested. MFL and restoration plan development initiated intensive watershed and hydrodynamic modeling efforts to identify relationships between upstream flow and downstream salinity and suggested target MFL and restoration flows (SFWMD, 2002, 2005, 2006). However, these models focused primarily on the river channel and did not address the linkage with the vadose zone. The objective of this study is to develop relationships between surface water, groundwater, and vadose zone hydrology to better predict the effects of proposed restoration and management scenarios on ecological communities in the floodplain of the Loxahatchee River. This is achieved by long-term experimental characterization of soil moisture and porewater salinity dynamics in the floodplain at several depths and distances from the river—complemented by surface water and groundwater stage and salinity and meteorological monitoring—to identify differences between areas with varying soils, hydrology, and vegetation. It is the first effort of which we are aware that extends long-term, continuous hydrological monitoring into the vadose zone in support of wetland restoration.

Materials and Methods

Site Description

Historically part of the greater Everglades watershed, the Loxahatchee River is located on the southeastern coast of Florida, USA (26° 59' N, 80° 9' W) and is often referred to as the "last free-flowing river in southeast Florida" (South Florida Water Management District [SFWMD], 2006). The river has three main branches (the North, Southwest, and Northwest Forks), which join in a central embayment that connects to the Atlantic Ocean via Jupiter Inlet (Fig. 2-1). The watershed drains approximately 550 km^2 in Palm Beach and Martin Counties and includes several large, publicly owned areas including Jonathan Dickinson State Park (JDSP), the Loxahatchee Slough Preserve, and the J.W. Corbett Wildlife Management Area. In 1985 a 15.3-km stretch of the Northwest Fork became Florida's first National Wild and Scenic River (National Park Service [NPS], 2004).

The Northwest Fork of the Loxahatchee River (NW Fork) and its watershed contain a diverse array of terrestrial and aquatic ecosystems including sandhill, scrub, hydric hammock (a plant community characterized by 30 to 60 days of inundation yearly and mixed, facultative hardwood species), wet prairie, floodplain swamp, estuarine (mangrove) swamps, seagrass beds, tidal flats, oyster beds, and coastal dunes (Roberts et al., 2006; Treasure Coast Regional Planning Council [TCRPC], 1999). Many of these ecosystems remain relatively intact (VanArman et al., 2005) and support a diversity of protected animal and plant species, including the endangered Florida manatee (*Trichechus manatus latirostris*) and four-petal pawpaw (*Asimina tetramera* Small) (SFWMD, 2006). The upper watershed of the NW Fork is also home to one of the last remnants of bald cypress floodplain swamp in southeast Florida. However,

changing hydrology and salinity regimes in the river and its floodplain have been linked to vegetative changes in the floodplain forest (SFWMD, 2002). Of primary concern are: 1) the transition from bald cypress floodplain swamp to mangrove-dominated communities in the tidal floodplain as salinity increased, and 2) inadequate hydroperiod in the upstream riverine floodplain, which has shifted the system towards drier plant communities (SFWMD, 2009). Similar changes in the composition of floodplain vegetation as a result of reduced flooding frequency have been observed regionally and globally (e.g., Darst and Light, 2008; Leyer, 2005).

Altered hydroperiods and encroaching salinity in the NW Fork have been linked to four major factors: 1) construction of major and minor canals that direct water away from the historic watershed; 2) the permanent opening of Jupiter Inlet in 1947 (Fig. 2-1); 3) construction of the C-18 canal in 1958, which transferred a majority of flow from the NW Fork to the Southwest Fork (Fig. 2-1); and 4) lowering of the regional groundwater table by municipal withdrawals (SFWMD, 2002). These hydrologic changes have been linked to changes in the vegetative composition of the floodplain, where studies have documented the upriver retreat of bald cypress since at least the turn of the 20th century (General Land Office [GLO], 1855; Alexander and Crook, 1975; McPherson, 1981; Ward and Roberts, 1996; Roberts et al., 2008).

Based on interpretation of aerial photography (SFWMD, 2002), in 1940 mangroves were dominant as far as 9.7 km upstream of the river mouth (indicated as RK 9.7) and extended upstream to RK 12.5 (Fig. 2-2a). Bald cypress floodplain swamp communities were present upstream of RK 10.5 and were dominant above RK 12.9. By 1995 large areas of mangroves had been destroyed due to urbanization in the lower section of the

river (Fig. 2-2b). However, mangrove-dominated communities had replaced bald cypress as far upstream as RK 16.9, and upstream bald cypress-dominated swamp had transitioned to shorter-hydroperiod freshwater swamp (with bald cypress present, but declining). Only minor changes in vegetative coverage were observed between 1985 and 1995, likely due to increased flows following a 1982 consent decree between the Florida Wildlife Federation and the SFWMD (SFWMD, 2006).

The MFL for the NW Fork of the Loxahatchee River (SFWMD, 2002) was adopted in 2003 and a restoration plan (SFWMD, 2006) was completed in 2006 with the goal of protecting the river's remaining cypress swamp and hydric hammock communities, as well as estuarine resources including oysters (*Crassostrea virginica*), fish larvae, and sea grasses—all identified as VECs. These MFL and restoration scenarios rely primarily on increased freshwater flow over Lainhart Dam (Fig. 2-1), which was found to be the most important driver of upstream hydroperiod and downstream surface water salinity (SFWMD, 2006). In spite of the Loxahatchee's "free-flowing" appellation, flow over Lainhart dam (calculated from headwater surface water elevation) is controlled by managing conveyance through the G-92 water control structure (Fig. 2-1).

Experimental Setup

Twenty-four frequency domain reflectometry (FDR) dielectric probes (Hydra Probe, Stevens Water Monitoring Systems, Beaverton, OR, USA) measuring soil moisture, bulk electrical conductivity, and temperature were installed at four locations and three depths along two previously established vegetation survey transects perpendicular to the river (Fig. 2-3). Probe installation elevations were determined using established survey benchmarks and a rotary self-leveling laser (model LM500, CST/Berger, Watseka, IL, USA). Each cluster of three probes was wired to a field data

logger (CR10/CR10-X, Campbell Scientific, Logan, Utah, USA), which recorded data every 30 minutes. Every two to four weeks, system batteries were changed and data were downloaded to a laptop. Data collection began in September 2004 at Transect 1 and January 2005 at Transect 7 and continued through September 2008.

Transect 1 (T1) is in an upstream, riverine area (RK 23.3; Fig. 2-1) not impacted by daily tides and has elevations ranging from 4.19 m (elevations are referenced to the National Geodetic Vertical Datum of 1929 [NGVD29]) to 1.66 m in the river channel (Fig. 2-3a). Soils on the higher elevation hydric hammock consist of Winder fine sand, transitioning to sandy clay loam at depths of ~90 cm (Mortl, 2006). In the lower floodplain, soils are classified as fluvents— stratified entisols made up of interbedded layers of sand, clay, and organic matter, typical of areas with frequent flooding and deposition (Sumner, 2000)—with sand content increasing with depth (Mortl, 2006). This freshwater transect contains hydric hammock at higher elevations and mature bald cypress swamp (average diameter at breast height [DBH] = 49 cm) at lower elevations. Invasion of less flood-tolerant species into the hydric hammock and riverine floodplain in this and other upstream areas has been documented (SFWMD, 2009), indicating the ecological impact of shortened hydroperiod.

Transect 7 (T7) is in a downstream, transitional area (RK 14.6; Fig. 2-1) that receives daily tidal flooding of varying salinity over most or all of its length and has elevations ranging from 3.07 m in the upland to 0.40 m in the floodplain (Fig. 2-3b). Soil on T7 is a highly organic muck (Terra Ceia Variant Muck; Soil Survey Staff, 1981) with depths of over 1 m, underlain by sand (Mortl, 2006). Vegetation studies indicate that this transect has been impacted by saltwater intrusion, logging, and invasion by exotic

plants (SFWMD, 2006). Presently, T7 contains a mix of floodplain swamp communities representing a gradient of decreasing salinity tolerance with increasing distance from the river. From the river's edge to approximately 30 m inland, floodplain vegetation is classified as upper tidal swamp dominated by red mangrove (*Rhizophora mangle* L.), which is highly salt tolerant. With increasing distance from the river, this community transitions to mixed tidal swamp dominated by pond apple (*Annona glabra* L.), which is moderately salt tolerant (~30 to 75 m from the river); riverine mixed swamp, which includes a mix of flood-tolerant hardwoods dominated by bald cypress, pond apple, wax myrtle (*Myrica cerfiera* L.), pop ash (*Fraxinus caroliniana* Mill.), and sabal palm (*Sabal palmetto* [Walter] Lodd. Ex Schult. & Schult. f.) (~75 to 110 m from the river); and finally riverine swamp, dominated by bald cypress and pop ash (110 to 140 m from the river) (SFWMD, 2009; Fig. 2-3b).

Dielectric Probe Principles and Operation

The Hydra FDR dielectric probe determines soil moisture and electrical conductivity (EC) by measuring soil dielectric properties. Dielectric permittivity (ε) is related to the dielectric constant (K), and the permittivity of free space (ε_o) by:

$$\varepsilon = K\varepsilon_0 \tag{2-1}$$

$$K = \varepsilon_r - i\varepsilon_i \tag{2-2}$$

where K is a complex number composed of real (ε_r) and imaginary (ε_i) dielectric constants (Campbell, 1990). The Hydra probe generates a 50 MHz electromagnetic wave, most of which is absorbed by the soil. The portion of the wave that reflects creates a standing wave, which characterizes K. The probe measures four analog voltage outputs: three to calculate ε_r and ε_i based on K and one to calculate soil

temperature. Temperature-corrected (25° C) ε_r is used to calculate volumetric soil moisture (θ) and temperature-corrected ε_i is used to calculate bulk soil EC (σ_b). Finally, σ_b and θ are used to calculate porewater EC (σ_w). Calculation of θ, σ_b, and σ_w were based on Hydra probe calibrations developed specifically for the soils of the Loxahatchee River floodplain by Mortl (2006).

Unlike synoptic weekly or monthly sample collection, automated, continuous, 30-minute monitoring of θ and σ_w using dielectric probes allowed us to investigate vadose zone hydrodynamics over different time scales (from storm event, to tidal cycle, to seasonal and interannual variation). In contrast to soil sample collection for moisture analysis and extraction of porewater for chemical analysis, this method did not require soil disturbance except during initial probe installation (and replacement, when necessary). Finally, unlike field studies of saltwater intrusion into coastal aquifers, which focus on groundwater EC in the saturated zone (e.g., Melloul and Goldenberg, 1997), the use of dielectric probes in this study allowed us to observe changes in root zone EC under inundated, saturated, and unsaturated conditions (while also providing soil moisture data).

Meteorological, Surface Water, and Groundwater Data

Average annual precipitation in the Loxahatchee River watershed is 155 cm yr^{-1}, with approximately two-thirds falling during the wet season from May to October (Dent, 1997). In southern Florida, average annual evapotranspiration (ET) losses are 114 cm yr^{-1} (SFWMD, 2002). For this study, rainfall data were recorded at the S46 hydraulic structure on the Southwest Fork and ET data were recorded at the JDWX weather station in JDSP (Fig. 2-1). These data are publicly available and were downloaded from

the SFWMD online environmental database, DBHYDRO (Stations S46_R and JDWX; accessed at http://my.sfwmd.gov/dbhydroplsql/).

Surface water elevation (SWE) and surface water EC (SWEC) were recorded at two stations in the NW Fork close to Transects 1 and 7. A SFWMD monitoring station on the headwater side of Lainhart Dam (0.45 km upstream of T1) measured average daily SWE and is available on DBHYDRO (station LNHRT_H; Fig. 2-1). The Loxahatchee River District (LRD) maintains a water quality monitoring station (datasonde station 69) on the NW Fork at Indiantown Road that measured SWEC hourly (Fig. 2-1; data acquired from LRD staff). A United States Geological Survey (USGS) monitoring station in the river at RK 14.6 (adjacent to T7) measured SWE and SWEC every 15 minutes (Station ID: 265906080093500; data acquired from USGS staff; station funded by SFWMD).

Finally, the SFWMD and Florida Park Service (FPS) installed and monitored twelve shallow groundwater wells in the floodplain of the NW Fork, including four on T7 and one on T1 (Fig. 2-3). In general, the ~500 m shallow aquifer in the area is made up of sand, limestone, and shell beds and is separated from the deeper Floridan aquifer by ~100 m of low permeability clay (Toth, 1987). However, the groundwater data presented in this study were collected in the top 1 to 5 m to assess possible shallow groundwater effects on floodplain vegetation. Wells were constructed of slotted 5.08 cm (nominally 2 in) PVC pipe housed in a 20.32 cm (nominally 8 in) PVC pipe, and were backfilled with 20/30 silica sand filter pack from 15.24 cm (nominally 6 in) below the bottom of the well to 60.96 (nominally 2 ft) above the top of the well screen. A 15.24 cm layer of 30/65 fine sand and 15.24 cm of bentonite clay were placed above the filter

pack, and the well was finished with Portland Type I neat cement grout to 15.24 cm below the top of well risers, which rose 91.44 cm (nominally 3 ft) above the ground surface. Screen size was 0.254 mm (nominally 0.01 in). Water table elevation (WTE) and groundwater EC (GWEC) data were measured every 30 minutes using TROLL 9000/9500 multi-parameter water quality probes (In-Situ Inc., Ft. Collins, CO, USA), and were analyzed in Muñoz-Carpena et al. (2008). Table 2-1 summarizes well attributes.

Soil Moisture – Surface Water Elevation Relationships

Soil moisture time series for each probe are presented as actual (measured) soil moisture using a soil-specific calibration. However, Mortl (2006) found the soils in the Loxahatchee River floodplain to fall into three distinct groups with widely varying hydrologic characteristics: sand, found primarily on the higher elevation hydric hammock on T1; fluvent, found in the floodplain on T1 and made up of interbedded layers of sand, clay, and organic matter (Sumner, 2000); and muck, found in the floodplain of T7 (Table 2-2). Thus, when comparing θ across soil categories it was helpful to normalize θ using effective soil moisture, which scales values from zero to unity and is calculated by:

$$\Theta_e = \frac{\theta - \theta_r}{\theta_s - \theta_r} \tag{2-3}$$

where Θ_e is effective soil moisture content (-), θ is the actual (measured) soil moisture content ($m^3\ m^{-3}$), θ_r is the residual soil moisture content ($m^3\ m^{-3}$), and θ_s is the saturated soil moisture content ($m^3\ m^{-3}$). Relationships between Θ_e and SWE were then explored at each transect.

For the twelve measurement locations at upstream T1, average daily Θ_e in the floodplain versus average daily SWE was fit to a common model (sigmoid, 2 parameters) of the form:

$$\Theta_e = \frac{1}{1 + e^{-\left(\frac{SWE - a}{b}\right)}} \quad (2\text{-}4)$$

where SWE is measured at Lainhart Dam (m, NGVD29), and *a* and *b* are curve parameters. The Nash-Sutcliffe Coefficient of Efficiency ($-\infty \leq C_{eff} \leq 1$, Nash and Sutcliffe, 1970) was used as a measure of goodness-of-fit. A general model and nomograph for Θ_e on T1 were then developed by investigating trends between the *a* and *b* parameters in Equation 2-4 and probe installation elevations, depths, and distances from the river. This resulting model was used to evaluate Θ_e profiles across T1 under different management scenarios.

At downstream T7, daily tidal flooding resulted in a limited range of θ near θ_s for all probes. However, responses to brief periods of drawdown in the shallowest (i.e., highest elevation) soils on T7 were evaluated using Fast Fourier Transform (FFT) smoothing (Press et al., 1992) of 15- and 30-minute θ and SWE data to investigate correlation between the series.

Surface Water, Groundwater, and Porewater EC Relationships

Based on output from a hydrodynamic salinity model (RMA-2 and RMA-4; USACE, 1996), the SFWMD (2006) developed regression equations for downstream surface water salinity at 15 sites in the NW Fork versus freshwater flow of the form:

$$Y = Y_0 + ae^{-bx} \quad (2\text{-}5)$$

where x is total freshwater flow ($ft^3 s^{-1}$) to the NW Fork from Lainhart Dam and from three tributaries (Kitching Creek, Cypress Creek, and Hobe Grove Ditch; Fig 1), Y is salinity (ppt), and Y_0, *a*, and *b* are parameters. The predictive ability of this model was tested at RK 14.6 (adjacent to T7) using flow and SWEC data observed over the four-year field study. Freshwater flow requirements to maintain SWEC below the 2 ppt bald cypress salinity threshold (equivalent to an EC of 0.3125 Siemens/meter [S/m] at 25° C [Richards, 1954]) were also identified based on measured data. Finally, σ_w values were compared with SWEC and GWEC at each transect and with the 0.3125 S/m threshold to: 1) explore relationships between the series; 2) determine the number of days that this threshold was exceeded in surface water, groundwater, and porewater; and 3) assess the likelihood that MFL and restoration scenarios will adequately control σ_w in the floodplain.

Results and Discussion

Global Descriptive Statistics

Despite difficult field conditions (hurricanes; frequent lightning strikes; inundation in saline water; equipment damage by insects and other animals; bioturbation of soil by plant roots and burrowing animals), frequent field visits ensured data completeness over the four-year study period with few gaps, with over 1.5 million measurements collected from the 24 dielectric probes (time series completeness ranged from 73% to 99.9%, (average 85%). Minimum, maximum, and average daily θ and σ_w for the 24 measurement locations are summarized in Table 2-3. (Mean daily θ and σ_w for the period of record are given in Appendix A.) Sandy soils on the hydric hammock on T1 (stations T1-60 and T1-50) had the lowest and most variable θ, with values observed

over a large range of moisture contents. On the other hand, θ was higher (at or near θ_s) and less variable in the floodplain of T1 (stations T1-30 and T1-1) and over the entire length of T7 (stations T7-135, T7-90, T7-25, and T7-2). θ_s was highest in the organic, low ρ_b muck and fluvent, but was variable within soil "groups," especially for the fluvent soil in the floodplain at T1, which had variable and alternating layers of sand, clay, and organic matter.

Probe calibrations for σ_w as a function of σ_b and θ do not hold under low soil moisture conditions (Highest, 2000), so σ_w was not calculated for the highest elevation soils on T1, which often had $\theta < 0.10$. Average σ_b measured in these soils were the lowest in the study ($0.001 \leq \sigma_b \leq 0.003$ S/m), however, suggesting that σ_w is not a concern in this area. Maximum daily average σ_w over the four-year study (0.220 S/m) was observed at upstream station T1-1, which is above the influence of daily tides. Maximum 30-minute σ_w (0.596 S/m) was recorded at downstream station T7-25, which receives daily tidal flooding.

The hydrological data collected during this study represent a wide range of climatic conditions, including four wet/dry seasonal cycles; two wet years with hurricane-induced flooding (2004 and 2005); and the driest two-year period (2006 to 2007) recorded in south Florida since 1932 (Neidrauer, 2009). The dynamics (magnitude, duration, and timing) of θ and σ_w variation, and how these variables relate to rainfall, surface water, and groundwater, are explored further in Figs. 2-4 and 2-5 and sections below.

Hydrological Time Series

Upstream transect 1

Fig. 2-4 shows selected hydrological time series collected on or near upstream T1. Large rainfall events coincided with peaks in SWE and WTE series, which were closely correlated (r = 0.93) during wet seasons (Fig. 2-4a). During dry periods, SWE at Lainhart Dam remained relatively level close to the dam overflow elevation due to the impoundment, and flow over the dam (~0.5 $m^3 s^{-1}$, about one-half of the MFL) was insufficient to keep the floodplain at T1 hydrated. WTE at T1 fell below SWE measured at Lainhart Dam in each of the four dry seasons observed, driven by ET and low rainfall (most drastically in 2006 and 2007). However, SWE data measured adjacent to the transect from July to December 2008 (SFWMD, unpublished data; not shown) showed that WTE at T1 was always greater than the adjacent SWE during this period, indicating that the NW Fork likely has consistent gaining stream conditions in this location.

SWE and WTE dynamics were reflected in θ time series (Fig. 2-4b-c), especially in the highest elevation soils on T1. For example, large θ peaks in surface soils in 2005 corresponded to intense rainfall events (and attendant increases in SWE and WTE) associated with three tropical storms that passed over the experimental area in July, September, and October of that year (Fig. 2-4b, solid line). Variation in θ was damped for middle elevation soils, but effects of environmental conditions (rain, SWE, and WTE) were still apparent (Fig. 2-4b, dashed line). The lowest elevation (i.e., deepest) soils experienced long periods of saturation (Fig. 2-4b, dotted line). Even at this depth, however, soils dried down to θ_r for long periods during the dry seasons of 2005, 2006, and 2007. This frequently dry soil profile in the hydric hammock root zone helps explain

the invasion of upland plant species such as slash pine (*Pinus elliottii* Engelm.) and the exotic Caesar-weed (*Urena lobata* L.) into the hydric hammock observed in SFWMD (2009).

In the lower floodplain, θ was less variable, although surface soils experienced considerable drying during all dry seasons (most markedly in 2006 and 2007; Fig. 2-4c, solid line). While θ values between 0.5 and 0.7 would not be considered "dry" in a mineral soil, they corresponded to very dry conditions at the soil surface of the highly organic and clayey soils in the floodplain at T1. Under these moisture conditions, soil shrank away from tree trunks, and facultative wetland plant species like sabal palm, Hottentot fern (*Thelypteris interrupta* [Willd.] K. Iwats.), and the exotic wild arrowleaf elephantear (*Xanthosoma sagittifolium* [L.] Schott) invaded the floodplain (SFWMD, 2009), competing with floodplain species for water, light, nutrients, and space. Overly dry surface soils are also unfavorable for bald cypress seed germination (Middleton, 1999). Even when surface soils re-saturated by fall (when cypress seeds drop) the area for successful seed germination was reduced by the invasion of facultative and upland species during previous dry-downs. Lower elevation soils in the floodplain on T1 remained consistently saturated, though at slightly different values of θ_s due to the heterogeneity of soil layering in the floodplain (Fig. 2-4c, dashed and dotted lines). This suggests that mature trees with developed root systems experienced little or no water stress.

On T1, SWEC and GWEC were low and had similar magnitudes (average of 0.054 and 0.068 S/m, respectively), remaining well below the 0.3125 S/m threshold over the entire study period (Fig. 2-4d). In the floodplain, σ_w was consistently higher than SWEC

and GWEC (by a factor of 2-3 times) (Fig. 2-4e-f), although no consistent relationships between σ_w and other hydrological or meteorological variables were found. Values of σ_w were highest in the surface soils closest to the river and exceeded the 0.3125 S/m threshold (though slightly) for 59 days in 2007 (Fig. 2-4f, solid line). Based on the data recorded in this study, it is unlikely that σ_w reaches high enough levels to cause acute salt stress to bald cypress on T1, even during extended dry periods. It may cause chronic stress for shallow-rooted, salt-sensitive species, however, which could be ameliorated by more frequent, longer-duration inundation of the floodplain by the adjacent (low EC) surface water (Richardson and Hussain, 2006; Abrol et al., 1988).

Downstream transect 7

Fig. 2-5 shows selected hydrological time series collected on or near downstream T7. SWE at downstream T7 is influenced primarily by daily and monthly tidal cycles, though high water events may also be associated with storm surges and large rainfall events. For example, high SWE in September 2004 was caused by tidal surge and increased freshwater flow in the NW Fork during Hurricanes Frances and Jeanne, which passed over the study site (Fig. 2-5a). WTE in the upland well on T7 (T7-W4; Fig. 2-5b, dark line) showed responses to wet and dry season rainfall patterns similar to those observed in upstream SWE and WTE. During the dry seasons of 2006 to 2007, WTE in this well fell considerably, but remained higher than WTE in floodplain wells (Fig. 2-5b, lower lines), which were lower (close to mean sea level, NGVD29) and more influenced by daily tidal oscillations. This indicates a variable but consistently positive flow of freshwater from the uplands to the river through the floodplain, even under extreme drought conditions.

Upland well T7-W4 had the lowest GWEC on T7 (Fig. 2-5c, lower dashed line). This low GWEC, combined with the maintenance of high WTE in the upland, likely plays a role in regulating σ_w and GWEC in the floodplain, mitigating the severity of saltwater intrusion at this transect. GWEC was generally highest closest to the river and decreased with distance towards the upland, though this trend reversed in 2007, when GWEC in well T7-W2 surpassed that of well T7-W1 for the duration of the year before falling in 2008 (Fig. 2-5c). GWEC approached the 0.3125 S/m threshold only briefly at the end of 2007 in well T7-W2, several months after peaks in SWEC and σ_w (Fig. 2-5d-f). Based on these data, it is unlikely that groundwater directly contributes to increases in the σ_w observed on this transect; instead GWEC shows a damped and delayed response to high EC surface water.

Peaks in SWEC at T7 occurred in four distinct periods corresponding to dry seasons with low rainfall and low upstream SWE (Fig. 2-5d), though the peak was earlier in 2005 (centered around March) than in other years (centered around May). SWEC measured at 15-minute intervals reached maxima of 1.250 to 2.890 S/m during the dry seasons of 2005 to 2008 (4 to 9 times the 0.3125 S/m threshold). Since SWEC at RK 14.6 varied over a tidal cycle, daily average SWEC maxima were lower (~1 to 5 times the threshold), but still exceeded the threshold for 6 days in 2005; 18 days in 2006; and 64 days in 2007.

Peaks in σ_w corresponding to SWEC were observed across T7 during each dry season (Fig. 2-5e-f). At station T7-135 (farthest from the river), peaks in σ_w increased in magnitude from 2005 through 2007, but reached the critical limit only for a brief period in 2007, and only in the highest elevation soils (Fig. 2-5e, solid line). The lowest

elevation soils at this station (Fig. 2-5e, dotted line) had low σ_w throughout the measurement period, similar in magnitude to GWEC in upland well T7-W4 (Fig. 2-5c). Despite repeated SWEC peaks at RK 14.6, σ_w in the soil profile 135 m from the river remained relatively low. Time series of σ_w from station T7-90 (not shown) were similar to those at station T7-135, with σ_w approaching the critical value only in the dry season of 2007.

Station T7-25 is closer to the river, where vegetation transitions to salt-tolerant mangroves (Fig. 2-3b). Here σ_w was higher (Fig. 2-5f), exceeding the critical value for a considerable time in 2007: 53, 55, and 34 days in the surface, middle, and lower probe elevations, respectively (not including days during a gap in data). Linear interpolation of the σ_w trend during this data gap yields an estimate of 83, 85, and 64 days in 2007 when σ_w exceeded the critical threshold at the three measurement elevations. Data from station T7-2 (not shown) closely mirrored the timing and magnitude of σ_w data from station T7-25, but with slightly lower σ_w and longer lags (up to 90 days) between SWEC and σ_w peaks in the lowest elevation soils.

Table 2-4 summarizes the duration of SWEC, GWEC, and σ_w exceedances on T7 from 2005 to 2008. SWEC exceeds the 0.3125 S/m limit for extended periods of time in three of the four study years, but does not explain the distribution of variably salt-tolerant vegetation across the transect, since the entire floodplain is inundated twice daily by tidal flooding. While GWEC generally decreased with increasing distance from the river, it was lower than the critical salinity threshold at all locations on all but three days of the four year study period, and thus also failed to explain observed vegetation patterns. On the other hand, the twelve σ_w data series described EC dynamics at the

interface between surface water and groundwater (i.e., in the vadose zone), and showed that σ_w in the soil profile was above the critical limit 2 m and 25 m from the river (where vegetation is dominated by salt-tolerant mangroves), but below the limit 90 m and 135 m from the river (where vegetation consists of riverine and mixed swamps, dominated by bald cypress and pop ash; Fig. 2-3b). This suggests that σ_w dynamics help to explain the distribution of variably salt-tolerant species across the floodplain, which neither SWEC nor GWEC were able to do.

Finally, T7 has very little variation in elevation and received tidal inundation over most or all of its length nearly every day. Thus, θ values on this transect were relatively constant at or near θ_s and are not shown.

Surface Water – Soil Moisture Relationships

Upstream transect 1

Average daily θ in the floodplain of T1 was scaled to Θ_e, plotted against average daily SWE at Lainhart Dam, and fit to the common sigmoid model given in Equation 2-4 (Fig. 2-6) with good results (overall C_{eff} = 0.92 for the 12 measurement locations). Values of θ_s for the three soil groups given in Mortl (2006) were based on composite soil samples and did not represent the variability in θ_s observed on T1, especially in the layered soils of the fluvent. Thus, Θ_e was calculated using observed θ maxima during periods when WTE (measured in well T1-W1) was above probe installation elevation. Fit parameters, θ_s values used for calculation of Θ_e, and C_{eff} values for each time series are summarized in Table 2-5. For soils that exhibited a wide range of θ (high and middle elevation sandy soils on the hydric hammock), the model did a good job of predicting soil moisture based on SWE ($0.64 \leq C_{eff} \leq 0.82$). For deeper sandy soils,

which were below the water table for long periods, and surface soils of the lower floodplain, which only rarely dry out, the sigmoid model performed fairly ($0.33 \leq C_{eff} \leq 0.78$). For the lowest elevation soils of the floodplain, which remained saturated for the entire study period, the two-parameter model is simplified to the equation $\Theta_e = 1$, independent of SWE (with a corresponding $C_{eff} = 1.0$).

While consideration of rain, ET, antecedent moisture conditions, and surface topography would improve the model's predictive ability, this simplified relationship is useful for evaluating the effects of river management on θ profiles, since MFL and restoration scenarios are based on flow at Lainhart Dam (calculated from SWE). We also recognize that underlying this Θ_e-SWE model is the fundamental relationship describing θ as a function of soil water pressure head (ψ) (e.g., Brooks and Corey, 1964; van Genuchten, 1980). Under relatively hydrostatic conditions (i.e., no inflow, outflow, or redistribution of soil water above the water table), ψ can be estimated as the distance to the water table (Skaggs, 1991). Since SWE and WTE at T1 are tightly coupled (overall $r^2 = 0.88$), directly linking θ to SWE is consistent with these fundamental relationships.

In general, Equation 2-4 yielded increasingly dry soil moisture profiles with increasing elevation. To expand the applicability of this model to the remainder of the floodplain at T1, trends between *a* and *b* parameters and probe installation elevations and distances from the river were examined. Plotting *a* and *b* versus probe installation elevation and fitting a 3rd order polynomial yielded good results ($r^2 = 0.96$ and 0.78 for *a* and *b*, respectively), with:

$$a = 1.425x^3 - 13.421x^2 + 42.241x - 41.171 \quad (2\text{-}6)$$

$$b = 0.248x^3 - 2.112x^2 + 5.873x - 5.249 \quad (2\text{-}7)$$

where x is topographical elevation (m, NGVD29). Overall C_{eff} for the twelve Θ_e time series using the approximations in Equations 2-6 and 2-7 was 0.83. Including both elevation and distance from the river as variables for fitting the parameters in Equation 2-4 yielded a better fit (3rd order polynomial in elevation and distance; r^2 of 0.99 and 0.96 for *a* and *b* parameters; overall C_{eff} = 0.91), as might be expected based on the effects of surface topography, shape of the water table, and soil heterogeneity.

To assess the added benefit of the more complex model based on elevation and distance from the river, both models were used to estimate Θ_e at the soil surface, 10 cm below ground surface (bgs), and 50 cm bgs at four distances from the river (60, 50, 30, and 1 m) under three flow scenarios in the MFL and restoration plan. Differences in model results were generally small (average absolute difference of 4.6, 4.3, and 5.4% at the three depths). The largest differences were seen 50 m from the river (Fig. 2-3a), where elevation changes abruptly. Ultimately, the simpler model was preferred because it had fewer parameters, performed adequately, and is consistent with the underlying soil physics (assuming a relatively flat water table over the length of T1).

A nomograph describing Θ_e at T1 was developed based on the simpler model (Fig. 2-7), which can be used to estimate moisture profiles across the floodplain under different river management scenarios. For example, the MFL of 1 $m^3 s^{-1}$ corresponds to SWE of 3.31 m at Lainhart Dam. This yields a Θ_e profile ranging from 0.06 on top of the hydric hammock to 1.00 in the consistently flooded soils of the floodplain, with Θ_e = 0.86 at the lower floodplain soil surface (average elevation 2.81 m, black circle in Fig. 2-7). Specific moisture thresholds for bald cypress seed germination success have not been

identified; however assuming that a value of $\Theta_e \geq 0.90$ corresponds to "moist" organic soil conditions, ideal bald cypress seedling germination conditions at the soil surface would require maintenance of SWE at Lainhart Dam between 3.35 m and 3.52 m (gray shaded area in Fig. 2-7), above which the floodplain is generally inundated (SFWMD, 2006). The restoration plan calls for a variable dry season flow between 1.42 and 3.11 $m^3 s^{-1}$, which corresponds to SWE of 3.36 to 3.52 m at Lainhart Dam. Thus, dry season restoration flows should provide good conditions for bald cypress seedling germination in the floodplain, while the MFL is likely insufficient to maintain the bald cypress ecosystem at T1.

Downstream transect 7

Due to daily tidal inundation, θ was relatively consistent over the study period, with very little variation regardless of elevation or distance from the river. However, inspection of θ data from the highest elevation (i.e., shallowest) probe revealed a correlation between θ and SWE. Fig. 2-8 shows a six-day time series of soil moisture for the highest elevation probe on T7 (T7-135, 0.37 m). Fourier smoothing of 30-minute θ data and 15-minute SWE data to 6-hour time series reveals that when mean SWE is above the probe elevation, θ and SWE are tightly coupled, with coinciding peaks and valleys corresponding to low and high tides. When mean tide drops below probe elevation, this relationship breaks down, and the surface soil continues to dry (though slightly).

The total range of variation in soil moisture observed at T7 is small (a change of 1.24% between saturation and "drawdown" moisture contents in Fig. 2-8) and is unlikely to affect seed germination or seedling survival at this transect. Instead, germination and

seedling survival here are likely more limited by tidal inundation range and periods of high SWEC and σ_w.

Surface Water, Groundwater, and Porewater EC Relationships

A basic premise of the restoration plan is that supplying additional freshwater flow over Lainhart Dam will reduce SWEC downstream, reducing the extent of saltwater intrusion. Plotting SWE at Lainhart dam against SWEC at RK 14.6 confirms this relationship (Fig. 2-9). The regression equation developed for downstream salinity based on total freshwater flow to the NW Fork (Equation 2-5; SFWMD, 2006) did a fair job of representing the observed data from 2004 to 2008 at this location (C_{eff} = 0.42, r^2 = 0.51). Re-fitting the parameters in Equation 2-5 using four years of observed data yielded only slightly better results (C_{eff} = 0.55, r^2 = 0.54). This is because SWEC at RK 14.6 was highly variable when total flow to the NW Fork was less than ~2.7 $m^3 s^{-1}$. As noted in SFWMD (2006), freshwater flow was identified as the most important variable affecting downstream SWEC, but daily variations in tide, wind speed and direction, groundwater fluxes, and precipitation and ET also drive downstream SWEC.

Accepting this variability, it is useful to identify specific management thresholds required to maintain SWEC below the 0.3125 S/m threshold, again using SWE at Lainhart Dam as the primary controllable variable in the system. Based on the range of measurements observed during this study, SWE at Lainhart dam should be maintained ≥ 3.40 m to keep SWEC at RK 14.6 below the threshold 100% of the time, while maintaining SWE at 3.31 m would prevent 95% of all salinity events exceeding 0.3125 S/m (vertical dashed line in Fig. 2-9). SWE of 3.31 m at Lainhart Dam corresponds to a freshwater flow of ~1.0 $m^3 s^{-1}$, which is the MFL selected for the NW Fork of the

Loxahatchee River. The restoration plan identifies a mean monthly restoration flow of 1.95 $m^3 s^{-1}$, which corresponds to a SWE of 3.42 m. Thus, despite only fair agreement between earlier modeling results and observed data, flows identified in the MFL and Restoration Plan would have been sufficient to maintain SWEC at RK 14.6 below 0.3125 S/m 95% and 100% of the time, respectively, during this four-year study.

Next, σ_w in the floodplain was compared with SWEC in the river channel and GWEC at each transect. At upstream T1, σ_w was consistently 2-3 times SWEC and GWEC, however no clear relationships between σ_w and SWE, SWEC, WTE, or GWEC series were apparent. At T7, there was a lag between SWEC and σ_w time series. These delays ranged between 22 and 90 days and increased with depth and distance from the river. Peaks in σ_w were also more persistent than those in SWEC, lasting as much as seven months after SWEC had returned to lower levels (Fig. 2-5e-f). These σ_w dynamics suggest that salts move from the river into the floodplain soils as a diffusive wave at T7. During wet seasons and on the rising limb of σ_w peaks, σ_w was highest in surface soils and decreased with depth at all locations. This trend was reversed on the falling limb of σ_w peaks, as the deeper soils lagged behind (e.g., Fig. 2-5f).

Since soils at T7 are consistently at or near saturation, high EC surface water inundating the floodplain causes little advective flux of salts into the soil. Instead, salts in daily tidal floodwaters diffuse into the porewater of saturated surface soils and then move downward in the soil profile as a diffusive front. This pattern is reversed when SWEC decreases and tidal floodwaters flush salts from the system, reducing σ_w from the top down. This mechanism also explains the lag between SWEC and σ_w series.

Despite this lag and the persistence of high σ_w after SWEC decreases, some trends between the two series at T7 are apparent. Most importantly, SWEC peaks at RK 14.6 were always greater than the corresponding σ_w peaks, indicating that restoration scenarios designed to maintain SWEC in the river channel below the 0.3125 S/m threshold will also prevent σ_w exceedances in the floodplain. The spatial relationship between SWEC and σ_w across the floodplain at T7 is illustrated in Fig. 2-10, which shows the average, minimum, and maximum ratios between SWEC and σ_w peaks for high, middle, and low elevation measurement locations. In general, the σ_w/SWEC ratio was high close to the river and decreased with distance, though the highest ratios were observed slightly away (25 m) from the river. This agrees with observations from other tidal systems (e.g., Adams, 1963; Niering and Warren, 1980), where greater high tide flushing and low tide drainage were hypothesized to cause lower salinities at the channel edge than in the interior. At the extremes, σ_w peaks in the floodplain reached a maximum of 63% of the SWEC peaks observed at RK 14.6 (in the highest elevation soils at station T7-25; Fig. 2-10a) and less than 1% of SWEC (in the lowest elevation soils at station T7-135; Fig. 2-10c). While wide, these ranges can be used to determine the range of probable σ_w peaks in the floodplain based on measured or modeled SWEC at RK 14.6.

Summary and Conclusions

Bald cypress floodplain swamp and hydric hammock have been identified as valued ecosystem components (VECs) in the Northwest Fork of the Loxahatchee River (NW Fork), which has suffered from increased salinity and reduced hydroperiod due to hydrologic modifications in the watershed. The NW Fork has been the focus of

intensive data collection and modeling efforts aimed at developing ecosystem restoration scenarios to benefit VECs, but previous studies had overlooked hydrological conditions in the floodplain vadose zone. To meet the goal of protecting and restoring bald cypress swamp, this four-year study investigated soil moisture (θ) and soil porewater electrical conductivity (σ_w) dynamics in the floodplain of the Loxahatchee River at two transects—an upstream, freshwater transect dominated by bald cypress (T1) and a downstream, transitionally-tidal transect with a mix of freshwater and salt-tolerant species (T7). These data were complemented by collocated surface water and groundwater stage and salinity and meteorological data.

The study provides a quantitative validation of our qualitative expectations that complex interactions of rainfall, surface water, and groundwater dominate the dynamics of θ and σ_w in coastal wetlands, and that hydraulic structure effects in these areas propagate in the floodplain vadose zone some distance from the structure. In particular, upstream σ_w rarely exceeded tolerance thresholds for bald cypress, but did so more frequently (and for longer duration) in some downstream areas. These data provided a better explanation for the observed spatial patterns of floodplain vegetation than either surface water or groundwater data, reinforcing the importance of monitoring in the vadose zone.

Additionally, mechanistic frameworks using conditional modeling approaches can benefit from an improved understanding of which variables are most important within the floodplain. For instance, dynamic θ conditions in the upstream riverine floodplain were successfully modeled as a function of surface water elevation (SWE), while θ variation in the downstream tidal floodplain was small (though twice daily tidal

inundation might limit seed germination and seedling survival to isolated microtopographic points). The θ and σ_w relationships drawn in the study allow us to assess the likely impacts of restoration and management scenarios on the ecological communities in the floodplain of the Loxahatchee River. For example, the proposed restoration flow scenario (which was developed based on floodplain inundation and downstream surface water quality performance measures) will provide good θ conditions for bald cypress seed germination in the riverine floodplain at T1 during the dry season and maintain σ_w in the soil profile below the bald cypress tolerance threshold at T7.

The field and analytical methods used here can be successfully applied to other locations where restoration of floodplain ecosystems depends on hydrological conditions in the vadose zone. These efforts would be further improved by species-specific studies of moisture requirements for seed germination and studies on the effects of variable tidal inundation on the seeds and seedlings of important floodplain species. Continued monitoring of river and floodplain hydrology and vegetation in the Loxahatchee River will be important to determine whether the restoration flow scenario is achieving the goal of protecting and restoring VECs.

Table 2-1. Locations and attributes of the five groundwater wells in the study. Wells are distributed across two transects (T1 and T7). River kilometer indicates distance from the river mouth. Well elevation denotes elevation at the ground surface.

Well	Transect Type	River Kilometer	Distance from River (m)	Well Elevation (m, NGVD29)	Screened elevation (m, NGVD29)
T1-W1	Riverine	23.3	50	3.28	1.51 – 2.12
T7-W1	Transitional	14.6	2	0.36	-1.49 – -0.88
T7-W2			30	0.43	-1.40 – -0.79
T7-W3			90	0.56	-1.13 – -0.52
T7-W4			130	2.94	-0.73 – 0.79

Table 2-2. Characteristics of the three Loxahatchee River floodplain soil categories described by Mortl (2006).

Soil Category	ρ_b (g cm^{-3})[†]	K_s (cm/hr)[‡]	θ_r[§]	θ_s[§]	%C[¶]
Sand	1.36 ± 0.18[#]	37.04 ± 7.70	0.04	0.40	0.45
	(1.06 - 1.55)	(29.26 - 48.42)			(0.10 - 0.48)
Fluvent	0.69 ± 0.38	84.33 ± 83.52	0.20	0.90	11.0
	(0.30 - 1.22)	(0.81 - 166.17)			(1.0 - 15.0)
Muck	0.25 ± 0.15	3.05 ± 2.29	0.20	0.90	20.0
	(0.14 - 0.54)	(0.23 - 7.18)			(5 - 25)

[†]Field bulk density
[‡]Saturated hydraulic conductivity
[§]Residual (θ_r) and saturation (θ_s) soil moisture
[¶]Percent carbon
[#]Mean ± SD (range in parenthesis)

Table 2-3. Summary of experimental data from the 24 probes on Transect 1 (T1, upstream) and Transect 7 (T7, downstream). Probe naming convention indicates transect number (T1/T7), distance from the river (m), and probe elevation (m, NGVD29).

		θ† (m^3 m^{-3})		σ_w‡ (S/m)	
Probe	*n*	Transect 1 - Hydric Hammock/Riverine Swamp			
T1-60 (3.90 m)	69169	0.06 ± 0.05	(0.01 - 0.41)§	---¶	---¶
T1-60 (3.80 m)	69077	0.13 ± 0.09	(0.02 - 0.50)	---¶	---¶
T1-60 (3.60 m)	69004	0.24 ± 0.11	(0.01 - 0.40)	---¶	---¶
T1-50 (3.71 m)	72765	0.11 ± 0.08	(0.02 - 0.56)	---¶	---¶
T1-50 (3.41 m)	72681	0.22 ± 0.13	(0.03 - 0.45)	---¶	---¶
T1-50 (3.06 m)	72739	0.29 ± 0.08	(0.07 - 0.38)	0.052 ± 0.011	(0.000 - 0.099)
T1-30 (2.76 m)	67061	0.70 ± 0.06	(0.56 - 0.76)	0.089 ± 0.057	(0.000 - 0.210)
T1-30 (2.51 m)	66970	0.75 ± 0.02	(0.71 - 0.79)	0.128 ± 0.044	(0.000 - 0.205)
T1-30 (2.21 m)	66917	0.74 ± 0.01	(0.71 - 0.77)	0.091 ± 0.007	(0.078 - 0.110)
T1-1 (2.71 m)	65446	0.80 ± 0.07	(0.56 - 0.91)	0.220 ± 0.063	(0.114 - 0.412)
T1-1 (2.46 m)	63948	0.77 ± 0.03	(0.71 - 0.82)	0.124 ± 0.029	(0.072 - 0.229)
T1-1 (2.24 m)	67057	0.66 ± 0.01	(0.62 - 0.69)	0.153 ± 0.015	(0.110 - 0.193)
Probe	*n*	Transect 7 - Mixed Freshwater and Mangrove Swamps			
T7-135 (0.37	65447	0.80 ± 0.05	(0.75 - 0.90)	0.065 ± 0.069	(0.000 - 0.379)
T7-135 (0.17	65447	0.83 ± 0.05	(0.75 - 0.88)	0.043 ± 0.054	(0.000 - 0.285)
T7-135 (-0.10	65448	0.78 ± 0.02	(0.75 - 0.81)	0.007 ± 0.017	(0.000 - 0.091)
T7-90 (0.27 m)	65565	0.77 ± 0.02	(0.74 - 0.84)	0.131 ± 0.058	(0.040 - 0.287)
T7-90 (0.10 m)	64998	0.79 ± 0.02	(0.75 - 0.86)	0.121 ± 0.037	(0.057 - 0.273)
T7-90 (-0.10 m)	64124	0.77 ± 0.02	(0.75 - 0.81)	0.120 ± 0.048	(0.042 - 0.332)
T7-25 (0.20 m)	61006	0.80 ± 0.03	(0.75 - 0.86)	0.094 ± 0.098	(0.000 - 0.596)
T7-25 (-0.03 m)	60956	0.82 ± 0.04	(0.75 - 0.90)	0.109 ± 0.087	(0.024 - 0.553)
T7-25 (-0.23 m)	61009	0.82 ± 0.03	(0.75 - 0.91)	0.104 ± 0.087	(0.020 - 0.501)
T7-2 (0.30 m)	60062	0.77 ± 0.03	(0.75 - 0.83)	0.114 ± 0.101	(0.018 - 0.556)
T7-2 (0.14 m)	56569	0.77 ± 0.02	(0.75 - 0.79)	0.123 ± 0.093	(0.018 - 0.480)
T7-2 (-0.20 m)	57375	0.75 ± 0.01	(0.75 - 0.77)	0.103 ± 0.078	(0.021 - 0.337)

† Soil moisture

‡ Porewater electrical conductivity

§ Mean ± SD (range in parentheses)

¶ Calibration for σ_w does not hold at low θ, however average bulk soil EC (σ_b) was extremely low in these soils

Table 2-4. Number of days that the 2 ppt (0.3125 S/m) bald cypress tolerance threshold was exceeded in porewater, surface water, and groundwater at Transect 7. Vadose zone monitoring stations and groundwater wells in which EC did not exceed 0.3125 S/m in any year are excluded.

Porewater	2005	2006	2007	2008
T7-135 (0.37 m)	0	0	26	0
T7-90 (-0.10 m)	0	0	6	0
T7-25 (0.20 m)	0	0	83	0
T7-25 (-0.03 m)	0	0	85	0
T7-25 (-0.23 m)	0	0	64	0
T7-2 (0.30 m)	0	0	113	0
T7-2 (0.14 m)	0	0	51	0
T7-2 (-0.2 m)	0	0	9	0
Surface Water				
RK 14.6	6	18	64	0
Groundwater				
T7-W2	0	0	3	0

Table 2-5. Saturated soil moisture content (θ_s) used to calculate effective soil moisture (Θ_e) and parameters fit to Equation 2-4 to model Θ_e as a function of surface water elevation on Transect 1. The Nash-Sutcliffe Coefficient of Efficiency (C_{eff}) was used to assess model goodness-of-fit.

Probe	θ_s	*a*	*b*	C_{eff}
T1-60 (3.90 m)	0.40	3.91	0.24	0.64
T1-60 (3.80 m)	0.35	3.63	0.15	0.72
T1-60 (3.60 m)	0.28	3.33	0.06	0.78
T1-50 (3.71 m)	0.34	3.63	0.16	0.77
T1-50 (3.41 m)	0.35	3.41	0.07	0.82
T1-50 (3.06 m)	0.33	3.26	0.06	0.65
T1-30 (2.76 m)	0.74	3.01	0.12	0.54
T1-30 (2.51 m)	0.74	2.75	0.12	0.33
T1-30 (2.21 m)	0.71	---†	---†	1.00
T1-1 (2.71 m)	0.80	3.13	0.09	0.51
T1-1 (2.46 m)	0.75	2.76	0.12	0.34
T1-1 (2.24 m)	0.63	---†	---†	1.00

†For permanently flooded soils, the model for Θ_e simplifies to $\Theta_e = 1$, with $C_{eff} = 1.0$

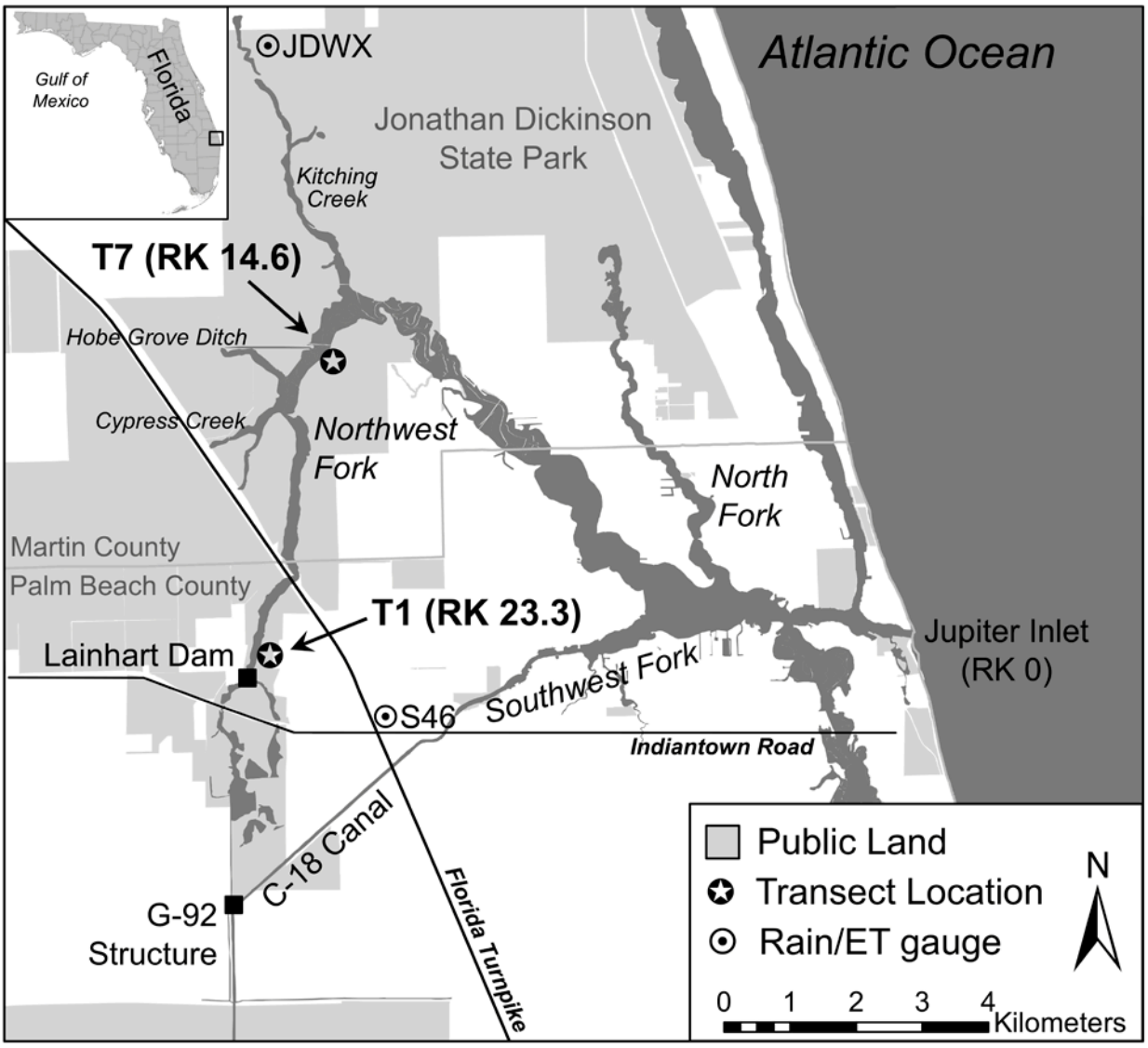

Figure 2-1. The Loxahatchee River watershed and surrounding area with transect locations (T1/T7), meteorological measurement locations (S46 and JDWX weather stations), and major hydraulic infrastructure. Transect notation is followed by distance from river mouth (river kilometer, RK).

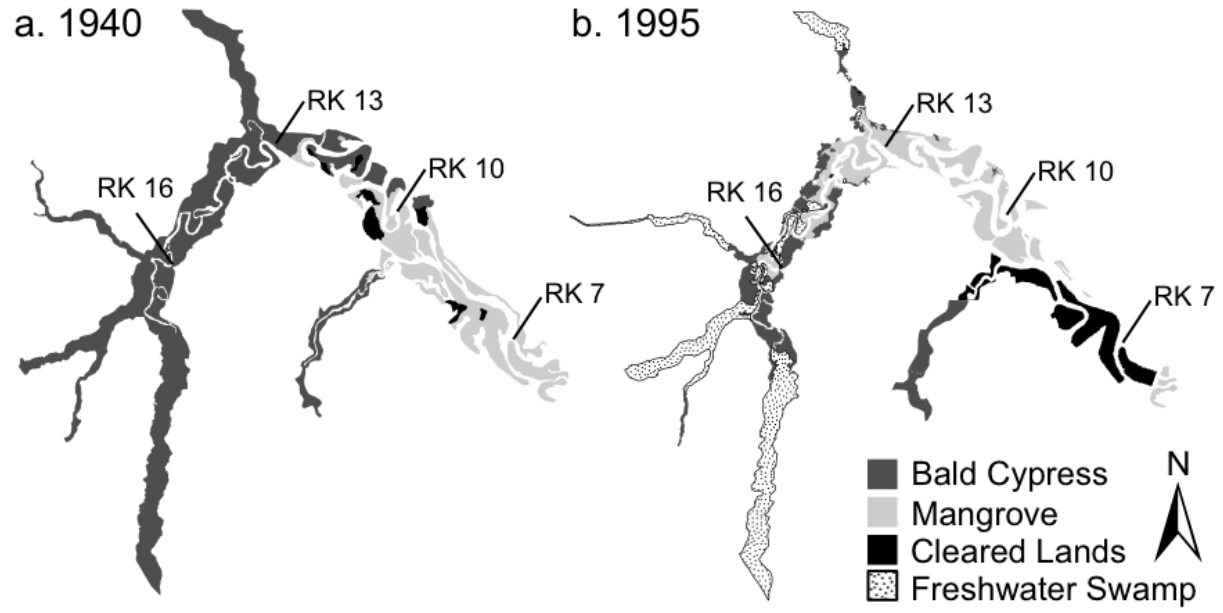

Figure 2-2. Interpretation of aerial photography of vegetation communities in the floodplain of the Northwest Fork of the Loxahatchee River in (a) 1940 and (b) 1995. Distance upstream from river mouth denoted by river kilometer (RK). By 1995, mangroves had displaced large areas of bald cypress in the lower and middle sections of the river due to saltwater intrusion. Bald cypress were present, but declining, in upstream freshwater swamp due to reduced hydroperiod. Adapted from SFWMD (2002; data acquired from SFWMD staff).

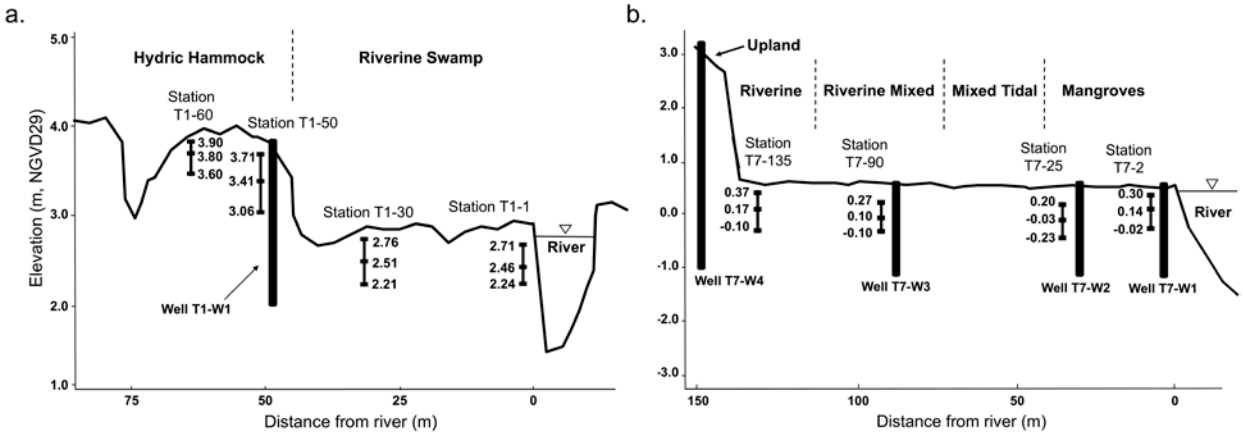

Figure 2-3. Topography and instrumentation layout of vadose zone monitoring stations and groundwater wells on (a) Transect 1 (b) and Transect 7. Station names denote transect number (T1/T7) and distance from the river (m). Probe installation elevations (m, NGVD29) listed below each station.

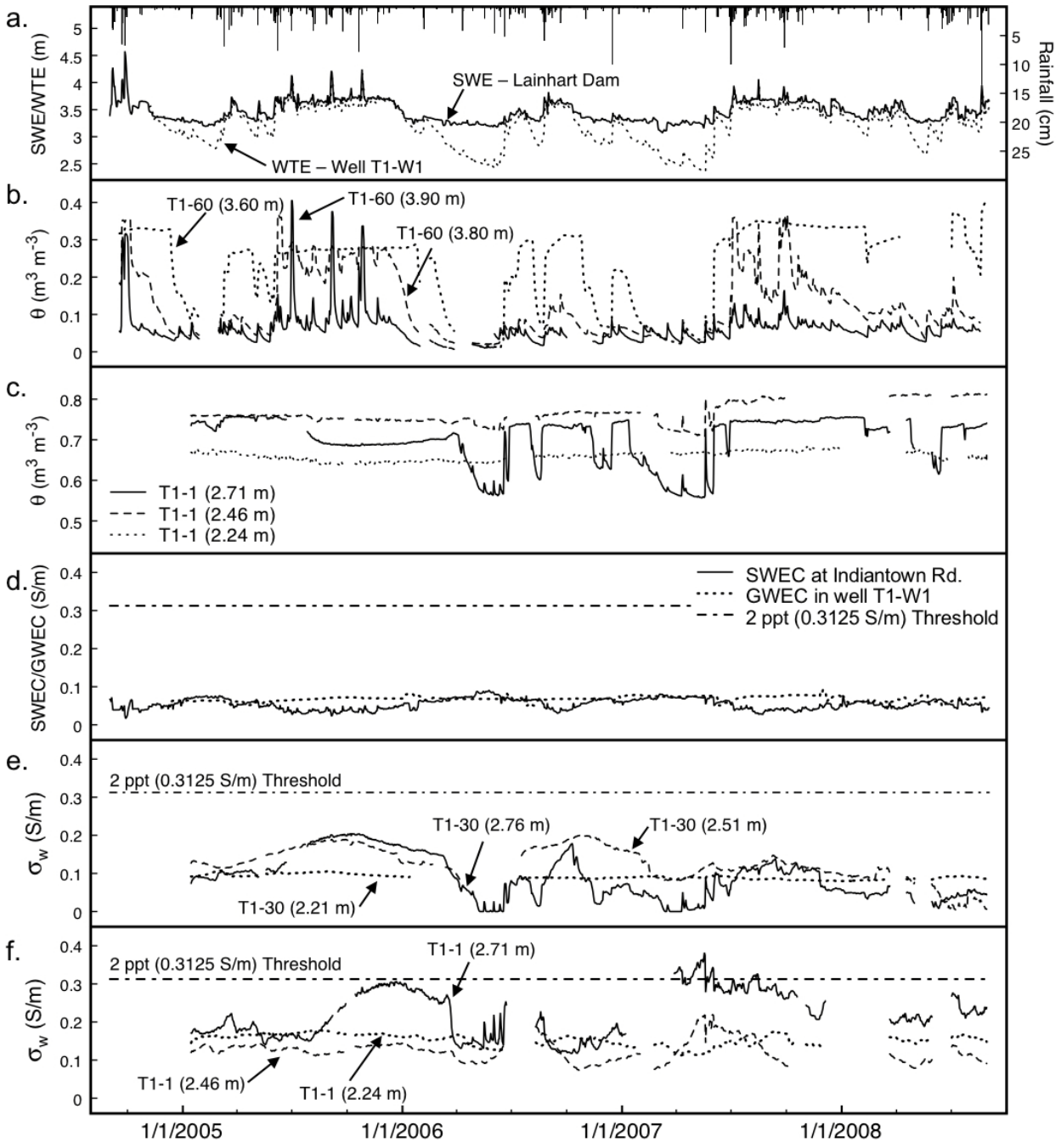

Figure 2-4. Precipitation, surface water elevation (SWE), water table elevation (WTE), soil moisture (θ), surface water and groundwater electrical conductivity (SWEC and GWEC), and soil porewater EC (σ_w) measured at selected stations on or near upstream Transect 1. Naming of vadose zone data series (θ and σ_w) indicates transect number (T1/T7), distance from river (m), and probe installation elevation (m, NGVD29).

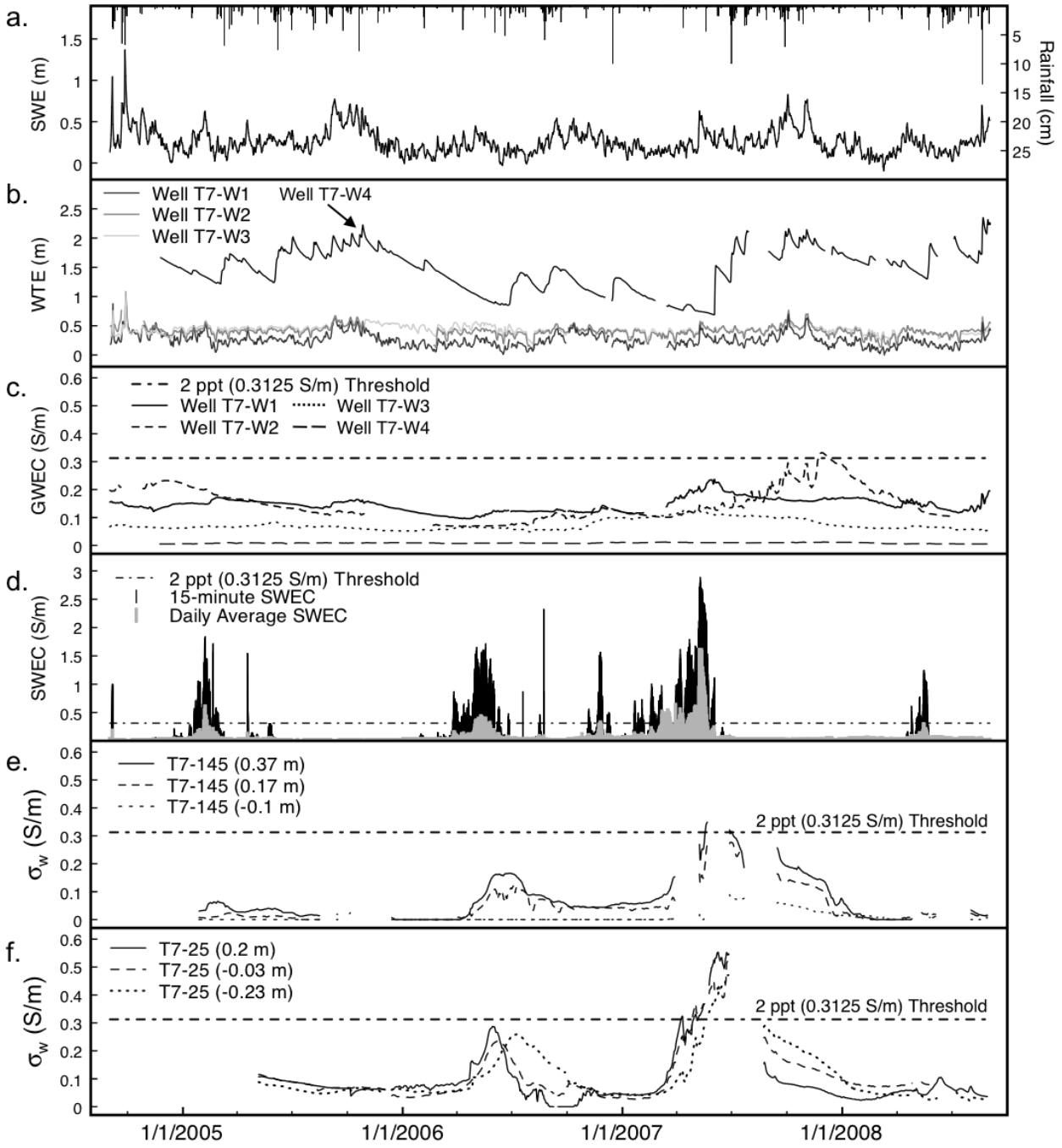

Figure 2-5. Precipitation, surface water elevation (SWE), water table elevation (WTE), surface water and groundwater electrical conductivity (SWEC and GWEC), and soil porewater EC (σ_w) measured at selected stations on or near downstream Transect 7. Naming of vadose zone data series (σ_w) indicates transect number (T1/T7), distance from river (m), and probe installation elevation (m, NGVD29).

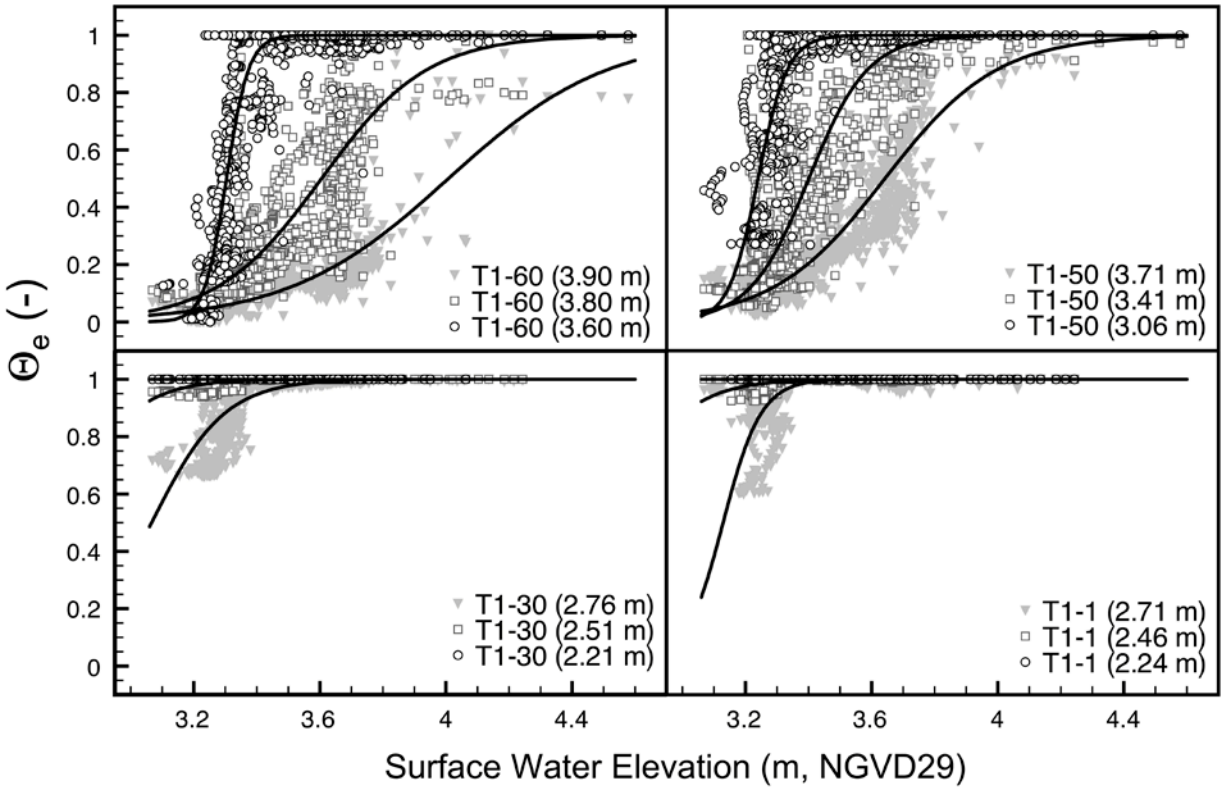

Figure 2-6. Observed (symbols) and modeled (lines) effective soil moisture (Θ_e) versus surface water elevation at Lainhart Dam for the 12 monitoring locations on Transect 1.

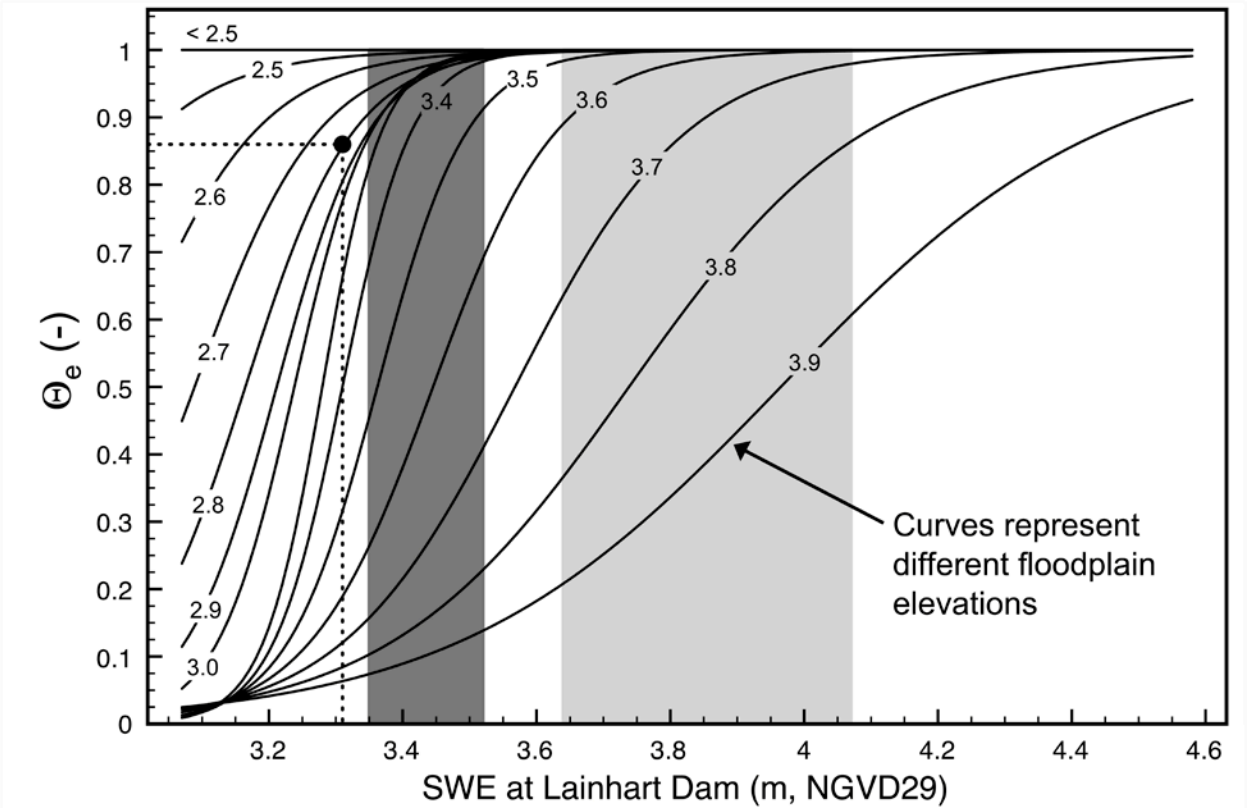

Figure 2-7. Nomograph for estimating effective soil moisture (Θ_e) profiles on Transect 1 based on surface water elevation (SWE) at Lainhart Dam and soil elevation (m, NGVD29; labeled on curves). Filled circle represents Θ_e at the average soil surface elevation (2.81 m) in the lower floodplain under the minimum flow level (SWE =3.31 m). Dark shaded area corresponds to dry season flow levels (3.35 ≤ SWE ≤ 3.52) and light shaded area corresponds to wet season floods with 1- to 2-year return interval (3.64 ≤ SWE ≤ 4.07), as identified in the restoration plan.

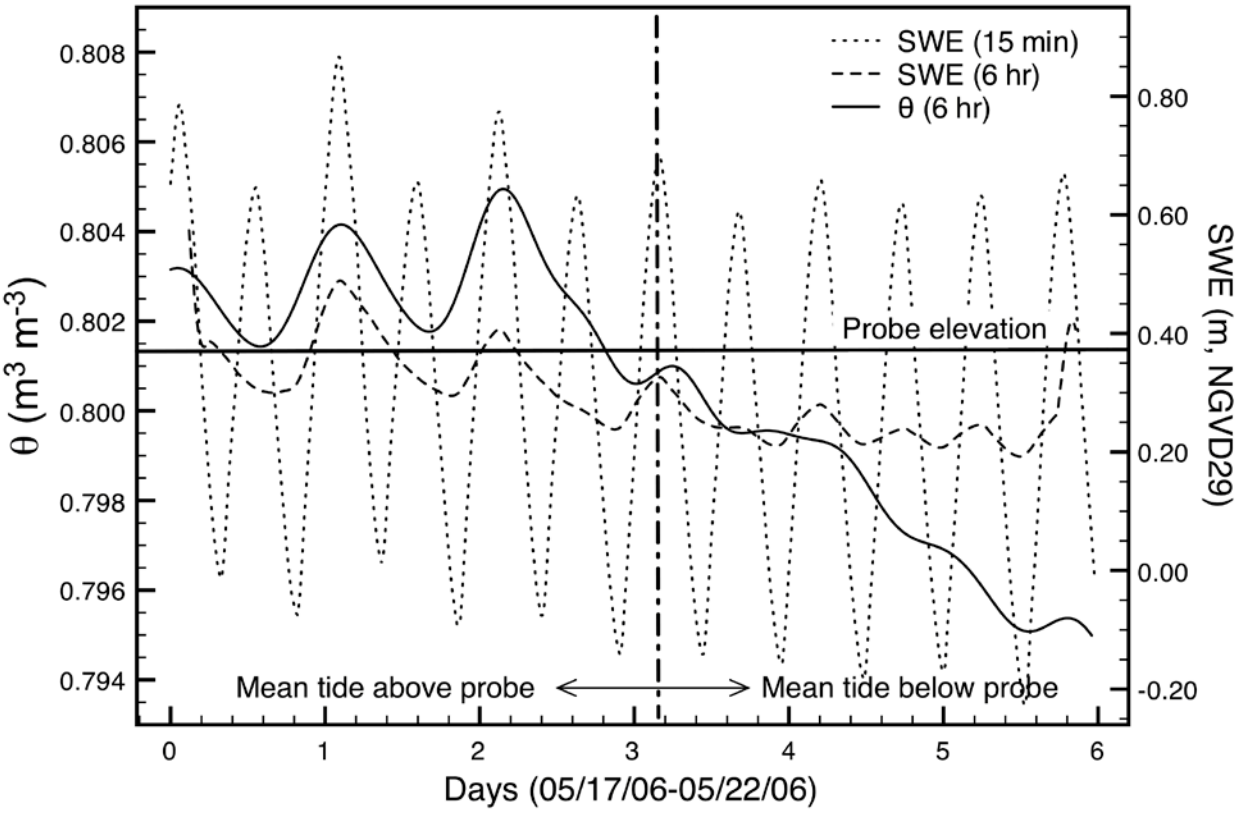

Figure 2-8. Relationship between soil moisture (θ) and surface water elevation (SWE) in the highest elevation (i.e., shallowest) probe on downstream, tidally influenced Transect 7 over six days in May 2006. Changes in θ were small (~1%), and tightly coupled with SWE, but only when mean tide was above probe elevation.

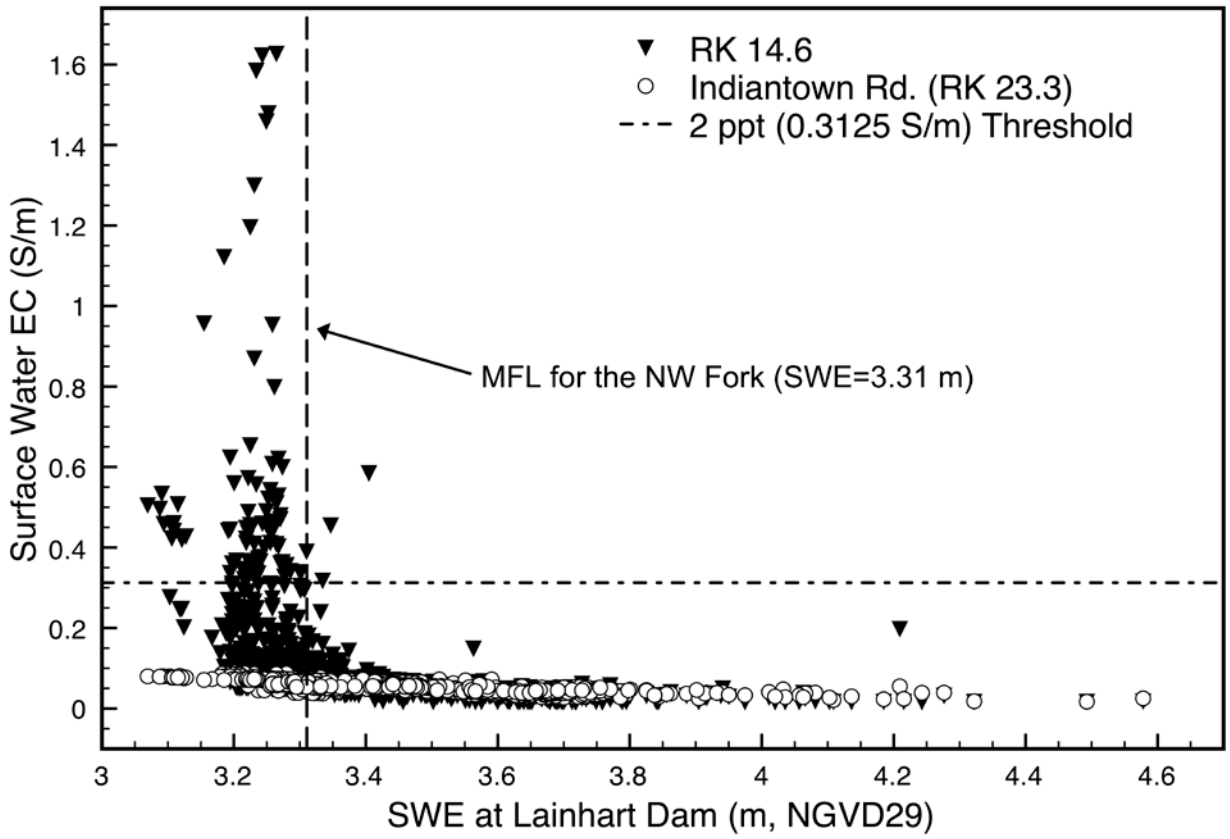

Figure 2-9. Surface water elevation (SWE) at Lainhart Dam versus surface water electrical conductivity (SWEC) at Indiantown Rd. (near Transect 1) and RK 14.6 (near Transect 7). Downstream SWEC is variable below SWE of 3.4 m, however 95% of SWEC exceedances above the 2 ppt (0.3125 S/m) threshold for maintenance of bald cypress health occur when SWE ≤ 3.31 (vertical dashed line).

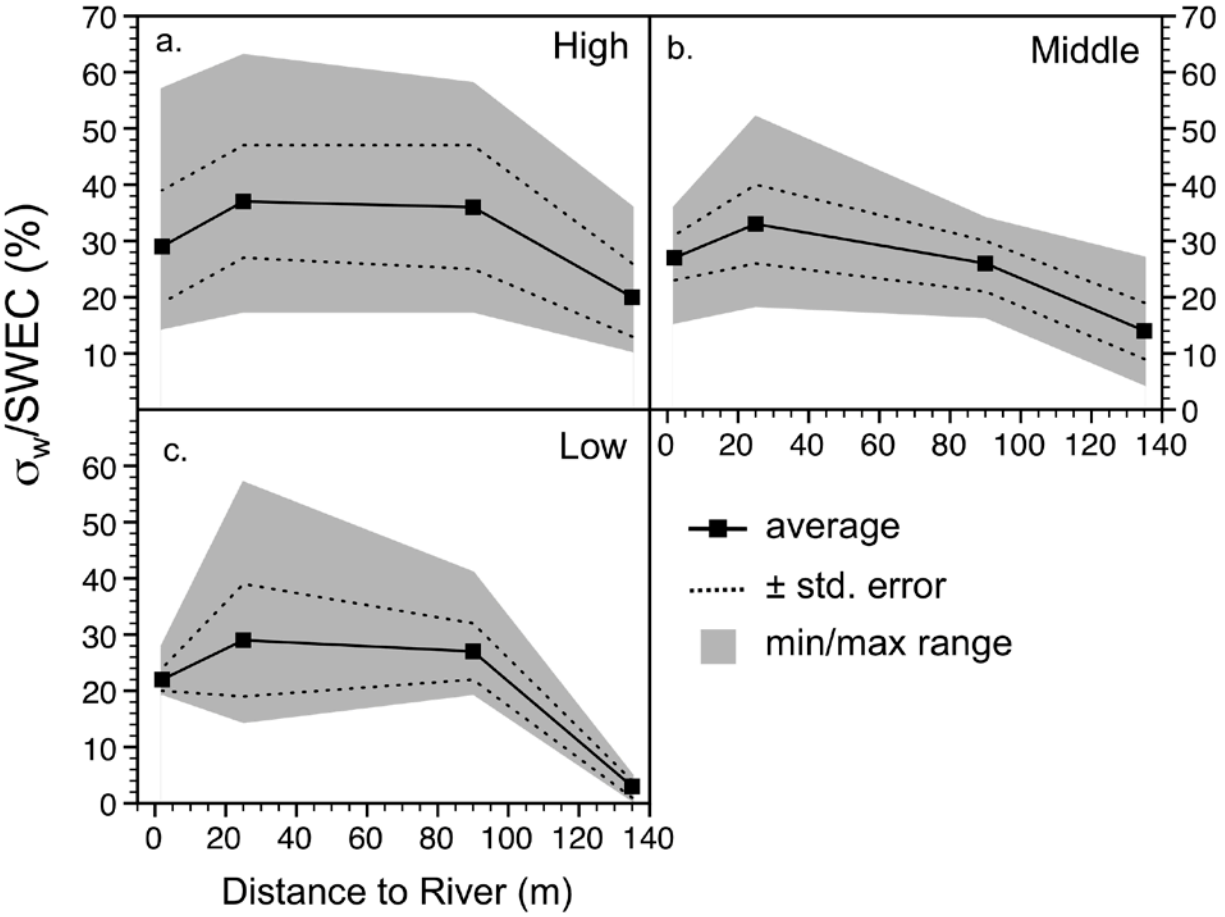

Figure 2-10. Ratio of surface water electrical conductivity (SWEC) peaks reached in porewater electrical conductivity (σ_w) in (a) high, (b) middle, and (c) low elevation measurement locations on Transect 7, calculated from daily average data. Ratios are < 100% at all depths and distances, so restoration scenarios that succeed in maintaining SWEC below 0.3125 S/m will also maintain $\sigma_w \leq 0.3125$ S/m in the floodplain vadose zone.

CHAPTER 3
UNTANGLING COMPLEX SHALLOW GROUNDWATER DYNAMICS IN THE FLOODPLAIN WETLANDS OF A SOUTHEASTERN U.S. COASTAL RIVER

Introduction

Description and modeling of hydroperiod, surface water salinity, groundwater elevation and salinity, soil moisture, and soil porewater salinity are essential to understanding the hydrological and ecological functioning of coastal floodplain wetlands (e.g., Glamore and Indraratna, 2009; Nyman et al., 2009; Benke et al., 2000). However, finding direct relationships between basic hydrological inputs (rainfall, evapotranspiration, surface water elevation and salinity, groundwater elevation and salinity, etc.) is often difficult because of complex interactions between surface water, groundwater, and porewater in a variably saturated matrix with heterogeneous soils, vegetation, and topography. For example, depth, duration, frequency, and salinity of floodplain inundation are functions of tidal range, distance from the ocean, distance from the river channel, local elevation (microtopography), volume of freshwater flow, and the direction, volume, and salinity of groundwater fluxes (e.g., Wang, 1998; Liu, 2001; Melloul and Goldenberg, 1997), as well as soil hydraulic characteristics and floodplain vegetation properties.

In these complex systems, long-term monitoring can characterize the ranges and temporal variation of hydrological and water quality variables (e.g., Muñoz-Carpena et al., 2008) and support the development of initial relationships between measured variables (e.g., Kaplan et al., 2010a). However, investigating relationships between multivariate time series to improve understanding of system dynamics using visual inspection and comparative statistics is difficult, subjective, and may not appropriately characterize the system (Ritter et al., 2007). Nevertheless, a better understanding of

hydrological dynamics is vital to the development of management scenarios to protect valued ecosystems, especially in modified wetland systems. Thus, an alternative method for identifying common trends and causal factors is required. This study applies Dynamic Factor Analysis (DFA), a times series dimension reduction technique, to untangle complex groundwater dynamics in the floodplain wetlands of a managed coastal river in the southeastern U.S.

DFA is a multivariate application of classic time series analysis originally developed for the interpretation of economic time series (Geweke, 1977) and can be a powerful tool for the modeling of short, incomplete, non-stationary time series in terms of common trends and explanatory variables (Zuur et al., 2003a). With DFA, underlying temporal variation in observed data (response variables) is modeled as linear combinations of common trends (unexplained variability), a constant level parameter, zero or more explanatory variables (additional observed time series), and noise (Zuur et al., 2003b). Like other time series models, DFA aims to maintain a good fit while minimizing the number of common trends. Using DFA, different formulations of dynamic factor models (DFMs) are possible and thus, the best model selection is often made using goodness-of-fit indicators. The Nash and Sutcliffe coefficient of efficiency ($-\infty \leq C_{eff} \leq 1$; Nash and Sutcliffe, 1970) can be used to judge model performance. Additionally, Akaike's information criterion, AIC (Akaike, 1974) is often used as a decision tool for choosing between competing models (Zuur et al., 2003b).

The ability to model time series as a combination of common trends and explanatory variables is especially useful for analyzing complex environmental systems, where DFA can help assess what explanatory variables (if any) affect the time series of

interest, and thus may be worthy of closer attention. DFA has been successfully applied in hydrology to identify common trends in groundwater levels (Kovács et al., 2004; Ritter and Muñoz-Carpena, 2006), soil moisture dynamics (Ritter et al., 2009), and interactions between hydrological variables and groundwater quality trends (Muñoz-Carpena et al., 2005; Ritter et al., 2007). Regalado and Ritter (2009a; 2009b) used DFA for identifying common patterns of unexplained variability in soil water repellency measurements. It has also been used to identify trends and environmental variables affecting squid populations (Zuur and Pierce, 2004) and commercial fisheries (Erzini, 2005; Tulp et al., 2008).

Here, DFA is applied to study the interactions between floodplain groundwater elevations and other hydrological variables in the floodplain wetlands of the Loxahatchee River (Florida, USA), where reduced freshwater flow has led to saltwater intrusion and a transition to salt-tolerant, mangrove-dominated communities (South Florida Water Management District [SFWMD], 2006). Groundwater plays a vital role in the water balance of many wetlands and is increasingly recognized as an important driver of ecological processes (Hancock et al., 2009) and the development of particular ecological communities in wetlands from Florida, USA (Harvey and McCormick, 2009) to Australia (Hatton et al., 1998). This is particularly true in coastal wetlands, where the effect of groundwater on salinity gradients can largely dictate habitat conditions in the estuary (Jassby et al., 1995). Except for one study of biogeochemical transport and submarine groundwater discharge (Swarzenski et al., 2006), the role of groundwater in the Loxahatchee River and its floodplain is largely uninvestigated. The specific objectives of this research are to apply DFA to identify (a) important common trends

among the time series (unexplained variability) and (b) the external local and/or regional hydrological factors (explained variability) that drive the observed shallow water table variation.

Materials and Methods

Study Site

Historically part of the greater Everglades watershed, the Loxahatchee River is located on the southeastern coast of Florida, USA (26° 59' N, 80° 9' W; Fig. 3-1) and is often referred to as the "last free-flowing river in southeast Florida" (SFWMD, 2006.) The river has three main branches (the North, Southwest, and Northwest Forks), which join in a central embayment that connects to the Atlantic Ocean via Jupiter Inlet. The watershed drains approximately 550 km^2 in Palm Beach and Martin Counties and includes several large, publicly owned areas including Jonathan Dickinson State Park (JDSP), the Loxahatchee Slough Preserve, and the J.W. Corbett Wildlife Management Area. In 1985 a 15.3-km stretch of the Northwest Fork became Florida's first National Wild and Scenic River (National Park Service [NPS], 2004) and intensive data collection and modeling efforts in support of management and restoration planning have been underway for several years (e.g., SFWMD, 2002, 2006, 2009; VanArman et al., 2005; Mortl, 2006; Muñoz-Carpena et al., 2008, Kaplan et al., 2010a,b).

The Northwest Fork of the Loxahatchee River (NW Fork) and its watershed contain a diverse array of terrestrial and aquatic ecosystems including sandhill, scrub, hydric hammock (a plant community characterized by 30 – 60 days of inundation yearly and mixed, facultative hardwood species), wet prairie, floodplain swamp, estuarine (mangrove) swamps, seagrass beds, tidal flats, oyster beds, and coastal dunes (Roberts et al., 2006; Treasure Coast Regional Planning Council [TCRPC], 1999).

Many of these ecosystems remain relatively intact (VanArman et al., 2005) and support a diversity of protected animal and plant species, including the endangered Florida manatee (Trichechus manatus latirostris) and four-petal pawpaw (Asimina tetramera Small) (SFWMD, 2006). The upper watershed of the NW Fork is also home to one of the last remnants of bald cypress (*Taxodium distichum* [L.] Rich.) floodplain swamp in southeast Florida. However, changing hydrology and salinity regimes in the river and its floodplain have been linked to vegetative changes in the floodplain forest (SFWMD, 2002). Of primary concern is the transition from bald cypress floodplain swamp to mangrove-dominated communities in the tidal floodplain as salinity increased and inadequate hydroperiod in the upstream riverine floodplain, which has shifted the system towards drier plant communities (SFWMD, 2009).

Altered hydroperiods and encroaching salinity in the NW Fork have been linked to four major factors: 1) construction of major and minor canals that direct water away from the historic watershed; 2) the permanent opening of Jupiter Inlet in 1947 (Fig. 3-1b); 3) construction of the C-18 canal in 1958, which transferred a majority of flow from the NW Fork to the Southwest Fork (Fig. 3-1b); and 4) lowering of the regional groundwater table by community consumption (SFWMD, 2002). These hydrologic changes have been linked to changes in the vegetative composition of the floodplain, where studies have documented the upriver retreat of bald cypress since at least the turn of the 20th century (General Land Office [GLO], 1855; Alexander and Crook, 1975; McPherson, 1981; Ward and Roberts, 1996; Roberts et al., 2008).

The health of the Loxahatchee River and its adjacent ecosystems is a priority for many residents, visitors, agencies, and political leaders. As such, a number of planning

efforts have been initiated over the past twenty years, including the North Palm Beach County Comprehensive Everglades Restoration Plan (CERP) project (part of the 30-year, $8- to $15 billion Everglades restoration project). Additionally, as in many other U.S. states (e.g., Johnson, 2008), Florida law requires its water management agencies to establish Minimum Flows and Levels (MFLs) to protect water resources (Section 373.042[1], Florida Statutes). MFL criteria are also designed to protect valued ecosystem components (VECs) from "significant harm." The MFL for the NW Fork (SFWMD, 2002) was adopted in 2003 and a restoration plan (SFWMD, 2006) was completed in 2006 with the goal of protecting the river's remaining cypress swamp and hydric hammock communities, as well as estuarine resources including oysters (Crassostrea virginica), fish larvae, and sea grasses—all identified as VECs. These MFL and restoration scenarios rely primarily on increased freshwater flow over Lainhart Dam (Fig. 3-1b), which was found to be the most important driver of upstream hydroperiod and downstream surface water salinity. In spite of the Loxahatchee's "free-flowing" appellation, flow over Lainhart dam (calculated from headwater surface water elevation) is controlled by managing conveyance through the G-92 water control structure (Fig. 3-1b).

Experimental Setup

In cooperation with the Florida Park Service (FPS), the SFWMD developed a network of twelve groundwater wells along five previously established vegetation survey transects perpendicular to the NW Fork (T1, T3, T7, T8, and T9; Fig. 3-1b). Water table elevation (WTE) data were collected using TROLL 9000/9500 multi-parameter water quality probes (In-Situ Inc., Ft. Collins, CO, USA) from September 2004 through January 2009. WTE data were measured every 30 minutes and converted to daily

averages for this study. Upriver transects T1 and T3 each had one well, while transitional and tidal transects (T7, T8, and T9) had multiple wells to document differences in WTE across the floodplain (Fig. 3-2). Table 3- 1 summarizes well attributes. A full description of the groundwater dataset and QA/QC procedure is available in Muñoz-Carpena et al. (2008).

Transects 1 and 3 are upriver locations, not directly impacted by daily tides. T1 is located 23.3 km upstream of the river mouth (indicated as river kilometer, RK, 23.3) and has elevations ranging from 4.19 m (referenced to the National Geodetic Vertical Datum of 1929 [NGVD29]) on the top of a hydric hammock to 1.66 m in the river channel (Fig. 3-2a). This freshwater transect is dominated by upland forest and hydric hammock at higher elevations and mature bald cypress swamp (average diameter at breast height, DBH = 49 cm) in the lower floodplain (SFWMD, 2006). T3, located at RK 19.5, has several shallow braided streams in the floodplain and elevations ranging from 1.69 m in the floodplain to -3.00 m in the river channel (Fig. 3-2b). This transect contains freshwater riverine swamp, but is dominated by pop ash (*Fraxinus caroliniana* Mill.) with only four (very large) bald cypress in the canopy (average DBH = 92 cm). Intrusion of less flood-tolerant species into the riverine floodplain in these and other riverine transects has been documented, indicating the ecological impact of shortened hydroperiod in this area (SFWMD, 2006, 2009).

Moving downriver, transects 7, 8, and 9 all receive daily tidal flooding of varying salinity over most or all of their length. T7 is in a transitionally tidal area (RK 14.6) and has elevations ranging from 3.07 m in the upland to 0.40 m in the floodplain (Fig. 3-2c). Vegetation studies indicate that this transect has been impacted by saltwater intrusion,

logging, and invasion by exotic plants (SFWMD, 2006). T7 presently contains upper tidal swamp (dominated by red mangrove, *Rhizophora mangle* L.), which transitions to mixed riverine swamp approximately 30 m from the river channel. Transect 8 is located approximately 150 m upstream of the confluence of the NW Fork and Kitching Creek at RK 13.1. This transect has elevations ranging from 2.76 m in the upland to 0.23 m at the creek edge and transitions from hydric hammock in the uplands to upper tidal swamp in the floodplain (Fig. 3-2d). The canopy is dominated by pond apple (*Annona glabra* L.), wax myrtle (*Myrica cerifera* L.), and bald cypress, though red and white mangrove (*Laguncularia racemosa* [L.] C. F. Gaertn.) seedlings and sub-canopy are present, especially within a braided channel with direct connection to the creek (SFWMD, 2009). T9 is located at RK 10.5 on a small peninsula in the NW Fork and has elevations ranging from 2.89 m in the upland to 0.40 m at the river's edge (Fig. 3-2e). This transect consists of lower tidal swamp, dominated by red and white mangrove except on an elevated trail, which supports sabal palm (*Sabal palmetto* [Walter] Lodd. Ex Schult. & Schult. f.). Roberts et al. (2008) documented intense vegetation changes on this transect, with a transition from freshwater to saltwater swamp species in less than 50 years.

Dynamic Factor Analysis

DFA is based on structural time series models (Harvey, 1989), and aims to describe a set of *N* time series (termed response variables) using a Dynamic Factor Model (DFM) that includes *M* common trends (*M*<*N*), *K* explanatory variables, a level or intercept parameter, and noise (Lütkepohl, 1991; Zuur et al., 2003b):

N time series = *M* common trends + level parameter + *K* explanatory variables + noise (3-1)

In contrast to physically based or mechanistic models, DFMs are not built upon the underlying mechanisms of a given system, but upon the common patterns among, and interactions between, response variables and explanatory factors. Thus, it requires no detailed information about the interactions between response and explanatory time series (Ritter et al., 2009). In the case presented here, this means that a complete a priori understanding of how groundwater (i.e., the response time series), surface water, and other hydrological variables interact in the floodplain is not necessary.

By performing DFA, one or more common trends in the response time series are identified, which represent latent (unidentified) variation. The goal of DFA is to minimize the number of common trends (keeping M as small as possible) while still achieving a good fit. The use of explanatory variables can help improve the model fit and identify which environmental factors most affect the response variables. Equation 3-1 may be written in mathematical form as follows:

$$s_n(t) = \sum_{m=1}^{M} \gamma_{m,n} \alpha_m(t) + \mu_n + \sum_{k=1}^{K} \beta_{k,n} v_k(t) + \varepsilon_n(t) \quad (3\text{-}2)$$

$$\alpha_m(t) = \alpha_m(t-1) + \eta_m(t) \quad (3\text{-}3)$$

where $s_n(t)$ is a vector containing the set of N time series being modeled (response variables); $\alpha_m(t)$ [same units as the response variables] is a vector containing the mth common trend; $\gamma_{m,n}$ [dimensionless] are factor loadings or weighting coefficients, which indicate the importance of each of the common trends within the DFM; μ_n [same units as the response variables] is a constant level parameter ; $v_k(t)$ [units vary] is a vector containing 0 – K explanatory variables; and $\beta_{k,n}$ [inverse units to convert explanatory variables to response variable units] are regression parameters, which indicate the

importance of each of the explanatory variables within the DFM. In this study, *N* represents the twelve WTE time series. The terms $\varepsilon_n(t)$ and $\eta_m(t)$ [same units as the response variables] are independent, Gaussian noise with zero mean and unknown diagonal or symmetric/non-diagonal covariance matrix. Using a symmetric, non-diagonal matrix can lead to adequate model fits using fewer common trends than with a diagonal matrix, but causes the number of parameters in the DFM to increase considerably (Zuur et al., 2003a).

Common trends, α_m(t), are modeled as a random walk (Harvey, 1989) and are predicted using the Kalman filter/smoothing algorithm and the Expectation Maximization (EM) technique (Dempster et al., 1977; Shumway and Stoffer, 1982; Wu et al., 1996). Factor loadings ($\gamma_{m,n}$) and level parameters (μ_n) are also calculated using the EM technique. Regression parameters ($\beta_{k,n}$) are modeled using linear regression (Zuur and Pierce, 2004). DFA deals with missing data in the response series by using a "design matrix" to identify missing observations and modify the factor loading, regression, and error matrices. The Kalman filter and smoothing algorithm then skips these missing observations (Zuur et al., 2003b).

Factor loadings ($\gamma_{m,n}$) and regression parameters ($\beta_{k,n}$) accompanying the common trends and explanatory variables allow for identification of the most relevant common trends and explanatory variables for each response variable. The magnitude of the $\beta_{k,n}$ and their associated standard errors were used to assess whether response and explanatory variables were significantly related (t-value > 2). Additionally, cross-correlation between response variables and common trends was quantified using canonical correlation coefficients ($\rho_{m,n}$). Values of $\rho_{m,n}$ close to unity indicate that the

common trend is highly associated with that response variable. In the following sections, “minor” correlations will refer to those with $|\rho_{m,n}| < 0.25$; “low” correlations to $0.25 \leq |\rho_{m,n}| < 0.50$; “moderate” correlations to $0.50 \leq |\rho_{m,n}| \leq 0.75$; and “high” correlations to $|\rho_{m,n}| > 0.75$.

One possible limitation of DFA, which has not previously been identified in the literature is that common trends and explanatory variables are fit simultaneously. Thus, the method may identify one or more common trends that closely resemble candidate explanatory variables. If a common trend produced by DFA improves the model more than a similar explanatory variable, the resulting DFM will rely on the trend (which will have relatively high factor loadings) while overlooking the effect of the explanatory variable (which will have relatively low regression coefficients), potentially leading to spurious interpretation of results (i.e., deeming that an explanatory variable is unimportant). To ensure against this possibility, we calculated correlations between common trends and explanatory variables in DFMs that include both. High correlations between the series may indicate that an explanatory variable has been inappropriately disregarded in the model.

Explanatory Variables

Additional meteorological and hydrological variables were measured across the watershed, and a total of 29 daily time series (twelve response variables and seventeen candidate explanatory variables, each with 1589 daily values) were investigated for use in this analysis (Table 3-2). Not all candidate explanatory variables were used in the final DFMs since multi-collinearity may exist between explanatory variables measured at nearby locations. The severity of multi-collinearity was quantified using the variance inflation factor (VIF) of each set of explanatory variables (Zuur et al., 2007).

Combinations of explanatory variables that resulted in VIF > 5 were avoided in these analyses (Ritter et al., 2009), and in those cases where this criterion was exceeded, the single candidate explanatory variable that best minimized AIC and maximized C_{eff} was selected. For example, if using two surface water elevation time series as explanatory variables resulted in VIF > 5, the series that yielded the poorer modeling results was discarded.

Breakpoint rainfall data were recorded at the SFWMD S-46 structure on the Southwest Fork of the Loxahatchee River and at the JDWX weather station in Jonathan Dickinson State Park, where daily reference evapotranspiration (ET_0) values were also measured (Fig. 3-1b). These data are publicly available and were downloaded from the SFWMD's online database DBHYDRO (Stations S46_R and JDWX; accessed at http://www.sfwmd.gov/org/ema/dbhydro/index.html). Note that WTE data are autocorrelated (i.e., WTE at time *t* is dependent on WTE at *t*-1), while this is not true for rainfall and ET, which contain no consistent information about previous data. In order to make rainfall and ET_o data useful to the DFA (Ritter et al., 2009), the difference between cumulative rainfall and cumulative ET_o was used to create two net local recharge (R_{net}) time series. Rainfall was measured at the S-46 and JDWX gauging stations (Fig. 3-1b), but ET_o was only computed from measurements at JDWX, so cumulative ET from this station was used to calculate both R_{net} series ($R_{net,S46}$ and $R_{net,JDWX}$). Though only 11.2 km apart, the two rain stations exhibited large differences in cumulative rainfall over the four-year study period. The effect of this spatial variability on model results was explored by developing DFMs using each of the R_{net} series, both series, and their average and comparing model results.

Surface water elevation (SWE) data were recorded at five locations in the NW Fork and one station upstream on Kitching Creek (Fig. 3-1b). A SFWMD monitoring station on the headwater side of Lainhart Dam (0.45 km upstream of T1) measured average daily SWE and is available on DBHYDRO (station LNHRT_H; Fig. 3-1b). Cooperatively monitored United States Geological Survey (USGS)/SFWMD stations located at RK 14.6 (adjacent to T7), RK 13.1 (at confluence with Kitching Creek, near T8), RK 9.5 (~0.8 km downstream of T9), RK 1.1 (near the Jupiter inlet), and 2.8 km upstream of the confluence of the NW Fork with Kitching Creek each measured SWE every 15 minutes (Fig. 3-1b). These data were acquired from USGS staff and converted to daily averages.

Daily average WTE from nine USGS wells (Fig. 3-1a) in and around the Loxahatchee River watershed (denoted as WTE_R) are publicly available and were downloaded from the USGS National Water Information System (accessed at http://waterdata.usgs.gov/nwis/). An initial cross-correlation analysis identified possible lead/lag relationships between WTE and WTE_R series, and candidate WTE_R series were lagged from +3 to -3 days to determine if lagged series improved the final DFM.

Analysis Procedure

DFA was implemented using the Brodgar v. 2.5.7 statistical package (Highland Statistics Ltd., Newburgh, UK), which is based on the statistical software language "R" version 2.9.1 (R Core Development Team, 2009). Response and explanatory variables were normalized (mean subtracted, divided by standard deviation) in Brodgar. This allowed us to compare the relative importance of explanatory variables across the set of response variables (Zuur et al., 2003b; Zuur and Pierce, 2004). The DFA was carried out sequentially and resulted in three models (Table 3-3). First, DFMs were built with

an increasing number of common trends until satisfactory model performance was achieved according to goodness-of-fit indicators (Zuur et al., 2003a). This DFM is referred to as Model I. Once the minimum number of common trends (M) was identified, different combinations of explanatory variables were incorporated until a satisfactory combination of common trends and explanatory variables was identified without exceeding the VIF criterion (Model II). This reduced the unexplained variability and improved description of WTE in the floodplain. Finally, a reduced model was explored by removing common trends and using only the best subset of explanatory variables identified in the DFA to create a multi-linear model (Model III) using a multiple regression code run in Matlab (2009b, The MathWorks, Inc., Natick, MA, USA).

Goodness-of-fit was assessed by visual inspection of the observed versus predicted WTE and quantified with the Nash Sutcliffe coefficient of efficiency ($-\infty \leq C_{eff} \leq 1$, Nash and Sutcliffe, 1970) and Akaike's information criterion (AIC; Akaike, 1974). C_{eff} compares the variance about the 1:1 line to variance of the observed data, with $C_{eff} = 1$ indicating that the plot of predicted vs. observed data matches the 1:1 line. The AIC is a statistical criterion that balances goodness-of-fit with model parsimony by rewarding goodness-of-fit but including a penalty term based on the number of model parameters. For two different DFMs, the DFM with largest C_{eff} and smallest AIC was preferred.

Results and Discussion

Experimental Time Series

The hydrological data collected during this study represent a wide range of climatic conditions, including four wet/dry season cycles; two wet years with hurricane-induced flooding (2004 and 2005); and the driest two-year period (2006 to 2007) recorded in south Florida since 1932 (Neidrauer, 2009). Daily time series of hydrological variables

are presented in Fig. 3-3. Rainfall (Fig. 3-3a) followed a seasonal pattern, with wet season (May to October) rain accounting for 73 to 80% of yearly totals over the four years (mean 77%; Fig. 3-3a). This is in agreement with previous seasonal rainfall observations in the Loxahatchee River Basin, which have shown that approximately two-thirds of yearly rain falls in the wet season between May and October (Dent, 1997). Significant spatial variation between rainfall data collected at the S-46 and JDWX stations was also found. Though the rain gauges were only 11.2 km apart, and roughly equidistant from the shore in flat terrain, cumulative rainfall at the JDWX gauge in JDSP was 2151 mm greater than that at the S-46 structure over the four-year study period, yielding divergent R_{net} series (Fig. 3-3b). Correlation between the rainfall time series was also low ($r^2 = 0.18$), further justifying the use of both series in the DFM developed (see following sections). Both rainfall series passed QA/QC procedures by the SFWMD and were deemed reliable.

WTE was variable across wells and transects, as well as over seasons and years. WTE ranged from a maximum of 3.80 m upstream at well T1-W1 to a minimum of -0.88 m in the tidal floodplain of T8 (T8-W1) and was highest in upriver wells (T1-W1, T3-W1) and downriver, higher elevation wells (T7-W4, T8-W3) (Fig. 3-3c). Visual inspection of WTE in these higher elevation wells suggested common trends associated with wet and dry season rainfall patterns. For example, the impact of late season rains in 2004 and 2005 and dry summers in 2006 and 2007 on the WTE are apparent across these wells. WTE in lower elevation wells closer to the river appeared to be more influenced by daily tidal flooding (Fig. 3-3d). Some seasonal wet/dry patterns were still apparent, but less so, as the signal was damped by daily and monthly tidal fluctuations. Note high water

events in September 2004 during hurricanes Frances and Jeanne. WTE generally decreased from upstream (T1) to downstream (T9). One exception to this is well T7-W4, which maintained higher WTE than well T3-W1 (which is further upstream) throughout most of the period of record (Fig. 3-3c) due to its high elevation (Table 3-1).

Figures 3e-f show temporal variation in the six SWE and nine WTE_R series explored as candidate explanatory variables. In the upriver SWE series (RK 23.3 and Kitching Creek), large rainfall events coincided with peaks in SWE and distinct drawdowns during each of the four dry seasons were observed (most drastically in 2006 and 2007). Daily average SWE measured near T7, T8, T9, and the Jupiter Inlet were nearly identical and overlap in the figure ($0.94 \leq r^2 \leq 0.99$ for these four series; Fig. 3-3e). WTE_R series measured in and around the Loxahatchee River exhibited a large range (from close to sea level to over 10 m), but consistently mirrored the wet and dry season variations observed in the two upriver SWE series (Fig. 3-3f).

Other WTE trends in the floodplain of the Loxahatchee River became apparent when looking closely at a single transect. For example, WTE increased with distance from the river on T7, with the highest elevation well (T7-W4) showing the maintenance of much higher WTE (Fig. 3-4). During the dry seasons of 2006 to 2007 this freshwater (Muñoz-Carpena et al., 2008) head fell, approaching, but not reaching WTE in the floodplain. This indicates a variable, but consistently positive flow of freshwater from the upland towards the river even in extremely dry seasons, which likely plays a role in mitigating the severity of saltwater intrusion on T7. This highlights the importance of understanding the dynamics of this hydrological flux. The same pattern was apparent on T8 (not shown), with higher WTE maintained in well T8-W3, except for the dry

seasons of 2006 and 2007, when the groundwater levels in T8-W2 and T8-W3 met during an extreme WTE drawdown. At T9, which is on a peninsula with the river on two sides, these patterns were not as apparent, with higher elevation and lower elevation wells sharing similar WTE (not shown).

Dynamic Factor Analysis

Baseline DFA (no explanatory variables)

The DFA was advanced in three discrete steps. First, different DFMs were obtained by increasing the number of common trends until a maximum C_{eff} and minimum AIC were achieved. With a diagonal matrix, AIC is minimized and C_{eff} maximized with six trends (M=6; Table 3-4). The minimized AIC of 4840 and maximized C_{eff} of 0.94 using six common trends (Model I) were then used as targets for subsequent DFMs. That six common trends (representing unexplained, but shared, information) were necessary to achieve the best DFM with no explanatory variables suggests that several latent effects influence the variability of WTE across the watershed. It is instructive to examine these common trends and their associated canonical correlation coefficients ($\rho_{m,n}$) since high $\rho_{m,n}$ values indicate high correlation between two latent variables.

Three example trends from Model I with high $\rho_{m,n}$ values are shown in Fig. 3-5. Though only describing latent (unknown) variability at this stage in the DFA, these trends and their patterns of correlation are useful for developing ideas about how WTE varies in the Loxahatchee River floodplain and where to look for the most useful explanatory variables. For example, the trend in Fig. 3-5a is highly to moderately correlated (positively) with all five higher elevation wells (T1-W1, T3-W1, T7-W4, T8-

W3, and T9-W3), but relatively unimportant (minor and low correlations) for the seven lower floodplain wells (T7-W1, T7-W2, T7-W3, T8-W1, T8-W2, T9-W1, and T9-W2). On the other hand, the trend in Fig. 3-5b is negatively correlated with the upland and upriver wells (low to minor correlations), but positively and more strongly correlated with floodplain wells (moderate to low correlations). This geographic and topographic distribution of $\rho_{m,n}$ values across the twelve wells suggests that the use of explanatory variables that represent distinct parts of the river may help reduce the unexplained variability represented by these trends. The trend in Fig. 3-5c has low to moderate correlation with two of the twelve wells, both on T8, and the correlations are in opposite directions—the rest of the correlations are minor. This indicates a latent effect specific to these wells and could be an indicator of anomalous data or other environmental factor (or factors) that only affects these wells (i.e., pumping in the area). Model I requires this common trend to achieve the best match of WTE data in these wells. From the remaining three common trends (not shown), no clear spatial or physical interpretations could be drawn.

DFA with explanatory variables

Next, explanatory variables were added in an attempt to reduce the number of common trends required to achieve an adequate fit of WTE (and to reduce the canonical correlation coefficients and factor loadings of remaining trends). Candidate explanatory variables included surface water elevations (SWE) at six locations in the NW Fork, regional groundwater elevations (WTE_R) in nine groundwater wells in and around the Loxahatchee River watershed, and net local recharge (R_{net}) calculated from two rain gauges and one ET monitoring station, for a total of seventeen possible

explanatory time series. When two or more candidate explanatory variables were collinear or multi-collinear (resulting in VIFs > 5), the explanatory variable resulting in the best overall model fit (highest C_{eff} and lowest AIC) was selected.

For the SWE time series, upstream river stage at Lainhart Dam (RK 23.3) and tidal river stage at RK 14.6 provided the best benefit to the model and were not collinear. That both upriver and tidal SWE series were required for the best DFM follows from Model I, whose trends were split across high and low elevation floodplain wells. For WTE_R time series, USGS well M-1001 most improved the model. The DFM was not improved by lagging any of the WTE_R series by -3 to +3 days. The model was also improved by using both net local recharge series ($R_{net,S46}$ and $R_{net,JDWX}$) compared with either series alone or their average. Recorded rainfall at the S-46 and JDWX gauges were drastically different (Fig. 3-3b) and thus, when used to calculate R_{net}, each series had distinct information that improved the DFM. The use of both R_{net} series also highlighted the effects of the high spatial variability of rainfall in the region. The VIFs for this set of five explanatory variables did not exceed the VIF threshold ($1.30 \leq VIF \leq 2.51$). Correlations between common trends and this set of explanatory variables were low ($0.001 \leq r^2 \leq 0.34$), indicating that the importance of these explanatory variables was not masked by common trends (though we did observe high correlations between trends and explanatory variables in other DFMs, confirming that it is important to check for this correlation before interpreting DFA results).

In summary, the best DFM used five explanatory variables (K=5): SWE at RK 23.3 and 14.6 ($SWE_{RK23.3}$ and $SWE_{RK14.6}$); WTE from USGS well M-1001 (WTE_R_{M1001}); and both net local recharge series ($R_{net,S46}$ and $R_{net,JDWX}$). With these explanatory variables

the number of required common trends was reduced from six to three (M=3), reducing the unexplained variability in the model while achieving performance similar to that of Model I. This model (Model II) yielded an AIC value of 2998 (lower than the 4880 target from Model I) and a C_{eff} value of 0.91 across the twelve wells (compared with the target of 0.94). Model fits are illustrated in 3-6. Model fits are good to excellent ($0.78 < C_{eff} < 1.0$). Some higher elevation wells lack data from the beginning of the time series, and model results help paint a more complete picture of WTE in these wells during the hurricanes of 2004 (e.g., panels 1 and 2 in Fig. 3-6).

Table 3-5 summarizes the results obtained from Model II (M=3, K=5). Significant regression parameters (t-value > 2) are shown in bold. WTE in the 12 wells in the Loxahatchee River had variable relationships to the common trends from Model II, but canonical correlations were reduced from Model I, indicating a reduced dependence of the DFM on these latent series. The trends in Model II had zero "high" and four "moderate" correlations with response variables, compared to four "high" and seven "moderate" correlations in Model I.

The spatially distributed effects of the explanatory variables and common trends on Model II are compared in Fig. 3-7. Regression parameters ($\beta_{k,n}$; Figs. 3-7a-e) represent the relative importance of each explanatory variable to each response time series, with black bars indicating significant regression parameters by t-test. In general, inclusion of explanatory variables in Model II reduced factor loadings (Fig. 3-7f) over those in Model I (overall average $|\gamma_n|$ for the six trends in Model I was 0.13±0.16 compared to 0.05±0.04 in Model II), suggesting that the patterns observed in the

Loxahatchee River floodplain wells may be adequately described using only the selected explanatory variables (see following section).

Visualizing the spatial distribution of the importance of each explanatory variable in the floodplain can be useful when assessing river management options. For example, Fig. 3-7a shows that the Lainhart Dam surface water time series ($SWE_{RK23.3}$) was most important in describing variability in wells T1-W1 and T3-W1, but had reduced impact downriver. As the major management tool in the NW Fork, river stage (i.e., flow) at Lainhart Dam had only limited impact in maintaining WTE downstream of T3. Similarly, Fig. 3-7b demonstrates the strong importance of tidal surface water ($SWE_{RK14.6}$) in lower elevation wells further downstream. This variable was most important for explaining WTE variability on downstream transects (T7, T8, and T9) and was strongest for those wells closest to the river, decreasing with distance from the river—for example, from T7-W1 (strongly significant, with β=0.92) to T7-W4 (insignificant, with β=0.01). This explanatory variable, and by extension the response variables that it influences most, is most susceptible to sea level rise caused by climate change.

Figs. 3-7c-d show regression parameters for the two net local recharge series ($R_{net,S46}$ and $R_{net,JDWX}$). Though the importance of these two series is distributed across the twelve wells in the floodplain, a geographic pattern is apparent. Wells T1-W1 and T3-W1 are closer to the rainfall gauging station at the S-46 structure (3.2 and 3.9 km, respectively) than the JDWX gauging station (9.7 and 7.2 km, respectively). These wells are more strongly affected by $R_{net,S46}$, (significant, with β values of 0.73 and 0.56, respectively), than by $R_{net,JDWX}$ (insignificant β values of 0.10 and 0.13). The importance of the two net local recharge series are split fairly equally over the remainder of the

wells (average $\beta_{Rnet,\ S46}$: 0.46±0.34; average $\beta_{Rnet,\ JDWX}$: 0.65±0.35), with $\beta_{Rnet,\ JDWX}$ being slightly more important in describing the downstream wells. The importance of capturing this spatially distributed rainfall is reinforced when building a DFM using just one of the R_{net} series or the average of the two, which yielded poorer results ($4859 \leq AIC \leq 6998$; $0.88 \leq C_{eff} \leq 0.89$).

Fig. 3-7e shows that highest β values for WTE_R were associated with upstream wells (T1-W1, T3-W1) and downstream, high elevation wells (T7-W4, T8-W3, and T9-W3) wells, whose time series closely resembled regional groundwater circulation. Though the importance of regional groundwater elevation (WTE_R_{M1001}) increased with well elevation, it was significant for nine of the twelve wells. A lowered regional groundwater table has been identified as a cause of reduced hydroperiod and increased saltwater intrusion in the Loxahatchee River (SFWMD, 2002), and the dependence of floodplain WTE on regional groundwater is substantiated by these results. It is interesting to note that, although the regional groundwater trend and SWE at Lainhart Dam are correlated ($r^2 = 0.71$), including both explanatory variables in Model II allows us to decompose the general effect of the regional groundwater circulation from the more local effect of SWE at Lainhart Dam shown in Fig. 3-7a.

The remaining three trends in Model II and their associated $\rho_{m,n}$ values are given in Figure 3-8. These common trends represent the remaining unexplained (latent) variability among the WTE series. Common trend 1 has a high starting value, likely associated with high water events during the hurricanes of 2004, which may not be sufficiently described by explanatory variables, especially if measurement errors occurred during these extreme events. This trend is most important to wells T1-W1 and

T3-W1, which were also most strongly affected by SWE at Lainhart Dam. WTE in all wells are generally positively correlated with both common trends 1 and 2, but have low correlations (average $\rho_{1,n}$ value: 0.25±0.21; average $\rho_{2,n}$ value: 0.31±0.15). Common trend 3 is weaker and less consistent, with positive correlations for most floodplain wells and negative correlation for most upland wells, all of which were either "minor" or "low." Correlations between these remaining trends and the explanatory variables in Model II were also low, confirming that the importance of explanatory variables was not masked by common trends. Though not pursued here, in cases where common trends do mask explanatory variables, it may be possible to use a two-step process wherein the "ignored" explanatory variable(s) are fit to the data first using linear regression. DFA could then be run on the residuals of this process as previously described. This method would essentially be a time series-based partial regression technique (e.g., Zuur et al., 2007).

Multilinear regression model (DFA with no common trends)

Finally, common trends were removed from the model to assess the validity of a DFM using only explanatory variables. In this model (Model III), the five explanatory variables identified in the DFA were used to create a multi-linear model of the response variables. As expected, C_{eff} values for Model III were somewhat reduced from Model II (overall C_{eff} = 0.81, 0.59< C_{eff} <0.94; compared to C_{eff} = 0.91, 0.78< C_{eff} <1.0 for Model II), but are still adequate for most wells (Table 3-6). Model III accurately predicted WTE series in higher elevation wells farthest from the river (e.g., Fig. 3-9, well T3-W1) and in lower elevation wells close to the river (e.g., Fig. 3-9, well T7-W1), but performed worse for middle distance and elevation wells (e.g., Fig. 3-9, well T7-W3). Closer to the edges

of the system, explanatory variables act as boundary conditions (e.g., regional WTE at the farthest landward end of transects and SWE acting at the river) and their effects can be seen directly in the WTE series. In middle distance and middle elevation wells, the interaction of surface water and groundwater is most complex and non-linear, which may not be as well captured by a linear combination model. Despite these limitations, overall performance of Model III is adequate to describe variations in WTE in the Loxahatchee River floodplain and may be useful for assessment of Loxahatchee River restoration scenarios (SFWMD, 2006), especially considering the wide range of climatic conditions captured in the study. In general, all restoration scenarios rely primarily on increased freshwater flow over Lainhart Dam, which was found to be the most important driver of upstream hydroperiod and downstream surface water salinity. The Restoration Plan for the Northwest Fork of the Loxahatchee River (SFWMD, 2006) identified a single preferred restoration flow scenario (PRFS) that incorporated seasonally and yearly variable flows to maintain healthy, functioning ecosystems. In addition to estimating water table elevation under the PRFS, the models developed in this study can be applied to any number of possible future scenarios, including increased groundwater withdrawals, sea level rise, and changes in rainfall and ET patterns associated with climate change.

Summary and Conclusions

Detailed hydrological multivariate time series, obtained in and around the Loxahatchee River watershed in south Florida, were studied and modeled using dynamic factor analysis (DFA). The analysis was successfully applied to understand the hydrological processes in this area, which has been affected by reduced hydroperiod and increased saltwater intrusion. The technique proved to be a powerful

tool for the study of interactions among 29 long-term, non-stationary hydrological time series (twelve water table elevation [WTE] series and seventeen candidate explanatory variables). Upstream and tidal surface water elevations (SWE), regional groundwater circulation (WTE_R), and cumulative net local recharge (R_{net}) were found to be the most important factors responsible for groundwater variation in the floodplain wetlands of the Loxahatchee River, and the analysis quantified the spatial distribution of the importance of each explanatory variable to WTE in the twelve monitoring wells.

Upstream SWE at Lainhart Dam is the primary managed hydrological input in the Loxahatchee River and was important for describing variability in wells T1-W1 and T3-W1, but had limited impact on WTE on downstream transects. Although SWE at Lainhart Dam has been shown to largely dictate downstream surface water salinity (*SFWMD*, 2006), its role in explaining WTE variation is limited to the upstream, riverine river reaches. Tidal SWE at RK 14.6, which is susceptible to climate change-induced sea level rise, was important for explaining observed WTE variability for downstream, lower elevation wells.

WTE_R was significant for nine of the twelve wells, corroborating the noted dependence of floodplain WTE on regional groundwater (SFWMD, 2002). The best DFM used two R_{net} series, with wells T1-W1 and T3-W1 gaining the most benefit from the R_{net} series calculated using rain from the nearby (to these wells) S-46 structure. The importance of the R_{net} series from the JDWX gauging station were split fairly equally over the remainder of the wells. Using the average of the two series (a common technique in small watersheds) yielded inferior results. This highlights the importance of using the best available local rainfall data for hydrological modeling, whether empirical

or mechanistic, and stresses the need to move to more advanced rainfall measurement techniques, including Next Generation Radar (NexRad).

The DFM resulting from the DFA (Model II) had good results (overall $C_{eff} = 0.91$, $0.78 \leq C_{eff} \leq 1.0$, visual inspection) and is useful for filling in data gaps during the study period and identifying the relative importance and relationships between hydrological variables of interest. The reduced model with no common trends (Model III) did a fair to excellent job (overall $C_{eff} = 0.81$, $0.59 \leq C_{eff} \leq 0.94$), and is likely adequate for describing variations in WTE in the Loxahatchee River floodplain. This empirical model may be deemed useful for assessment of the effects of Loxahatchee River restoration and management scenarios on WTE dynamics.

The study also provides a quantitative validation of our qualitative expectations that tidal effects propagate some distance inland (along a river or estuary), river effects propagate some distance inland from the banks (here to swamps/floodplains), hydraulic structure effects propagate some distance from the structure, and net recharge effects are highly localized. Results of the analysis presented here have practical implications, in addition to guiding climate change mitigation planning and ecohydrologic analysis of salinity in coastal river wetlands. For example, mechanistic modeling efforts that consider spatial variability of land covers and soils would likely benefit from knowledge of where tidal effects end and the degree to which local rainfall variability is an important determining factor. Mechanistic frameworks using conditional modeling approaches can also benefit from knowing which explanatory variables are most important as a function of the relative location of a study area to the ocean, a tidal river, or hydraulic structures.

Table 3-1. Locations and attributes of the twelve groundwater wells in the study. Wells are distributed across five transects (T1, T3, T7, T8, and T9). River kilometer indicates distance from the river mouth. Well depth is given in depth below ground surface (bgs).

Well	Transect Type	River Kilometer	Distance to River (m)	Well Elevation (m, NGVD29)	Well Depth (m, bgs)
T1-W1	Riverine	23.3	50	3.28	1.77
T3-W1	Riverine	19.5	95	1.60	1.76
T7-W1	Transitional	14.6	2	0.36	1.84
T7-W2			30	0.43	1.82
T7-W3			90	0.56	1.69
T7-W4			130	2.94	3.67
T8-W1	Transitional	13.1	5	0.12	1.62
T8-W2			65	0.36	1.60
T8-W3			105	2.28	2.64
T9-W1	Tidal	10.5	70*	0.41	1.86
T9-W2			50*	0.62	1.86
T9-W3			30*	2.94	4.24

*shortest distance from well to river (T9 is on a peninsula)

Table 3-2. Hydrological time series used in the DFA.

Variable	Series Type	No. of series	Description
WTE	Response	12	Groundwater table elevation (m, NGVD29) from wells in the Loxahatchee River floodplain
SWE	Explanatory	6	Surface water elevation (m, NGVD29) from stations in the Loxahatchee River at RK 23.3 (near T1), RK 14.6 (near T7), RK 13.1 (near T8), RK 9.5 (near T9), RK 1.1 (near Jupiter Inlet), and on Kitching Creek
R_{net}	Explanatory	3	Cumulative net recharge (cumulative rainfall – cumulative ET_o, mm) calculated from weather stations at the S-46 structure and in Jonathan Dickinson State Park in the Loxahatchee River watershed (JDWX).
WTE_R	Explanatory	9	Groundwater table elevation (m, NGVD29) from USGS wells near the Loxahatchee River watershed

Table 3-3. Dynamic factor models (DFMs) tested in this study (see explanation in text).

DFM	No. of trends	Explanatory variables	Regression parameters	No. of parameters	C_{eff}
Model I	6	None	---	81	0.94
Model II	3	$SWE_{RK23.3}$, $SWE_{RK14.6}$, WTE_R_{M1001}, $R_{net,S46}$, $R_{net,JDWX}$	From DFA	117	0.91
Model III	0	$SWE_{RK23.3}$, $SWE_{RK14.6}$, WTE_R_{M1001}, $R_{net,S46}$, $R_{net,JDWX}$	Multiple regression	60	0.81

Table 3-4. Akaike's information criteria (AIC) and Nash-Sutcliffe coefficients of efficiency (C_{eff}) for dynamic factor models with no explanatory variables and 1 to 7 common trends. Best model in bold.

M	C_{eff}	AIC
1	0.44	32204
2	0.80	19860
3	0.85	15390
4	0.89	11211
5	0.90	7337
6	**0.94**	**4880**
7	0.93	6875

Table 3-5. Constant level parameters (μ_n), canonical correlation coeficents ($\rho_{m,n}$), factor loadings ($\gamma_{m,n}$), regression coefficients ($\beta_{k,n}$), and coefficients of efficiency (C_{eff}) from Model II (3 trends, 5 explanatory variables). Significant regression parameters in bold.

		Can. Correlations			Factor loadings			Regression coefficients ($\beta_{k,n}$)					
s_n	μ_n	$\rho_{1,n}$	$\rho_{2,n}$	$\rho_{3,n}$	$\gamma_{1,n}$	$\gamma_{2,n}$	$\gamma_{3,n}$	$SWE_{RK23.3}$	$SWE_{RK14.6}$	$R_{net,S46}$	$R_{net,JDWX}$	WTE_R_{M1001}	$C_{eff,n}$
T1-W1	-0.44	0.61	0.10	-0.30	0.08	0.02	0.00	**0.53**	-0.01	**0.73**	0.10	**0.22**	1.00
T3-W1	-0.26	0.52	0.14	-0.31	0.05	0.02	0.00	**0.58**	0.01	**0.56**	0.13	**0.19**	0.97
T7-W1	-0.10	0.19	0.23	0.02	0.00	-0.01	0.04	**-0.07**	**0.92**	**0.23**	0.05	**0.16**	0.94
T7-W2	0.58	0.16	0.35	0.26	0.00	0.02	0.18	0.02	**0.62**	**0.71**	**0.74**	-0.05	0.90
T7-W3	0.22	-0.08	0.09	-0.04	-0.01	-0.02	0.20	**0.12**	**0.47**	**1.05**	**1.00**	-0.12	0.83
T7-W4	1.20	0.27	0.43	-0.38	0.00	0.10	-0.01	**0.10**	-0.01	0.09	**0.77**	**0.24**	1.00
T8-W1	-0.14	0.05	0.30	0.27	0.00	-0.01	0.03	**0.19**	**0.74**	**-0.26**	0.00	**0.12**	0.78
T8-W2	0.01	0.45	0.36	0.04	0.03	0.01	0.12	**-0.08**	**0.43**	**0.54**	**0.72**	**0.19**	0.80
T8-W3	0.90	0.35	0.55	-0.14	0.02	0.10	0.00	**0.21**	**-0.09**	0.30	**0.65**	**0.2**	0.88
T9-W1	0.50	0.16	0.31	0.29	0.00	0.00	0.23	**-0.12**	**0.58**	**0.92**	**1.03**	0.06	0.97
T9-W2	0.09	0.02	0.30	0.24	0.01	0.00	0.16	**0.06**	**0.70**	**0.49**	**0.84**	0.01	0.98
T9-W3	1.06	0.35	0.54	-0.16	-0.01	0.07	0.03	**0.12**	**0.27**	0.03	**0.70**	**0.16**	0.86
												Overall:	0.91

Table 3-6. Model parameters, and coefficients of efficiency (C_{eff}) from Model III (no trends, 5 explanatory variables). Significant model parameters in bold.

	Model parameters					
s_n	$SWE_{RK23.3}$	$SWE_{RK14.6}$	WTE_R_{M1001}	$R_{net,S46}$	$R_{net,JDWX}$	C_{eff}
T1-W1	**0.69**	**-0.09**	**0.41**	**0.07**	-0.02	0.91
T3-W1	**0.70**	**-0.06**	**0.35**	**0.08**	0.00	0.94
T7-W1	**-0.07**	**0.95**	**0.09**	**0.08**	**-0.05**	0.93
T7-W2	**0.07**	**0.86**	**0.09**	**-0.05**	**-0.31**	0.76
T7-W3	**0.13**	**0.65**	**-0.32**	**0.42**	**0.30**	0.59
T7-W4	**0.18**	**0.03**	**0.68**	**0.07**	**0.23**	0.91
T8-W1	**0.18**	**0.78**	**0.07**	**-0.38**	**-0.09**	0.80
T8-W2	**0.06**	**0.55**	**0.35**	**-0.12**	0.01	0.68
T8-W3	**0.34**	**-0.04**	**0.69**	**-0.05**	**-0.04**	0.81
T9-W1	**-0.12**	**0.87**	**0.10**	**-0.06**	**-0.11**	0.81
T9-W2	**0.12**	**0.87**	**-0.04**	**-0.17**	**0.15**	0.86
T9-W3	**0.14**	**0.38**	**0.50**	-0.01	**0.05**	0.77
					Overall:	0.81

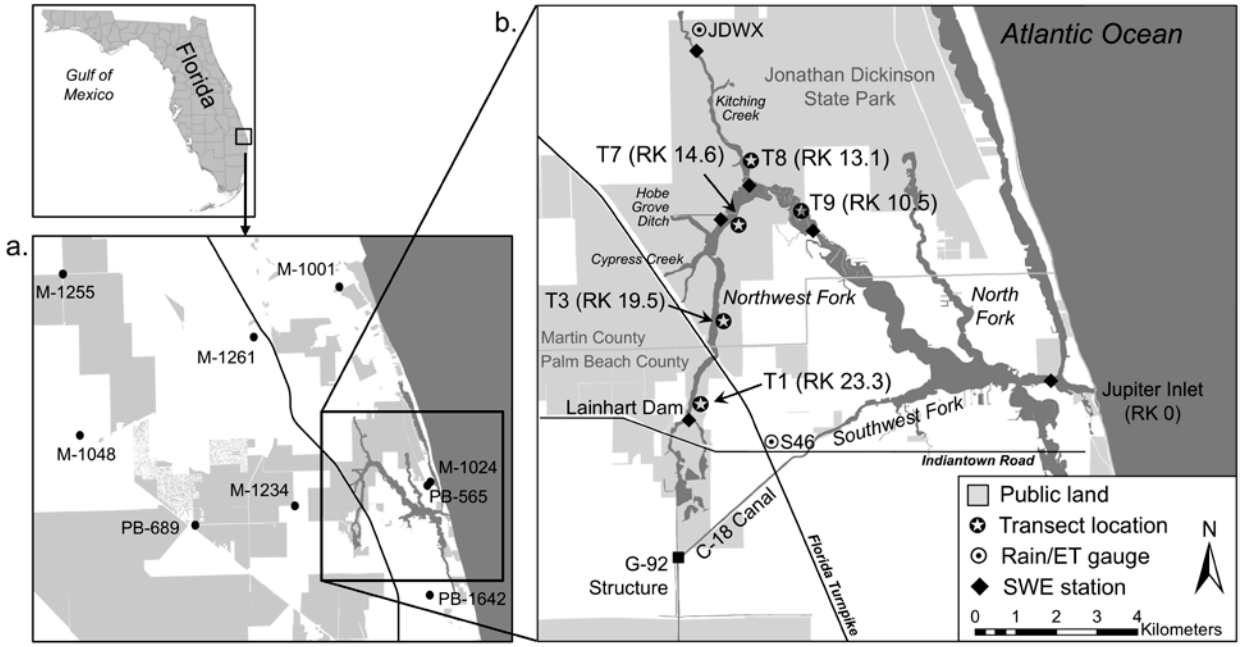

Figure 3-1. The Loxahatchee River and surrounding area, showing (a) the location of the nine regional USGS wells (WTE_R) used in this study and (b) transect locations (T1, T3, T7, T8, and T9), surface water elevation (SWE) and meteorological measurement locations, and major hydraulic infrastructure. Transect notation is followed by distance from river mouth (river kilometer, RK).

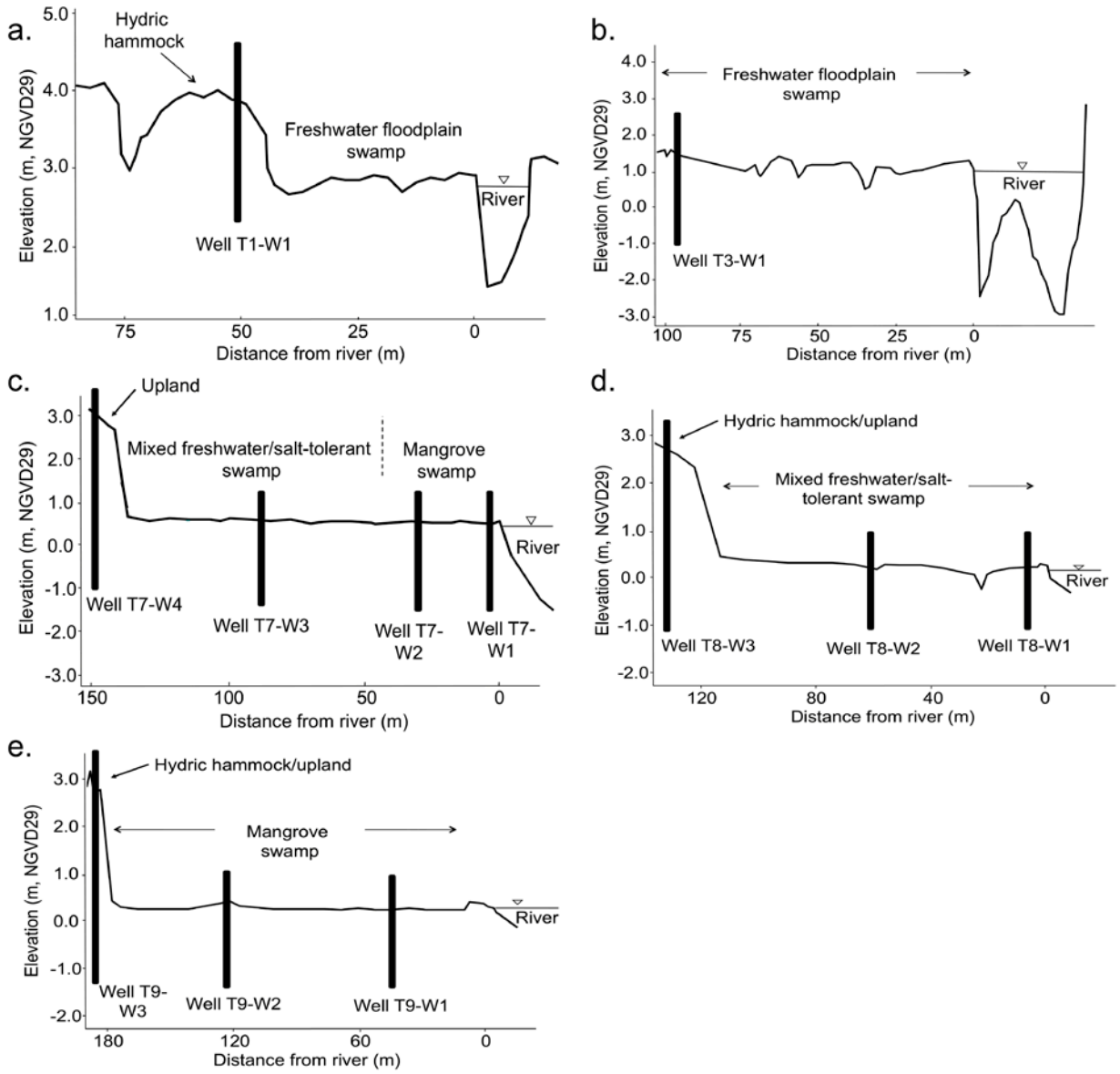

Figure 3-2. Transect topographic cross-sections, detailing well installation locations and elevations and predominant vegetation types.

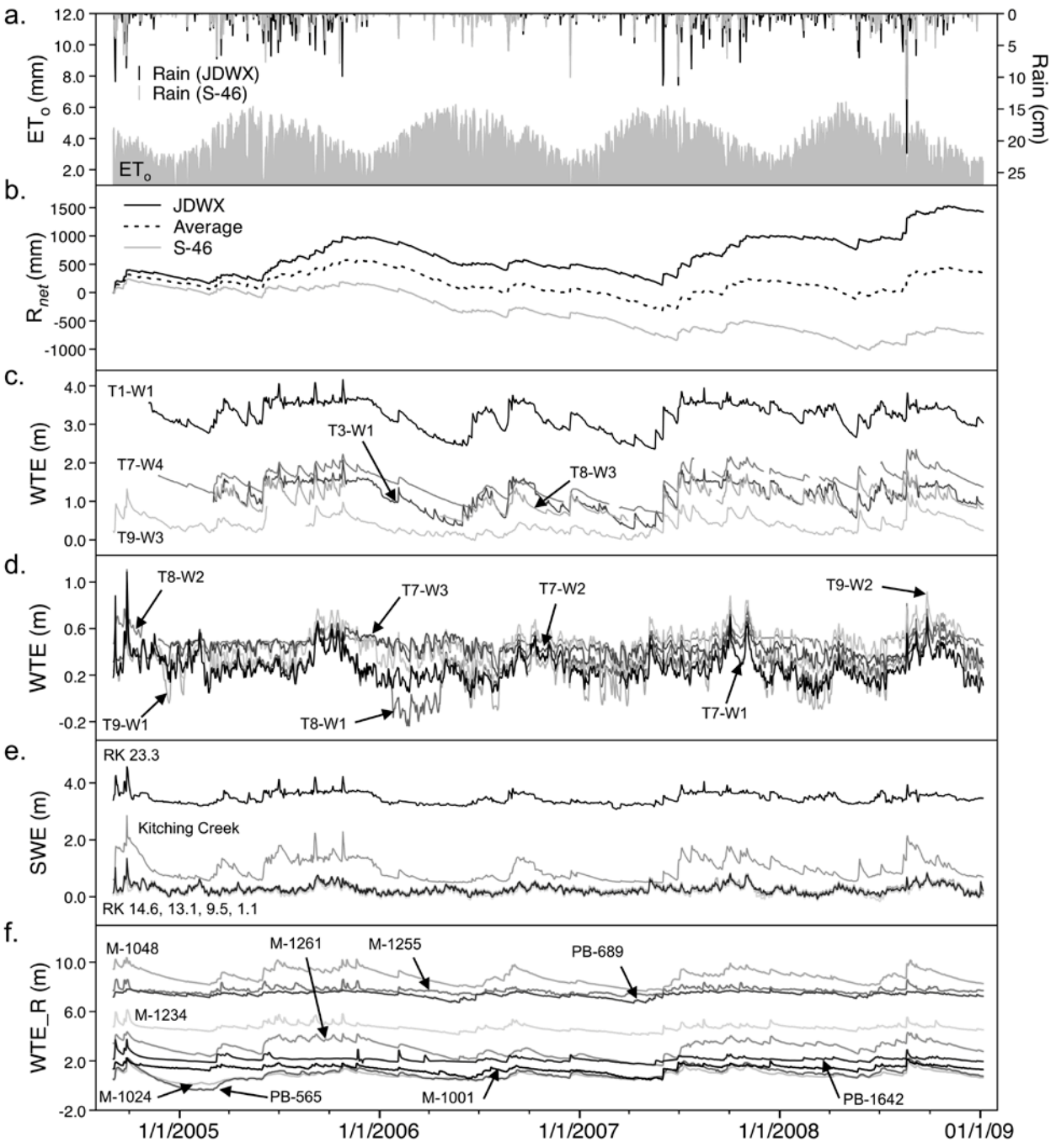

Figure 3-3. Precipitation, reference evapotranspiration (ET_0), calculated net local recharge (R_{net}), water table elevation (WTE), surface water elevation (SWE), and regional water table elevation (WTE_R) measured in and around the Loxahatchee River watershed. Gaps in times series in (c) represent missing data.

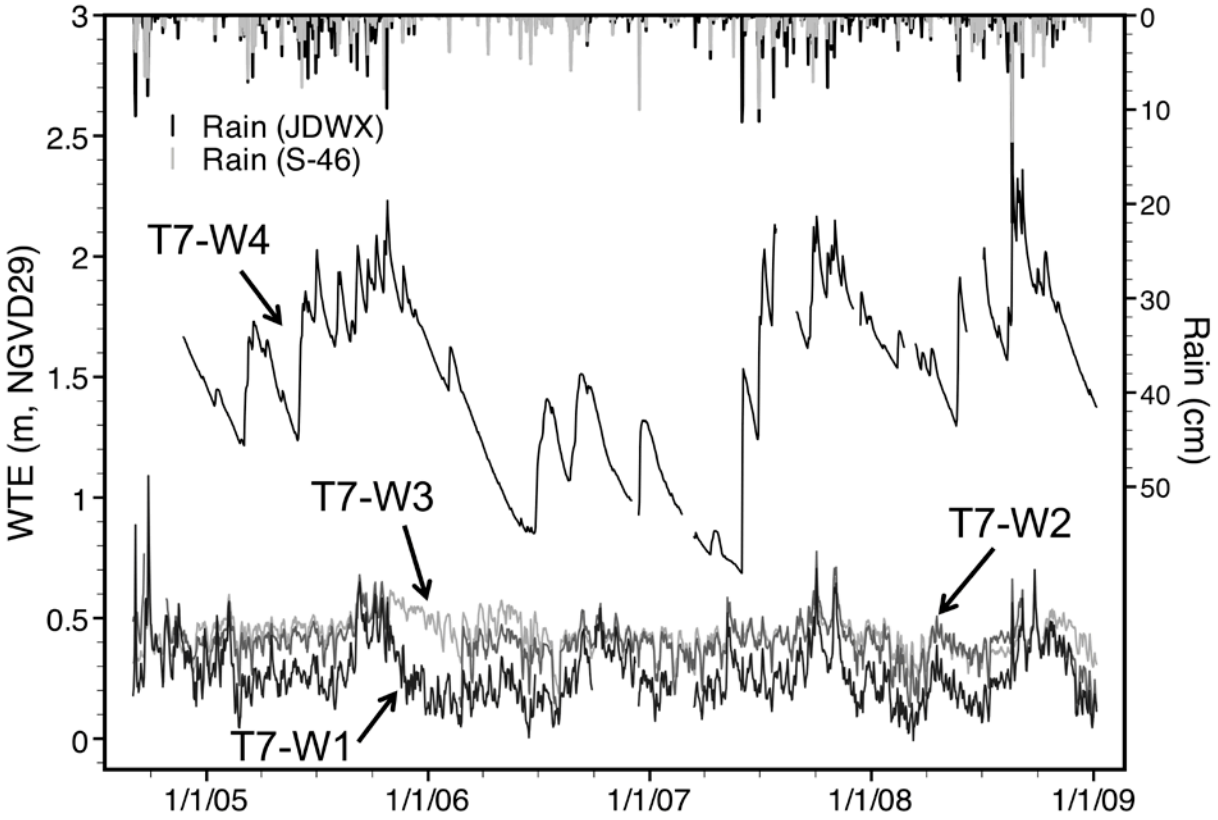

Figure 3-4. Average daily water table elevation (WTE) in the four wells on transect 7 (T7). Gaps in time series represent missing data.

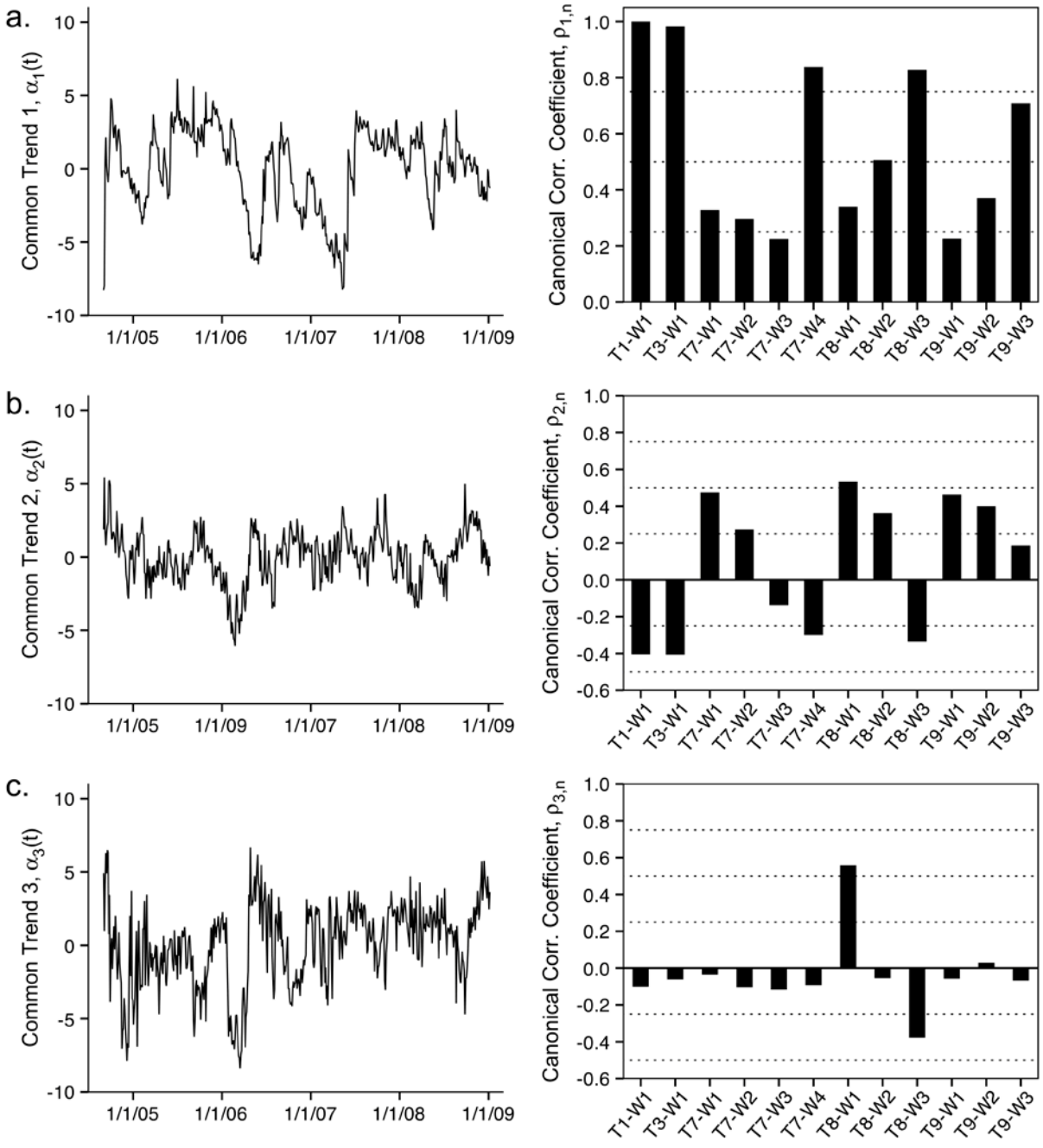

Figure 3-5. Three example trends from Model I (left) and their associated canonical correlation coefficients (right). Trend 1 (a) shows high correlation to higher elevation and upstream wells; trend 2 (b) is most associated with lower elevation lower elevation lower elevation lower elevation lower elevation floodplain wells; trend 3 (c) has low correlations except for wells T8-W1 and T8-W3.

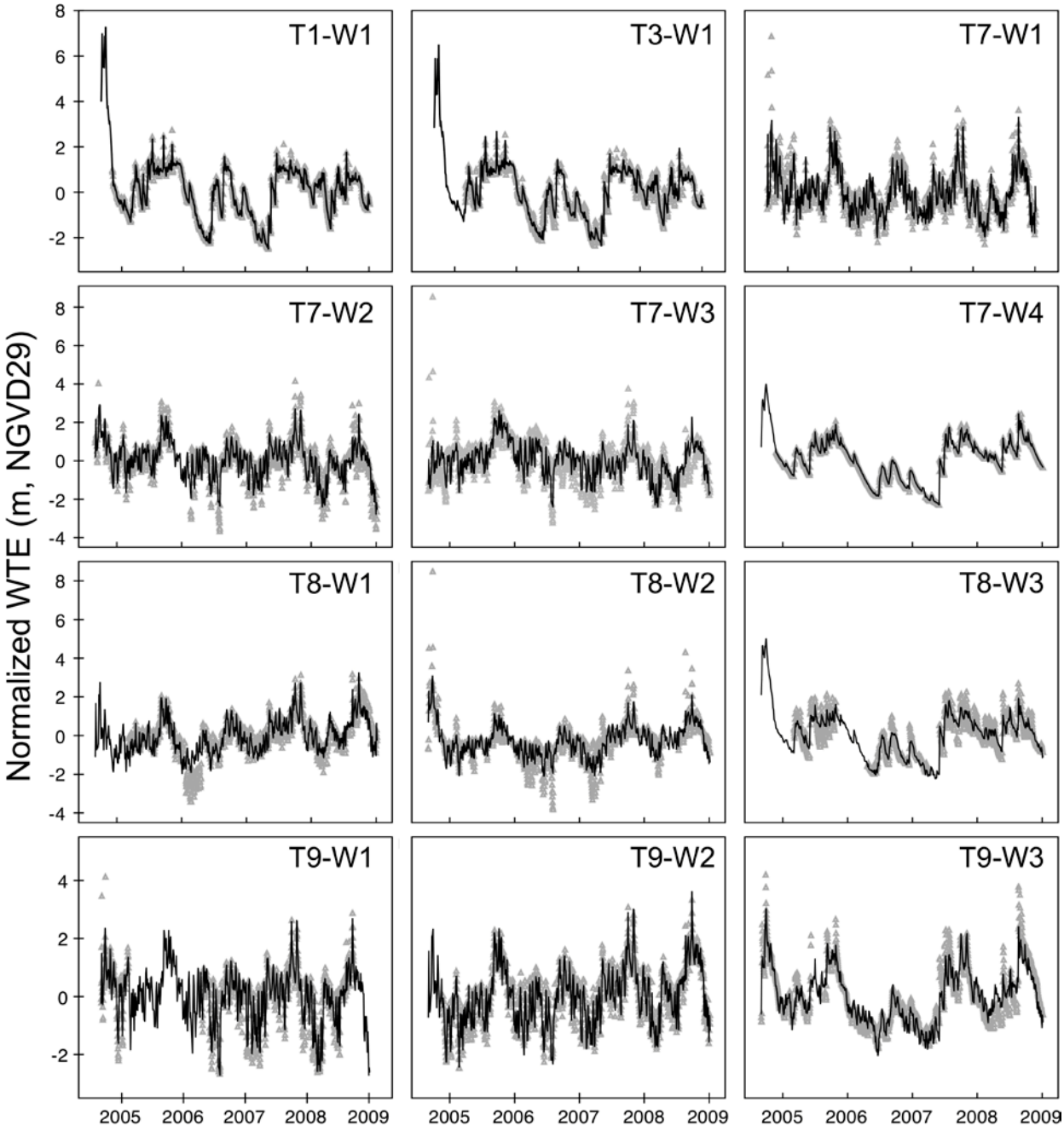

Figure 3-6. Observed (gray symbols) and modeled (black lines) normalized WTE for the twelve wells obtained from Model II using 3 common trends and 5 explanatory variables.

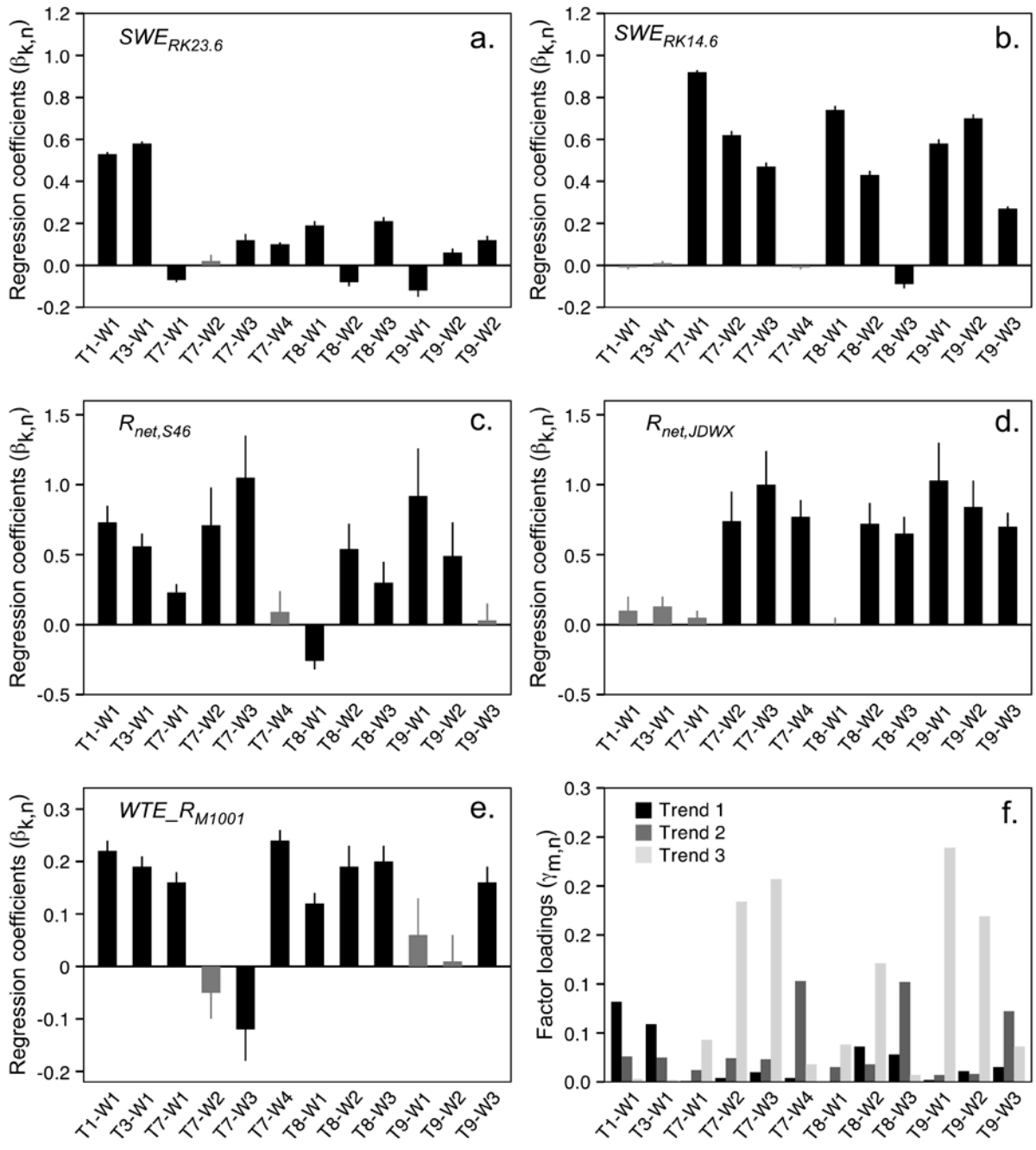

Figure 3-7. Regression parameters and factor loadings for Model II (M=3, K=5). Regression parameters (a-e) are shown with their standard errors, with black bars indicating significance.

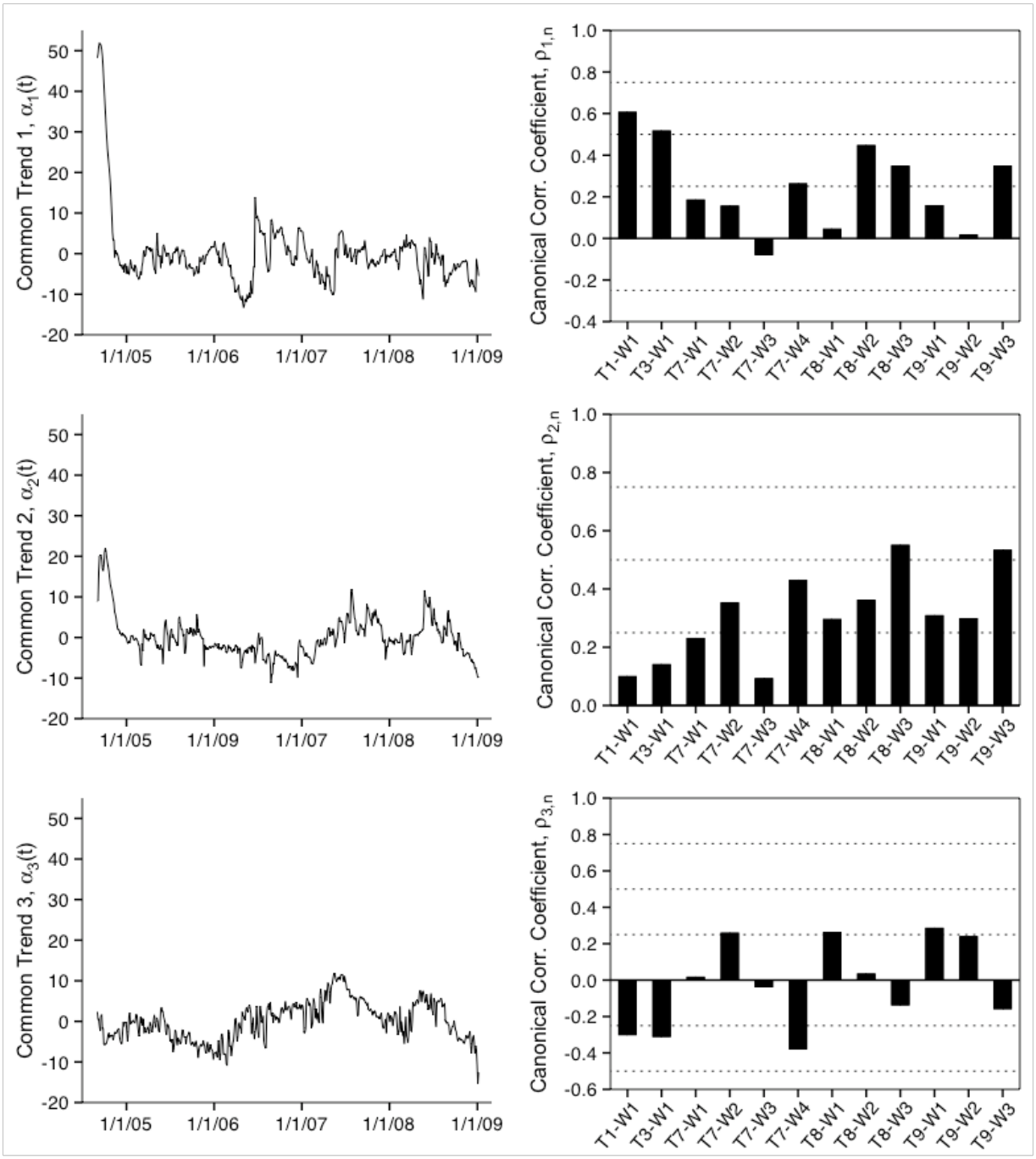

Figure 3-8. Common trends (left) and their associated canonical correlation coefficients (right) for Model II.

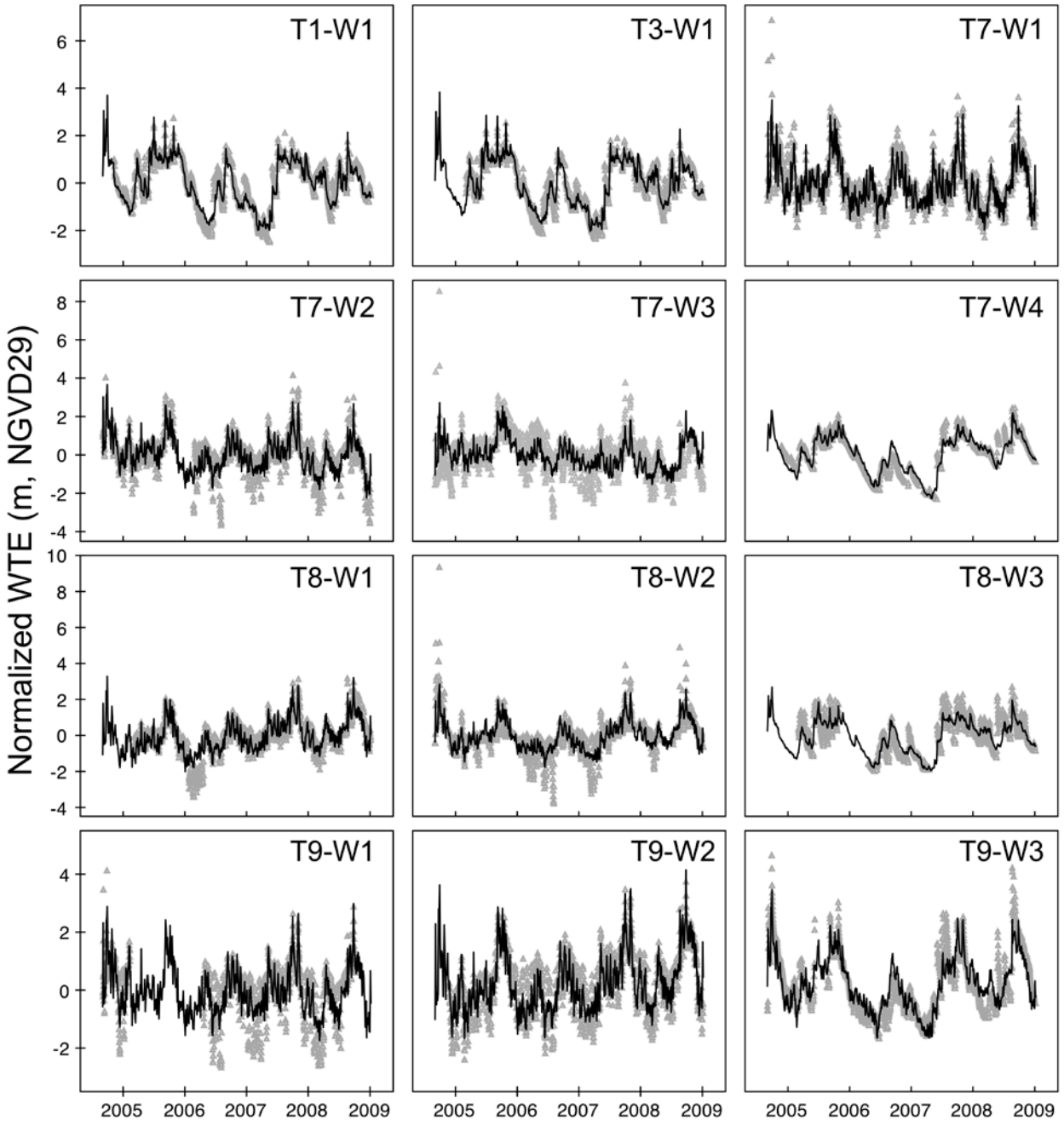

Figure 3-9. Observed (gray symbols) and modeled (black lines) normalized WTE for the twelve wells obtained from Model III using 5 explanatory variables and no trends.

CHAPTER 4
SHALLOW GROUNDWATER SALINITY IN A TRANSITIONING COASTAL FLOODPLAIN FOREST IMPACTED BY SALTWATER INTRUSION

Introduction

Saltwater intrusion is the invasion of fresh or brackish surface water or groundwater by water with higher salinity (USGS, 2000a) and has been well described by Knighton et al. (1991) as the "landward and upward displacement of the freshwater-saltwater interface in coastal aquifers, and increased saline water penetration in deltaic and estuarine areas." Saltwater intrusion has both natural (e.g., Flynn et al., 1995) and anthropogenic (e.g., Bechtol and Laurian, 2005) drivers and can lead to rapid and catastrophic loss of coastal wetlands (Wanless et al., 1989), especially where several drivers act simultaneously (e.g., deep-water canals, which increase the inland extent of saltwater inflow, combined with accelerated sea-level rise, hurricanes, or severe drought, e.g., McCarthy et al., 2001). While sea level has cycled up and down over the millennia, the coastal ecosystems currently ringing the continents have developed over a fairly stable period of sea-level rise (Wanless et al., 1994). Relatively fast-acting natural and anthropogenic drivers are currently overwhelming coastal wetlands with more frequent, longer, deeper, and saltier inundation in many areas (Burkett et al., 2001). Saltwater intrusion in coastal wetlands causes plant stress or mortality from prolonged submergence and/or high salinities; erosion of wetland substrate; conversion of freshwater habitats to brackish or saltwater habitats; and the transition of coastal saltwater habitats to open water (DeLaune et al., 1994). Barlow (2003) provides a thorough review of the causes and impacts of saltwater intrusion on the Atlantic Coast of the USA.

In systems where the causes of saltwater intrusion are primarily anthropogenic, the development of watershed and river management and restoration plans may allow ecological impacts to be minimized or reversed (Scruton, 1998), and a robust understanding of hydrological dynamics is vital to assess the potential impacts of these planning efforts. However, the dynamics of saltwater intrusion are controlled by the interactive effects of tidal activity, the timing and volume of freshwater discharge, wind speed and direction, and density gradients caused by salinity. With diurnal tidal cycles, stochastic annual weather patterns, and decadal climate cycles, the dynamic behavior of saltwater intrusion is highly complex (Wang, 1988). Interactions between surface water, groundwater, and porewater in variably saturated matrices with heterogeneous soils, vegetation, and topography (e.g., Gardner et al., 2002, Langevin et al., 2005, Kaplan et al., 2010a) often make finding direct relationships between basic hydrological inputs vexingly difficult. This complexity is almost certainly heightened in groundwater vis-à-vis surface water (e.g., Kiro et al., 2008). For example, the frequency and duration of groundwater salinity exceeding a critical ecological threshold (Jassby, 1995) are functions of surface water elevation and salinity, tidal range, distance from the ocean, distance from the river channel, local elevation (microtopography), volume of fresh surface water flow, and the direction, volume, and salinity of groundwater fluxes (e.g., Wang, 1988; Melloul and Goldenberg, 1997; Liu, 2001), as well as soil hydraulic characteristics and vegetation properties.

Full-scale, density-dependent, numerical models of water table elevation and groundwater salinity such as SEAWAT (Guo and Langevin, 2002) and MOCDENS3D (Essink, 2001) can be useful for improving our understanding of physical systems

(Langevin et al., 2005) and for assessing the potential effects of proposed management scenarios (Nassar et al., 2007), but require extensive subsurface stratigraphy and hydrogeology data to populate the model domain and often rely on simplifying assumptions to estimate model boundary conditions (Motz and Sedighi, 2009) and initial conditions (Lin et al., 2008). These models also focus almost exclusively on deeper groundwater systems, and may not be as useful for describing shallow groundwater, which can be in direct contact with coastal wetlands directly vía the root zone (Skalbeck et al., 2008) or through upward or lateral seepage (e.g., Gardner et al., 2002; Moffett et al., 2008). On the other hand, collection of long-term, high-resolution shallow water table elevation and salinity data can describe the dynamics (i.e., magnitude, range, daily, seasonal and interannual variation, etc.) and spatial variation of these variables (e.g., Lyons et al., 2004, Muñoz-Carpena et al., 2008, 2009). However, using visual inspection and comparative statistics to develop relationships between multivariate time series can be difficult, subjective, and may not improve our understanding of the hydrological relationships that characterize the system (Ritter et al., 2007). Thus, an alternative method for sifting through complex data sets to identify possible shared trends and relationships is required.

In this study, we applied Dynamic Factor Analysis (DFA), a multivariate times series dimension reduction technique, to investigate the complex groundwater salinity dynamics observed in the floodplain wetlands of the Loxahatchee River, a managed coastal river in southeastern Florida (USA). DFA is a statistical model, such that dynamic factor models (DFMs) produced by DFA are driven by measured data. Thus, the approach requires no *a priori* information about the physical system being modeled.

The ability to model time series as a combination of common trends (representing unexplained variability) and explanatory variables is especially useful for analyzing complex environmental systems, where DFA can help assess what explanatory variables (if any) affect the time series of interest, and thus may be worthy of closer attention. While DFA was initially developed to analyze economic time series (Geweke, 1977), it has been successfully applied to improve understanding of common trends and explanatory variables that describe variation in groundwater levels (Kovács et al., 2004; Ritter and Muñoz-Carpena, 2006; Kaplan et al., 2010b), soil moisture dynamics (Ritter et al., 2009), and interactions between hydrological variables and groundwater quality trends (Muñoz-Carpena et al., 2005; Ritter et al., 2007). DFA has also been successfully applied to model the dynamics of squid (Zuur and Pierce, 2004), Atlantic bluefish (Addis et al., 2008), and other commercial fisheries (e.g., Erzini, 2005; Tulp et al., 2008).

In this study, DFA was applied to study the interactions between floodplain groundwater salinity and other hydrological variables in the floodplain wetlands of the Loxahatchee River (Florida, USA), where watershed modifications and management over the past century have reduced freshwater flow and led to saltwater intrusion upriver into historically freshwater ecosystems. This changing hydrology has been associated with a transition to salt-tolerant, mangrove-dominated communities as salt water advanced upstream (South Florida Water Management District [SFWMD], 2006). While intensive data collection and modeling efforts have been directed at developing appropriate surface water management and restoration goals (SFWMD 2002, 2006), groundwater salinity has been largely overlooked. Thus, the specific objectives of this

research are to: 1) investigate shallow groundwater salinity in the floodplain wetlands of the Loxahatchee River along several transects perpendicular to the river (from upriver, freshwater areas through downriver, tidal areas) and 2) apply DFA to investigate the interactions between the groundwater salinity time series and other hydrological variables obtained throughout the watershed to (a) identify important common trends among the series and (b) identify the external hydrological factors (local and/or regional) that most fully explain observed variation in the time series.

Materials and Methods

Study Site and Experimental Setup

The Loxahatchee River is located on the southeastern coast of Florida, USA (26° 59' N, 80° 9' W; Fig. 4-1) and was historically part of the greater Everglades watershed. The watershed currently drains approximately 550 km^2 in Palm Beach and Martin Counties and includes several large, publicly owned areas including Jonathan Dickinson State Park (JDSP), the Loxahatchee Slough Preserve, and the J.W. Corbett Wildlife Management Area. The river's three main branches (the North, Southwest, and Northwest Forks) join in a central embayment that connects to the Atlantic Ocean via Jupiter Inlet (Fig. 4-1). The Loxahatchee River is often referred to as the "last free-flowing river in southeast Florida" (SFWMD, 2006) and in 1985, a 15.3-km stretch of the Northwest Fork (NW Fork) became Florida's first National Wild and Scenic River (National Park Service [NPS], 2004).

Altered hydroperiods and encroaching salinity in the NW Fork have been linked to undesired changes in the vegetative composition of the floodplain, where studies have documented the upriver retreat of bald cypress since at least the turn of the 20th century

(General Land Office [GLO], 1855; Alexander and Crook, 1975; McPherson, 1981; Ward and Roberts, 1996; Roberts et al., 2008). Of primary concern are: 1) the transition from bald cypress floodplain swamp to mangrove-dominated communities in the tidal floodplain as salinity increased; and 2) inadequate hydroperiod in the upstream riverine floodplain, which has shifted the system towards drier plant communities (SFWMD, 2009). Intensive data collection and modeling efforts in support of management and restoration planning have been underway for several years (e.g., SFWMD, 2002, 2006, 2009; VanArman et al., 2005; Mortl, 2006; Muñoz-Carpena et al., 2008, Kaplan et al., 2010a,b). Further description of the hydrological history and floodplain vegetation of the Northwest Fork of the Loxahatchee River (NW Fork) is found in SFWMD (2006, 2009).

To better understand the role of groundwater in river and floodplain hydrology, the SFWMD and Florid Park Service (FPS) developed a network of twelve groundwater wells along five previously established vegetation survey transects perpendicular to the NW Fork (T1, T3, T7, T8, and T9; Fig. 4-1). These five transects encompass a gradient of floodplain conditions that change with distance from the river mouth (indicated as river kilometer, RK). T1 and T3 are located in the upstream, riverine reach at RK 23.3 and RK 19.5, respectively (Fig. 4-1). The floodplain in the riverine reach does not receive daily tidal flooding and is therefore generally unaffected by high surface water salinity. Floodplain canopy vegetation in this reach is dominated by freshwater wetland species including bald cypress (*Taxodium distichum* [L.] Rich.), pop ash (*Fraxinus caroliniana* Mill.), red maple (*Acer rubrum* L.), pond apple (*Annona glabra* L.), and water hickory (*Carya aquatica* [Michx. f.] Nutt.) (SFWMD, 2009).

T7 and T8 are located at RK 14.6 and RK 13.1, respectively (Fig. 4-1), and represent the upper tidal reach of the NW Fork. As a transitional area, the floodplain in the upper tidal reach experiences variable tidal inundation over some or all of its extent, and the salinity of surface water is extremely dynamic over wet and dry seasons (Kaplan et al., 2010a). Vegetation in this area is a mix of freshwater and brackish species generally dominated by moderately salt-tolerant species (e.g., pond apple and cabbage palm, *Sabal palmetto* [Walter] Lodd. Ex Schult. & Schult. f.). Freshwater species (e.g., bald cypress) are found near the upland-floodplain border and salt-tolerant species (primarily red and white mangrove, *Rhizophora mangle* L. and *Laguncularia racemosa* [L.] Gaertn. f.) are found closer to the river's edge. T9 is located further downstream at RK 10.5 (Fig. 4-1) and represents the lower tidal reach of the NW Fork. The floodplain in this reach is subject to daily tidal flooding with surface water of variable, but consistently high, salinity. The lower tidal floodplain is dominated by salt-tolerant white and red mangroves (SFWMD, 2009).

Upriver transects T1 and T3 (Fig. 4-2a-b) each have one well, while transitional and tidal transects have multiple wells to document differences in groundwater salinities from the river channel towards the upland. T7 (Fig. 4-2c) has four wells and T8 and T9 (Fig. 4-2d-e) each have three wells. Water table elevation (WTE) and groundwater electrical conductivity (GWEC, expressed as electrical conductivity at 25˚ C, S/m) data were collected every 30 minutes using TROLL 9000/9500 multi-parameter water quality probes (In-Situ Inc., Ft. Collins, CO, USA) from September 2004 through January 2009. To confirm probe readings, depth to the water table was measured using an interface meter (Solinst, Ontario, CA) and electrical conductivity (EC) probes were calibrated

using standard solutions during each data download. Data were converted to daily averages to present the full period of record and for use in the DFA, but high-resolution (30-minute) data are also presented. Table 4-1 summarizes attributes of the twelve wells. A full description of the groundwater dataset and QA/QC procedure can be found in Muñoz-Carpena et al. (2008) and an in-depth analysis of WTE data is available in Kaplan et al. (2010b).

Dynamic Factor Analysis

DFA is a multivariate application of classic time series analysis and models temporal variation in observed data series as linear combinations of one or more common trends (representing unexplained variability), zero or more external explanatory variables (representing explained variability), a constant intercept parameter, and noise (Zuur et al., 2003b). Unlike other time series methods (e.g., ARIMA models), DFA is capable of modeling relatively short, incomplete, non-stationary time series (Zuur et al., 2003a). As with other modeling tools, DFA aims to balance goodness-of-fit and model parsimony by developing different DFMs. We assessed DFM performance using the Nash and Sutcliffe coefficient of efficiency ($-\infty \leq C_{eff} \leq 1$; Nash and Sutcliffe, 1970) and Akaike's information criterion, AIC (Akaike, 1974).

DFA is inherently a structural time series model (Harvey, 1989) that endeavors to model a set of N time series (dubbed response variables) using a DFM made up of M common trends ($M<N$), K explanatory variables, a level or intercept parameter, and noise (Lütkepohl, 1991; Zuur et al., 2003b):

N time series = M common trends + level parameter + K explanatory variables + noise (4-1)

As opposed to physically based models, which are built upon the mechanisms known to underlie a given system, DFA is a statistical modeling tool. DFMs are built upon the common patterns among, and interactions between, response variables and explanatory factors. Thus, no *a priori* understanding of the interactions between response and explanatory time series is required (Ritter et al., 2009). In the case presented here, this means that we need not know how groundwater salinity time series (i.e., response variables) interact with surface water and other hydrological variables (i.e., candidate explanatory variables) to perform the DFA.

DFA identifies one or more common trends in the response time series that represent unexplained, but shared, variation. The best DFM minimizes the number of common trends required to achieve a good fit as determined by C_{eff} and/or AIC. Appropriate explanatory variables may help improve the model and point out which environmental factors (if any) affect the response variables (and how). Equation 4-1 can be written in mathematical form as:

$$s_n(t) = \sum_{m=1}^{M} \gamma_{m,n} \alpha_m(t) + \mu_n + \sum_{k=1}^{K} \beta_{k,n} v_k(t) + \varepsilon_n(t) \quad (4\text{-}2)$$

$$\alpha_m(t) = \alpha_m(t-1) + \eta_m(t) \quad (4\text{-}3)$$

where $s_n(t)$ is a vector containing the set of N response variables; $\alpha_m(t)$ is a vector containing the mth common trend; $\gamma_{m,n}$ are factor loadings or weighting coefficients, which indicate the importance of each of the common trends within the DFM; μ_n is a constant level parameter; $v_k(t)$ is a vector containing 0 – K explanatory variables; and $\beta_{k,n}$ are regression parameters, which indicate the importance of each of the explanatory variables in the DFM. In this study, N represents the twelve GWEC time series. $\varepsilon_n(t)$

and $\eta_m(t)$ are independent, Gaussian noise with zero mean and unknown diagonal or symmetric/non-diagonal covariance matrix. A symmetric, non-diagonal matrix may yield adequate DFMs with fewer common trends than a diagonal matrix, but also increases the number of required parameters (Zuur et al., 2003a).

Common trends are predicted using the Kalman filter/smoothing algorithm and Expectation Maximization (EM) technique (Dempster et al., 1977; Shumway and Stoffer, 1982; Wu et al., 1996) and are modeled as a random walk (Harvey, 1989). The EM technique is also used to calculate factor loadings ($\gamma_{m,n}$) and level parameters (μ_n). Regression parameters ($\beta_{k,n}$) are modeled using linear regression (Zuur and Pierce, 2004).

The relative importance of common trends and explanatory variables was quantified using their associated factor loadings ($\gamma_{m,n}$) and regression parameters ($\beta_{k,n}$). The significance of relationships between response and explanatory variables was determined using the magnitude of the $\beta_{k,n}$ and their associated standard errors to calculate a t-value for each (significant relationships for t-values > 2). Canonical correlation coefficients ($\rho_{m,n}$) were used to quantify cross-correlation between response variables and common trends, with values of $\rho_{m,n}$ close to unity indicating high correlation between a common trend and response variable. In the following sections, "minor" correlations refer to those with $|\rho_{m,n}| < 0.25$; "low" correlations to $0.25 \leq |\rho_{m,n}| < 0.50$; "moderate" correlations to $0.50 \leq |\rho_{m,n}| \leq 0.75$; and "high" correlations to $|\rho_{m,n}| > 0.75$.

Explanatory Variables

Meteorological and hydrological variables have been collected in the NW Fork in support of MFL and restoration plan development for several years, and these time series were used as candidate explanatory variables in the DFA. A total of 45 time series (each with 1588 daily average values) were investigated for use as possible explanatory variables in the DFA (Table 4-2). Since multi-collinearity may exist between explanatory variables measured at nearby locations, not all candidate explanatory variables were used in final DFMs. The variance inflation factor (VIF) was used to quantify the severity of multi-collinearity of each set of explanatory variables (Zuur et al., 2007), and combinations of explanatory variables with VIFs > 5 were not used in these analyses (Ritter et al., 2009). When this criterion was exceeded, the candidate explanatory variable that best minimized AIC and maximized C_{eff} was selected.

Breakpoint rainfall data were acquired from gauging stations at the S-46 structure on the Southwest Fork of the Loxahatchee River (Fig. 4-1) and in Jonathan Dickinson State Park, where daily reference evapotranspiration (ET_0) values were also measured (JDWX weather station, Fig. 4-1). These data are available through the SFWMD's online database DBHYDRO (Stations S46_R and JDWX; accessed at http://www.sfwmd.gov/org/ema/dbhydro/index.html). Since GWEC data are autocorrelated (i.e., GWEC at time *t* is dependent on GWEC at *t*-1), while this is not true for rainfall and ET, the difference between cumulative rainfall and cumulative ET_o was used to calculate two net recharge (R_{net}) time series to make this data potentially useful in the DFA (Ritter et al., 2009). Rainfall collected at the two stations had low correlation (r^2 = 0.18) and considerably different cumulative rainfall totals over the four-year study period. The effect of this spatial variability on model results was explored by developing

DFMs using each of the R_{net} series, both series, and their average and comparing model results.

Surface water elevation (SWE) data were recorded at five stations in the NW Fork and one station upstream on Kitching Creek (Fig. 4-1). A SFWMD monitoring station on the headwater side of Lainhart Dam (0.45 km upstream of T1) measured average daily SWE and is available on DBHYDRO (station LNHRT_H). United States Geological Survey (USGS) monitoring stations located at RK 14.6 (adjacent to T7), RK 13.1 (at confluence with Kitching Creek, near T8), RK 9.5 (~0.8 km downstream of T9), RK 1.1 (near the Jupiter inlet), and 2.8 km upstream of the confluence of the NW Fork with Kitching Creek each measured SWE every 15 minutes (data acquired from USGS staff).

Surface water EC (SWEC) data were recorded at five stations in the NW Fork, including three stations with both surface and bottom EC sensors, for a total of eight SWEC series (Fig. 4-1). The Loxahatchee River District (LRD) maintains a water quality monitoring station (datasonde station 69) on the Northwest Fork at Indiantown Road that measured SWEC hourly (data acquired from LRD staff). USGS monitoring stations measured surface and bottom SWEC in the river at RK 14.6, RK 9.5, and RK 1.1 and surface GWEC at RK 13.1 every 30 minutes (data acquired from USGS staff).

Daily average WTE from nine USGS wells in and around the Loxahatchee River watershed (denoted as WTE_R) are publicly available and were downloaded from the USGS National Water Information System (accessed at http://waterdata.usgs.gov/nwis/) for the analysis of WTE in the Loxahatchee River floodplain (Kaplan et al., 2010b). Fitting one common trend to these nine series did a good job of representing WTE_R variation (C_{eff} = 0.83) and was used as a potential explanatory variable in this analysis.

Additionally, WTE data from the five highest elevation wells in this study were fit to a single common trend and explored as a possible explanatory variable.

Visual inspection suggested that variation observed in response variable (GWEC) time series might occur in a delayed and extended manner compared with candidate explanatory variables. To identify possible environmental variables that may better represent the dynamics of GWEC in the floodplain of the Loxahatchee River (and thus reduce the reliance of the final DFM on common trends), two additional explanatory variables were explored. The first focused on SWE at Lainhart Dam, which has been identified as the primary managed variable in the system when developing alternate restoration scenarios for the NW Fork (SFWMD, 2006). First, SWE at Lainhart Dam was converted to flow based on the structure's rating curve. Next, a "cumulative flow deficit" (CFD) was calculated by:

$$CFD(Q_{crit.})_t = \sum_{t=1}^{T} Q_{Lainhart,t} - Q_{crit.} \quad (4\text{-}4)$$

where CFD($Q_{crit.}$) is the cumulative flow deficit at time *t* (m^3), $Q_{crit.}$ is a critical daily flow rate (m^3 day^{-1}), $Q_{Lainhart,t}$ is the average daily flow measured at Lainhart Dam (m^3 day^{-1}). CFD accumulates daily flow ¨deficits¨ (sometimes positive, sometimes negative) over the period of record, integrating changes in the volume of freshwater flow to the NW Fork over an extended period. Various DFMs were then built using $Q_{crit.}$ values of 1.0, 1.5, 1.95, 2.5, 3.0, 3.7, and 4.0 m^3 s^{-1}, based in part on flow rates suggested in the MFL (~1.0 m^3 s^{-1}; SFWMD, 2002) and Restoration Plan for the NW Fork, which identified seasonally variable flow scenarios with mean monthly dry season flow = 1.95 m^3 s^{-1} and mean monthly wet season flow = 3.7 m^3 s^{-1} (SFWMD, 2006).

Next, since changes in SWEC also appeared to be reflected in a delayed and extended manner in GWEC series, a similar calculation was applied to SWEC data. To do so, several "cumulative salinity deviation" (CSD) series were calculated by:

$$CSD_t = \sum_{t=1}^{T} SWEC_t - SWEC_{POR} \quad (4\text{-}5)$$

where CSD_t is the cumulative salinity deviation at a particular SWEC measurement location at time *t* (S/m), $SWEC_t$ is the average daily surface water EC at that location at time *t* (S/m), and $SWEC_{POR}$ is the average SWEC over the four-year period of record (S/m). These salinity deviations (again, sometimes positive, sometimes negative) were cumulated over the period of record to integrate long-term changes in SWEC. The DFA was performed using CDS series calculated from SWEC series at RK 24.0, RK 14.6, RK 9.5, RK 13.1, and RK 1.1.

Analysis Procedure

DFA was implemented using Brodgar software (v. 2.6.5, Highland Statistics Ltd., Newburgh, UK), which uses the statistical software language "R" (v. 2.9.1, R Core Development Team, 2009). To compare the relative importance of common trends and explanatory variables across the set of response variables (Zuur et al., 2003b; Zuur and Pierce, 2004), response and explanatory variables were normalized in Brodgar (mean subtracted, divided by standard deviation). The DFA was performed in three discreet steps and yielded three models (Table 4-3). DFMs were first developed using an increasing number of common trends until satisfactory model performance was achieved according to goodness-of-fit indicators (Zuur et al., 2003a). This DFM is referred to as Model I. Next, different combinations of explanatory variables were incorporated to reduce unexplained variability and improve description of GWEC in the

floodplain. This DFM (Model II) aimed to achieve similar (or improved) goodness-of-fit metrics as Model I with fewer trends and without exceeding the VIF criterion. Finally, the best suite of explanatory variables identified in the DFA was used to create a reduced model using no common trends. This multi-linear model was created create using a multiple regression code run in Matlab (2009b, The MathWorks, Inc., Natick, MA, USA) and is referred to as Model III.

DFM goodness-of-fit was quantified using C_{eff} and AIC. C_{eff} compares the variance between predicted and observed data about the 1:1 line, with C_{eff} =1 indicating that the plot of predicted vs. observed data matches the 1:1 line (Nash and Sutcliffe, 1970). The AIC is a statistical criterion that balances goodness-of-fit with model parsimony by rewarding goodness-of-fit but including a penalty term based on the number of model parameters (Akaike, 1974). For two different DFMs, the DFM with largest C_{eff} and smallest AIC was preferred.

Results and Discussion

Experimental Time Series

Mean daily time series

The Loxahatchee River watershed experienced a wide range of climatic conditions over the four-year monitoring period, including four wet/dry season cycles; two very wet years with tropical storm- and hurricane-induced high water events (2004 and 2005); and the driest two-year period recorded in south Florida since 1932 (2006 to 2007; Neidrauer, 2009). Fig. 4-3 shows mean daily time series of selected meteorological and hydrological variables collected in the watershed over this time period. Rainfall (Fig. 4-3a) followed a seasonal pattern, with wet season (May to October) rain accounting for 73 – 80% of yearly totals over the four years (mean 77%). This is in agreement with

previous seasonal rainfall observations in the Loxahatchee River Basin, which have shown that approximately two-thirds of yearly rainfall occurs in the wet season between May and October (Dent, 1997). Significant spatial variation between rainfall data collected at the S-46 and JDWX stations was observed. Though the rain gauges were only 11.2 km apart, and roughly equidistant from the shore in flat terrain, cumulative rainfall at the JDWX gauge in JDSP was 2151 mm greater than that at the S-46 structure over the four-year study period, yielding divergent R_{net} series (Fig. 4-3b). Correlation between the rainfall time series was also low ($r^2 = 0.18$), further justifying the exploration of both series in subsequent DFM development.

Surface water elevations measured at five stations in the NW Fork are shown in Fig. 4-3c. Upriver SWE series (RK 23.3 and Kitching Creek) showed dynamics associated with large rainfall events and distinct dry season drawdowns. Mean daily SWE measured near T7, T8, T9, and the Jupiter Inlet were similar and overlap in Fig. 4-3c ($0.94 \leq r^2 \leq 0.99$ for these four series), though differences in minimum and maximum elevations were observed (see Fig. 4-4a-d). Common WTE trends fit to the five highest elevation wells in the project and to nine regional groundwater wells in the Loxahatchee River (WTE_R) were similar ($r^2 = 0.75$) and mirrored the wet and dry season variations observed in the two upriver SWE series (Fig. 4-3d). Calculated CFD for values of Q_{crit} ranging from 1.0 – 4.0 $m^3 s^{-1}$ are shown in Fig. 4-3e and CSD series calculated from SWEC data at five locations in the NW Fork are shown in Fig. 4-3f.

GWEC dynamics were observed over seasonal and yearly time periods as well as over shorter time ranges (i.e., individual tidal cycles and storm events). Fig. 4-4 shows mean daily GWEC graphed below minimum, maximum, and mean daily SWE

and 15-/60-minute and mean daily SWEC in the adjacent river channel. These data describe the long-term surface and groundwater dynamics over a longitudinal range from upstream, riverine reaches dominated by freshwater vegetation (T1 and T3; Fig. 4-4a) to upper and lower tidal reaches with transitional and estuarine swamp (T7, T8, and T9; Fig. 4-4b-d) . In general, GWEC was low in upstream and high elevation wells and increased with proximity to Jupiter Inlet and decreasing elevation. For example, global average GWEC in upstream wells T1-W1 and T3-W1 over the four-year period of record were 0.068 and 0.046 S/m, respectively, with little variation between wet and dry seasons or over the four-year study (Fig. 4-4a). On the other hand, average GWEC at downstream well T9-W1 was 1.556 S/m (~25 times the average GWEC observed in well T1-W1) and varied considerably over the period of record (Fig. 4-4d, black line).

On upstream transects T1 and T3, GWEC remained well below the 2 ppt (0.3125 S/m) salinity tolerance threshold identified for the maintenance of a healthy bald cypress ecosystem (Liu et al., 2006) and was not a significant source or store of salts in the floodplain (Fig. 4-4a, lower panel). A parallel study of vadose zone hydrology found soil porewater EC on T1 to be higher than the GWEC observed here, likely due to concentration of solutes by evapotranspiration, though it also remained below the 0.3125 S/m threshold (Kaplan et al., 2010a). Thus, vegetative changes observed in these reaches (SFWMD, 2006, 2009) may be attributed to reduced soil moisture and insufficient hydroperiod alone; it is unlikely that salinity is a contributing factor. While a strong negative correlation ($r^2 = 0.72$, $p < 0.0001$) existed between upstream SWE and SWEC (upper panels), correlations between these surface water data and GWEC in wells T1-W1 and T3-W1 were low ($0.02 \leq r^2 \leq 0.14$).

On downstream transects with multiple wells, GWEC was generally highest close to the river and decreased with distance towards the upland. On T7, this trend reversed in 2007, when GWEC in well T7-W2 surpassed that of well T7-W1 and remained higher for the duration of the year before falling in 2008 (Fig. 4-4b). On T7, the 0.3125 S/m threshold was exceeded for only 3 days in 2008 (in well T7-W2) despite higher SWEC values in the adjacent river channel and daily tidal inundation of the floodplain on this transect (note different y-axes on SWEC and GWEC panels). Dashed and dotted lines in upper panels indicate the mean, minimum, and maximum elevations of the lower floodplain (i.e., excluding the sharp transitional and upland areas on T7, T8, and T9; Fig. 4-2).

The distinct SWEC peaks observed at RK 14.6 during dry season, low-flow periods were less distinct, delayed, or absent in GWEC series on the adjacent floodplain at T7. As a result, correlations between SWEC and GWEC on T7 were small ($0.02 \leq r^2 \leq 0.18$). In wells T7-W1, T7-W2, and T7-W3, GWEC returned to background levels between 0.1 and 0.2 S/m after these SWEC increases, indicating that salts did not accumulate in the shallow groundwater but were flushed from the shallow groundwater during wet seasons. Lowest average GWEC among the twelve wells in the study was observed in well T7-W4. The fresh nature of this water and maintenance of high water table elevation in this location (Kaplan et al., 2010b) likely play a large role in maintaining the floodplain GWEC below the critical threshold on T7. The presence of salt-tolerant mangroves close to the river on this transect in spite of low GWEC values supports the findings of Kaplan et al. (2010a) who proposed that the distribution of

freshwater and salt-tolerant plant species in transitional areas requires an understanding of root zone salinity, which integrates the effects of SWEC and GWEC.

On T8, located on Kitching Creek 150 m upstream of RK 13.1 on the NW Fork, GWEC in the well closest to the river (T8-W1) was one to two orders of magnitude higher than in other wells (Fig. 4-4c), indicating a sharp salinity gradient in the shallow groundwater across the floodplain. This is similar to salinity patterns measured along a forest-to-marsh gradient in South Carolina (USA) by Gardner et al. (2002) and consistent with the idealized description of the saltwater wedge in the coastal aquifer (e.g., Miller, 1990). GWEC in well T8-W1 surpassed the 0.3125 S/m threshold for several months in 2006 and most of 2007, but returned to background levels during wet seasons (as on T7).

Correspondence between peaks in GWEC in well T8-W1 and the adjacent SWEC was clearer than on T7, indicating a more direct communication between surface and groundwater in this location, though correlations between SWE and all GWEC series on T8 were still low ($0.05 \leq r^2 \leq 0.14$). GWEC in wells T8-W2 and T8-W3 remained low, except for a small increase in well T8-W2 during a tidal surge and high water event associated with Hurricane Frances, which passed over the study site in September 2004 (shown in detail in subsequent section). The maintenance of low GWEC in these wells is likely due both to the maintenance of high WTE in the upland and lower floodplain inundation frequency as elevation increases with distance from the river (see Fig. 4-2). While slightly higher elevations towards the upland currently prevent daily tidal inundation over the transect's entire length (note min, max, and mean floodplain elevations in upper panel of Fig. 4-4c), predicted sea level rise of 18 to 59 cm over the

next century (IPCC, 2007) will eventually inundate the area, and it is likely that a transition towards salt-tolerant vegetation will continue on this transect.

On lower tidal transect T9, wells T9-W1 and T9-W2 had the highest GWEC of any wells in the study, while GWEC in well T9-W3 was two orders of magnitude lower (Fig. 4-4d), despite their similar slotted elevations (Table 4-1), again indicating a sharp salinity gradient. Whereas GWEC on T7 and T8 never reached the magnitude of adjacent SWEC at those transects, GWEC maxima in wells T9-W1 and T9-W2 and SWEC maxima were of similar magnitude at T9 (3 to 4 S/m, more than ten times the 0.3125 S threshold). Accordingly, vegetation on T9 is primarily lower tidal swamp, dominated by white and red mangrove.

Although aligned along a linear transect, the three wells on T9 are located on a small peninsula in the river and have a minimum distance to the river of 70, 50, and 30 m for wells T9-W1, T9-W2, and T9-W3, respectively. GWEC was usually highest in well T9-W2 (Fig. 4-4d), though peak GWEC was observed in well T9-W1 in 2007. GWEC in well T9-W1 oscillated between high and low values over the period of record, indicating some flushing of salts from the shallow groundwater, while GWEC in well T9-W2 was more constant, likely due to prolonged ponding of saline surface water behind elevated trails built on the peninsula in the 1960s (Roberts et al., 2008; Fig. 4-2). Again, correlation between SWEC and GWEC series was low ($0.03 \leq r^2 \leq 0.07$). Like on T7 and T8, the highest elevation well on T9 had low GWEC and high WTE and low EC groundwater seepage into the wetland has been observed off of the upland slope (Dick Roberts, Pers. Comm.).

Thirty-minute time series

While the dynamics of mean daily GWEC variation discussed above likely provide sufficient information at the management time scale (daily to monthly for the NW Fork of the Loxahatchee River; SFWMD, 2006), the high temporal resolution of the dataset allows us to observe additional WTE and SWEC dynamics over diurnal/tidal cycles and during storm events. For example, Fig. 4-5 shows the effect of tidal forcing on upper tidal T8 over a one-week period of high SWEC in May 2006. WTE peaks in well T8-W1 (dotted line) were coincident with tidal SWE (solid gray line), but the signal was damped in wells T8-W2 (dashed line) and T8-W3 (solid black line). During this time, the maximum tidal amplitude was 0.84 m in the surface water, and fell off quickly from 0.49 in well T8-W1 to 0.24 and 0.03 m in wells T8-W2 and T8-W3, respectively.

SWEC and GWEC peaks also varied with SWE, and an extended period of high SWEC during this 8-day period resulted in an oscillating, but steadily increasing GWEC trend driven by high SWEC (note different y-axes). The total increase in GWEC over this period was about 0.2 S/m, with a maximal diurnal variation of ~0.07 S/m. On the other hand, GWEC in wells T8-W2 and T8-W3 remained relatively constant at around 0.066 and 0.029 S/m, respectively, varying only within a range of ±0.0005 S/m over the same time period, which is likely inconsequential to floodplain vegetation. Thus, the impact of this extended period of high SWEC on GWEC during the dry season was generally limited to the floodplain areas closest to the river on this transect. One exception to this rule was observed during higher-than-usual SWE and WTE on T8 during the storm surge associated with Hurricane Frances (September 2004), which caused an abrupt spike in GWEC in well T8-W2 (Fig. 4-6). GWEC returned to background levels after about a week.

Upstream, small diurnal fluctuations in WTE and GWEC can be attributed to ET. Figure 7 shows high-resolution SWE, WTE, and GWEC data from a three-week period in Feb/March 2006. During daylight hours, WTE decreased by about 2 cm before rebounding at night (Fig. 4-7, solid line in lower panel). Though most noticeable during relatively stable environmental conditions (no rain, relatively constant adjacent SWE) these daily oscillations in WTE were as large as 9 cm during periods of high ET. This cycling of WTE was accompanied by a concomitant, but opposite, variation in GWEC, which increases slightly during the day and decreased at night (Fig. 4-7, dotted line in lower panel). The scale of GWEC oscillation is smaller, with maximum ET-driven daily oscillations on the order of 0.0003 S/m (i.e., ~0.002 ppt salinity). At this scale, the sharp rise in WTE and delayed flush of salts after a rain event was also clear (Fig. 4-7, upper panel). Downstream, combined tidal and diurnal ET signals made it more difficult to discern the effects of ET on WTE and GWEC.

Dynamic Factor Analysis

Baseline DFA (no explanatory variables)

The DFA was advanced in three discrete steps. First, different DFMs were obtained by increasing the number of common trends with the goal of achieving a maximum C_{eff} and minimum AIC. For this analysis, both diagonal and non-diagonal error covariance matrices were explored. However, use of a diagonal matrix resulted in calculation of one or more common trends that exactly fit one or more response variables. As suggested in Zuur et al. (2000), this may occur with highly variable and noisy datasets, and a non-diagonal error matrix was used in subsequent analyses to avoid this occurrence. With a non-diagonal matrix, AIC continued to decrease and C_{eff} to increase with up to ten trends (M = 10), the maximum number that Brodgar software

can calculate. That more than ten trends (representing unexplained information) were necessary to achieve the best DFM of twelve response variables suggested that multiple latent effects influence the variability of GWEC across the watershed.

To gain more insight into possible common trends affecting floodplain GWEC, a second baseline DFA was investigated with a subset of the original twelve series. Wells with low and relatively stable GWEC were excluded from this analysis. For example, GWEC in upstream and higher elevation wells T1-W1, T3-W1, T7-W4, T8-W3, and T9-W3 was never greater than 0.01 S/m (0.06 ppt). When compared with GWEC variation in the remaining seven wells, these five series may be considered more or less constant as straight lines of very low magnitude (see Fig. 4-4a-d). Normalizing small variations in these series to make them useful for DFA scales up small changes, which from a physical point of view may not be relevant. For example, these series all remained well below the 0.3125 S/m (2 ppt) bald cypress salinity tolerance threshold.

Results from the exploratory model with seven response variables (Y = 7; Model I) are given in Table 4-4. Even with the reduced set of response variables, AIC continued to decrease and C_{eff} to increase with increasing trends, with no inflection point identified. Though this phenomenon complicates the interpretation of DFA results, it can be explained by examining the definition of the AIC, which is computed as:

$$AIC = 2k - 2\ln(L) \tag{4-6}$$

where k is the number of DFM parameters and L is the maximized value of the likelihood function for the estimated model (i.e., an estimation of the sum of squared errors between observed and predicted values, RSS). When an additional trend is added to the DFM, the model uses a number of additional factor loadings equal to the

number of response variables. Thus, AIC increases linearly, since *k* is higher. On the other hand, if the inclusion of an extra trend helps to better predict the response time series, than AIC will also be reduced since RSS is lower. Due to this "balancing act," the AIC is generally a useful indicator of model performance and parsimony, but only if the improvement in predictions is comparable to the penalization due to the extra parameters. In the case of dynamic factor modeling of GWEC using four years of mean daily data, AIC was more sensitive to reductions in RSS than to increases in *k*. Although adding an extra trend may result in only a small improvement of the model performance (measured with C_{eff}), it may considerably increase the likelihood function (thereby decreasing the RSS). By contrast, the extra parameters imply a penalization with lower order of magnitude. For example, if the change in the likelihood functions is of the order of 1,000 and the change in the number of parameters is of the order of 10, than the AIC may be insensitive to the number of parameters. This would yield considerable reductions in AIC with small corresponding changes in C_{eff} and may be particularly true for long data sets like those analyzed here.

Since no inflection point in AIC was identified, we balanced the incremental benefit to C_{eff} with the number of extra model parameters added with each additional trend. The added benefit to C_{eff} of additional trends tapers off after four trends (Fig. 4-8). Thus, for subsequent analyses and identification of explanatory variables, the baseline DFA using seven response variables ($Y = 7$) and four common trends ($M = 4$) was used. This model is referred to as Model I and had overall $C_{eff} = 0.86$ ($0.45 \leq C_{eff} \leq 0.99$) and AIC = 3463. The objective of the subsequent DFA using explanatory variables was thus

to reduce the number of common trends required to achieve similar model performance to less than four in order to reduce the amount of unexplained variability in the DFM.

It is first instructive to examine the common trends from Model I and their associated canonical correlation coefficients ($\rho_{m,n}$) since high $\rho_{m,n}$ values indicate high correlation between two latent variables. The four common trends from Model I are shown in Fig. 4-9. Though only describing latent (unknown) variability at this stage in the DFA, these trends and their patterns of correlation are useful for developing ideas about how GWEC elevation varies in the Loxahatchee River floodplain and where to look for the most useful explanatory variables. For example, common trend 1 (Fig. 4-9a) was most highly correlated with GWEC in well T7-W1, but also had “moderate” correlation with well T8-W1, indicating some shared information between these two series close to the river in the upper tidal reach. Correlations with the other five wells were “low” or “minor.” Common trend 2 (Fig. 4-5b) on the other hand was only highly correlated with GWEC in well T7-W2 and captured the extended and delayed rise in GWEC that was observed only in this location (see Fig. 4-4b, gray line in lower panel). All other correlations with this trend were “low” or “minor.” Common trend 3 contained the most shared information, with “high” and “moderate” correlations with four of the seven wells (representing T7, T8, and T9). This trend represents the high GWEC observed in several wells in 2007. No clear spatial or physical interpretations could be drawn from common trend 4, but all correlations were “low” or “minor” for this trend, indicating a lower dependence of the DFM on this trend.

DFA with explanatory variables

Next, appropriate explanatory variables were added to reduce the number of common trends required to achieve an adequate fit of GWEC (and to minimize the factor loadings of any remaining trends). Approximately 150 combinations of common trends and candidate explanatory variables (summarized in Table 4-2) were explored in Brodgar. Finally, the best DFM was achieved using four explanatory variables (K=4): net recharge calculated with rainfall from the S46 weather station ($R_{net,S46}$), the trend representing regional groundwater circulation (WTE_R), the cumulative flow deficit with a critical flow of 3.0 $m^3 s^{-1}$ ($CFD_{3.0}$), and cumulative salinity deviation calculated with SWEC data from RK 9.5 ($CSS_{RK9.5}$). Other CFD and CSS series were collinear and thus could not be included in the DFM. Using both R_{net} series did not improve the model and $R_{net,S46}$ performed better than $R_{net,JDWX}$ or the average of the two series. Using these explanatory variables, it was possible to reduce the number of required common trends from four to three (M=3), thus slightly reducing the unexplained variability in the model. This model (Model II) yielded AIC = 1458 and overall C_{eff} = 0.85 across the seven wells, improving upon the target AIC of 3463 and nearly matching the target C_{eff} of 0.86 from Model I. Model fits are illustrated in Fig. 4-10. Model fits are fair to excellent ($0.52 \leq C_{eff} \leq 0.99$). Some higher elevation wells lack data from the beginning of the time series, and model results help paint a more complete picture of GWEC in these wells during the hurricanes of 2004 (e.g., wells T8-W1 and T9-W1 in Fig. 4-10).

Table 4-5 summarizes the results obtained from Model II (M = 3, 4 explanatory variables). Significant regression coefficients ($\beta_{k,n}$ with t-value > 2) are shown in bold.

GWEC in the seven wells used in this analysis had variable relationships to the common trends, but factor loadings were reduced slightly over those in Model I. Average $|\gamma_n|$ value for the three remaining trends in Model II = 0.07 ± 0.06 compared to average $|\gamma_n|$ = 0.10 ± 0.11 for the four trends in Model I. This small reduction in dependence on common trends indicated that a multilinear model without trends (Model III) might not be sufficient to describe the observed GWEC dynamics (see following section). The $\beta_{k,n}$ represent the importance of a corresponding explanatory variable on each response variable. Though variably significant to the seven GWEC time series, $\beta_{k,n}$ for the calculated variables cumulative flow debt (CFD) and cumulative salt surplus (CSS) were more significant than any of the "raw" explanatory variables explored for use in the DFA (e.g., SWE, SWEC, etc.). Incorporating these cumulated "memory" variables was important for improving the DFM since GWEC series varied in a delayed and extended manner compared with other hydrological variables.

The remaining three trends in Model II and their associated $\rho_{m,n}$ values are given in Figure 11. These trends represent the remaining unexplained (latent) variability among the GWEC series. The reduction in the dependence on common trends from Model I to Model II is evidenced by lower canonical correlations (e.g., no "high" correlations). Again, the relationships to trends were variable across wells. As with Model I, Trend 1 was most correlated with GWEC in well T7-W1, and described variation specific to this well. Trend 2 had "moderate" or "low" correlations with 6 of the 7 wells and the shape of the trend suggests that it captured high GWEC events in fall 2004 (during Hurricanes Frances and Jeanne) and during the dry seasons of 2006 and

2007. Trend 3 was “moderately” correlated with GWEC in well T7-W3, but had only minor correlations with the remaining six wells.

Multilinear regression model (DFA with no common trends)

Finally, common trends were removed from the model to assess the validity of a DFM using only explanatory variables. In this model (Model III), the four explanatory variables identified in the DFA were used to create a multi-linear model of the response variables. As expected, C_{eff} values for Model III were reduced from Model II (overall C_{eff} = 0.58, 0.38 ≤ C_{eff} ≤ 0.75; compared to C_{eff} = 0.85, 0.52 ≤ C_{eff} ≤ 0.99 for Model II). Visual inspection of the best and worst model fits from Model III indicated that the model without trends may adequately describe the observed GWEC variation in some wells (e.g., well T7-W2, Fig. 4-9a), but not others (e.g., well T9-W2, Fig. 4-9b). Where Model III is deemed adequate, it may be useful for assessment of Loxahatchee River restoration scenarios, especially considering the wide range of climatic conditions captured in the study.

Conclusions

Detailed multivariate hydrological time series obtained in and around the Loxahatchee River watershed in south Florida were studied and modeled using dynamic factor analysis (DFA) to improve our understanding of the hydrological processes in this area, which has been affected by reduced hydroperiod and increased saltwater intrusion. Short-and long-term shallow groundwater electrical conductivity (GWEC) dynamics were observed in the floodplain wetlands along a gradient from the river’s freshwater, riverine reach downstream through the upper and lower tidal reaches.

Sharp GWEC gradients were observed on transects with multiple wells, with high GWEC closer to the river decreasing by several orders of magnitude with increasing

distance from the river. Peaks in surface water electrical conductivity (SWEC) and GWEC were often poorly correlated, with GWEC series evolving in a delayed and extended manner relative to SWEC. Thus, surface water reached higher maximum salinities than groundwater in the adjacent floodplain, but average groundwater salinities were often higher over seasonal and yearly time periods. On riverine transects T1 and T3, GWEC was always well below the 0.3125 S/m environmental threshold proposed for ecological restoration of the freshwater floodplain swamp. GWEC also generally remained below this value on upper tidal transects T7 and T8, with the exception of well T8-W1, which had high values of GWEC for much of 2006 and 2007. GWEC in the lower tidal floodplain was above the threshold (in wells T9-W1 and T9-W2) over the entire four-year study.

High-resolution GWEC data revealed daily oscillations in GWEC in both tidal (Fig. 4-5) and riverine reaches (Fig. 4-7), though they had different driving forces (tidal forcing and ET, respectively). Flushing of salts from the shallow groundwater was also observed in both reaches, whether after hurricane-induced tidal inundation of saline water in the upper tidal floodplain (Fig. 4-6), or after a rain event in the riverine floodplain (Fig. 4-7, upper panel). On lower tidal transect T9, some flushing of accumulated salts likely occurred in well T9-W1 (Fig. 4-4d, black line in lower panel), but not in well T9-W2 (gray line in lower panel), likely due to several raised berms built on the peninsula, which increase infiltration of saline surface water into the shallow groundwater.

In five of the upstream and/or high elevation wells in the study, observed GWEC was very low (i.e., always <0.01 S/m, compared to the 0.3125 S/m threshold). When

normalized for use in the DFA, small variations in these time series were magnified, complicating interpretation of resulting Dynamic Factor Models (DFMs). Thus, DFA was performed on the seven remaining wells that had environmentally relevant GWECs. The technique proved to be a useful tool for the study of interactions among these long-term, non-stationary hydrological time series, and a DFM consisting of three common trends and four explanatory variables (Model II) simulated observed GWEC data well ($C_{eff} = 0.85$; $0.52 \leq C_{eff} \leq 0.99$). The best DFM used cumulative net recharge from the S46 weather station ($R_{net,S46}$), a single trend fit to nine regional USGS wells (WTE_R), cumulative flow deficit at Lainhart Dam calculated with a critical flow of 3.0 $m^3\ s^{-1}$ ($CFD_{3.0}$), and cumulative salinity deviation calculated from surface water electrical conductivity (SWEC) measured at RK 9.5 in the NW Fork ($CSD_{RK9.5}$). This model is useful for filling data gaps during the study period and identifying the relative importance and relationships between hydrological variables of interest. The reduced model with no common trends (Model III) did a fair to good job (overall $C_{eff} = 0.58$, $0.38 \leq C_{eff} \leq 0.75$), and may be adequate for describing variations in GWEC variation in some areas of the Loxahatchee River floodplain under different management and restoration scenarios.

Table 4-1. Locations and attributes of the twelve groundwater wells in the study. Wells are distributed across five transects (T1, T3, T7, T8, and T9). River kilometer indicates distance from the river mouth. Well elevation denotes elevation at the ground surface.

Well	Transect Type	River Kilometer	Distance to River (m)	Well Elevation (m, NGVD29)	Min slotted elevation (m, NGVD29)	Max slotted elevation (m, NGVD29)
T1-W1	Riverine	23.3	50	3.28	1.51	2.12
T3-W1	Riverine	19.5	95	1.60	-0.16	1.36
T7-W1	Transitional	14.6	2	0.36	-1.49	-0.88
T7-W2			30	0.43	-1.40	-0.79
T7-W3			90	0.56	-1.13	-0.52
T7-W4			130	2.94	-0.73	0.79
T8-W1	Upper tidal	13.1	5	0.12	-1.50	-0.89
T8-W2			65	0.36	-1.24	-0.63
T8-W3			105	2.28	-0.36	1.16
T9-W1	Lower tidal	10.5	70*	0.41	-1.45	-0.84
T9-W2			50*	0.62	-1.24	0.28
T9-W3			30*	2.94	-1.31	0.22

*shortest distance from well to river (T9 is on a peninsula)

Table 4-2. Hydrological time series used in the DFA.

Variable	Series Type	No. of series	Description
GWEC	Response	12	Groundwater electrical conductivity (S/m) from wells in the Loxahatchee River floodplain
R_{net}	Explanatory	2	Cumulative net recharge (cumulative rainfall – cumulative ET_o, mm) calculated from the S-46 and JDWX weather stations
SWE	Explanatory	6	Surface water elevation (m, NGVD29) from stations in the NW Fork at RK 23.3 (near T1), RK 14.6 (near T7), RK 13.1 (near T8), RK 9.5 (near T9), RK 1.1 (near Jupiter Inlet), and on Kitching Creek
SWEC	Explanatory	8	Surface and/or bottom surface water electrical conductivity (S/m) from stations in the NW Fork at RK 24.0, RK 14.6, RK 13.1, RK 9.5, and RK 1.1
WTE/ WTE_R	Explanatory	14	Water Table Elevation (WTE, m, NGVD29) from the twelve wells in this study and two single WTE trends—one calculated from the five highest-elevation wells in this study and one calculated from nine regional USGS wells in and around the Loxahatchee River watershed (WTE_R)
CFD	Explanatory	7	Calculated cumulative flow deficit (km^3) based on flow at Lainhart Dam (RK 23.3) (see explanation in text)
CSS	Explanatory	8	Calculated cumulative salinity deviation (S/m) from SWEC stations (see explanation in text)

Table 4-3. Dynamic factor models (DFMs) tested in this study (see explanation in text).

DFM	No. of trends	Explanatory variables	Regression parameters	No. of parameters	C_{eff}
Model I	4	None	---	57	0.86
Model II	3	$R_{net,S46}$, WTE_R, $CFD_{3.0}$, $CSS_{RK9.5}$	From DFA	81	0.85
Model III	0	$R_{net,S46}$, WTE_R, $CFD_{3.0}$, $CSS_{RK9.5}$	Multiple regression	28	0.58

Table 4-4. Nash-Sutcliffe coefficients of efficiency (C_{eff}) and Akaike's information criteria (AIC) and for dynamic factor models with no explanatory variables and 1 to 6 common trends.

M	C_{eff}	AIC
1	0.38	18226
2	0.51	13030
3	0.64	8489
4	0.86	3463
5	0.89	-1682
6	0.93	-6960

Table 4-5. Constant level parameters (μ_n), canonical correlation coeficents ($\rho_{m,n}$), factor loadings ($\gamma_{m,n}$), regression coefficients ($\beta_{k,n}$), and coefficients of efficiency (C_{eff}) from Model II (3 trends, 4 explanatory variables). Significant regression parameters in bold.

		Canon. correlations			Factor loadings			Regression coefficients ($\beta_{k,n}$)				
s_n	μ_n	$\rho_{1,n}$	$\rho_{2,n}$	$\rho_{3,n}$	$\gamma_{1,n}$	$\gamma_{2,n}$	$\gamma_{3,n}$	$R_{net,S46}$	WTE_R	$CFD_{3.0}$	$CSS_{RK9.5}$	$C_{eff,n}$
T7-W1	-0.49	0.73	0.05	0.01	0.19	0.00	0.01	**0.53**	0.02	-0.32	**1.49**	0.99
T7-W2	0.00	0.04	-0.41	0.17	0.02	-0.11	-0.04	**0.35**	**-0.02**	**-1.21**	**1.39**	0.88
T7-W3	0.12	0.05	0.34	0.67	0.01	0.03	0.15	0.21	0.00	0.38	0.43	0.99
T8-W1	-0.24	0.26	0.71	0.04	0.05	0.17	0.04	**-0.08**	0.01	**-1.10**	**2.14**	0.97
T8-W2	-0.03	0.05	0.46	0.17	0.01	0.12	0.09	**-0.38**	**0.02**	0.32	0.21	0.52
T9-W1	-0.07	0.27	0.70	-0.02	0.00	0.12	0.03	**0.96**	0.00	**0.93**	0.43	0.86
T9-W2	0.17	-0.29	0.52	0.02	-0.09	0.16	0.01	**-0.55**	**0.06**	-1.00	**1.47**	0.72
											Overall:	0.85

Table 4-6. Model parameters and coefficients of efficiency (C_{eff}) from Model III (no trends, 4 explanatory variables). Significant model parameters in bold.

	Model parameters				
s_n	$R_{net,S46}$	WTE_R	$CFD_{3.0}$	$CSS_{RK9.5}$	C_{eff}
T7-W1	**0.28**	**0.02**	**0.44**	**0.43**	0.49
T7-W2	**0.07**	**0.02**	**-1.48**	**1.77**	0.75
T7-W3	**0.45**	**-0.05**	0.05	**0.88**	0.60
T8-W1	**0.46**	**-0.05**	**-0.27**	**1.13**	0.70
T8-W2	-0.05	**-0.03**	**0.50**	**-0.16**	0.43
T9-W1	**1.39**	**-0.03**	**1.68**	**-0.30**	0.73
T9-W2	**-0.15**	**0.02**	**-0.66**	**0.99**	0.38
				Overall:	0.58

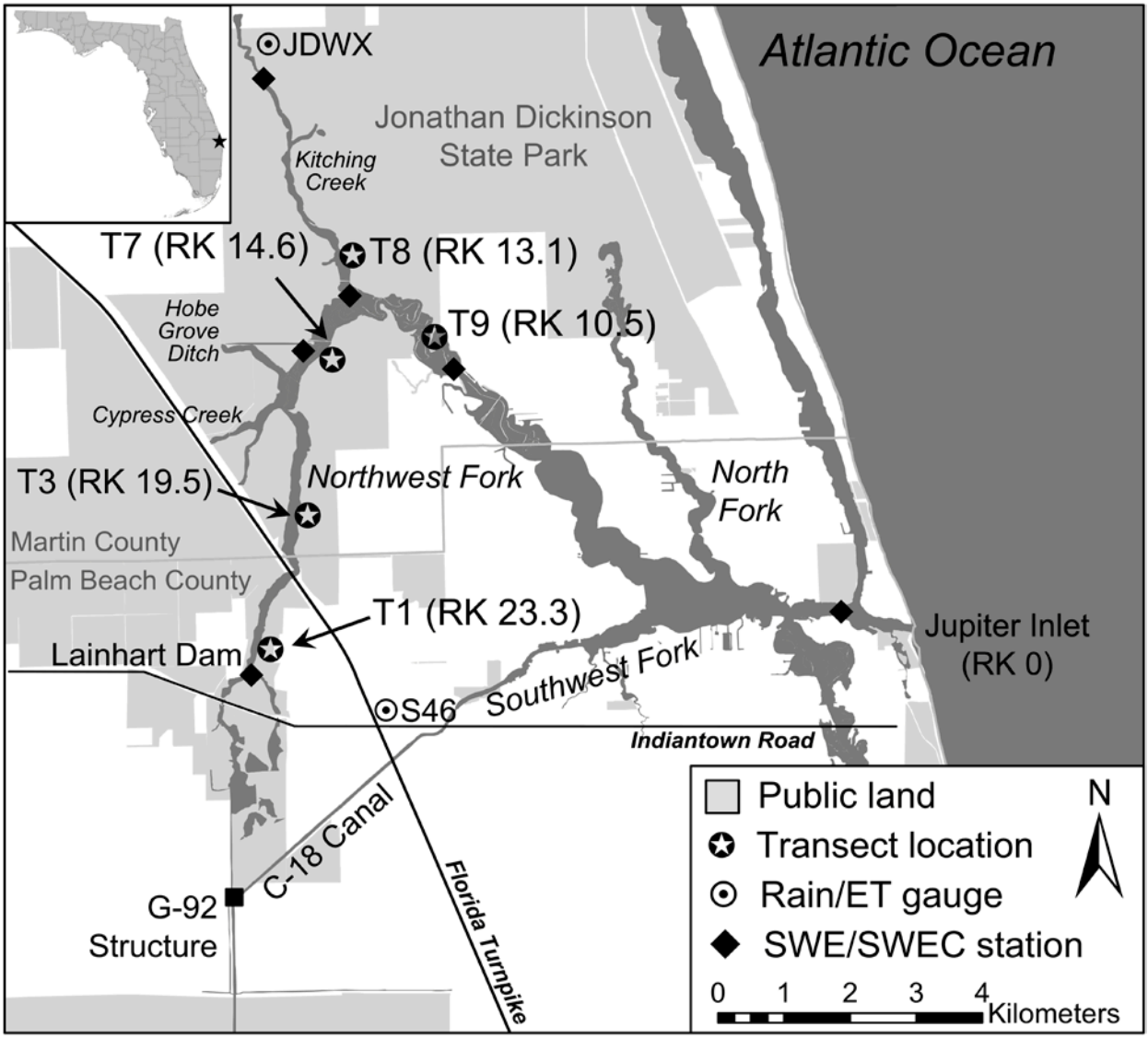

Figure 4-1. The Loxahatchee River and surrounding area with transect locations (T1, T3, T7, T8, and T9), meteorological and surface water elevation (SWE) and electrical conductivity (SWEC) measurement locations, and major hydraulic infrastructure. Transect notation is followed by distance from river mouth (river kilometer, RK).

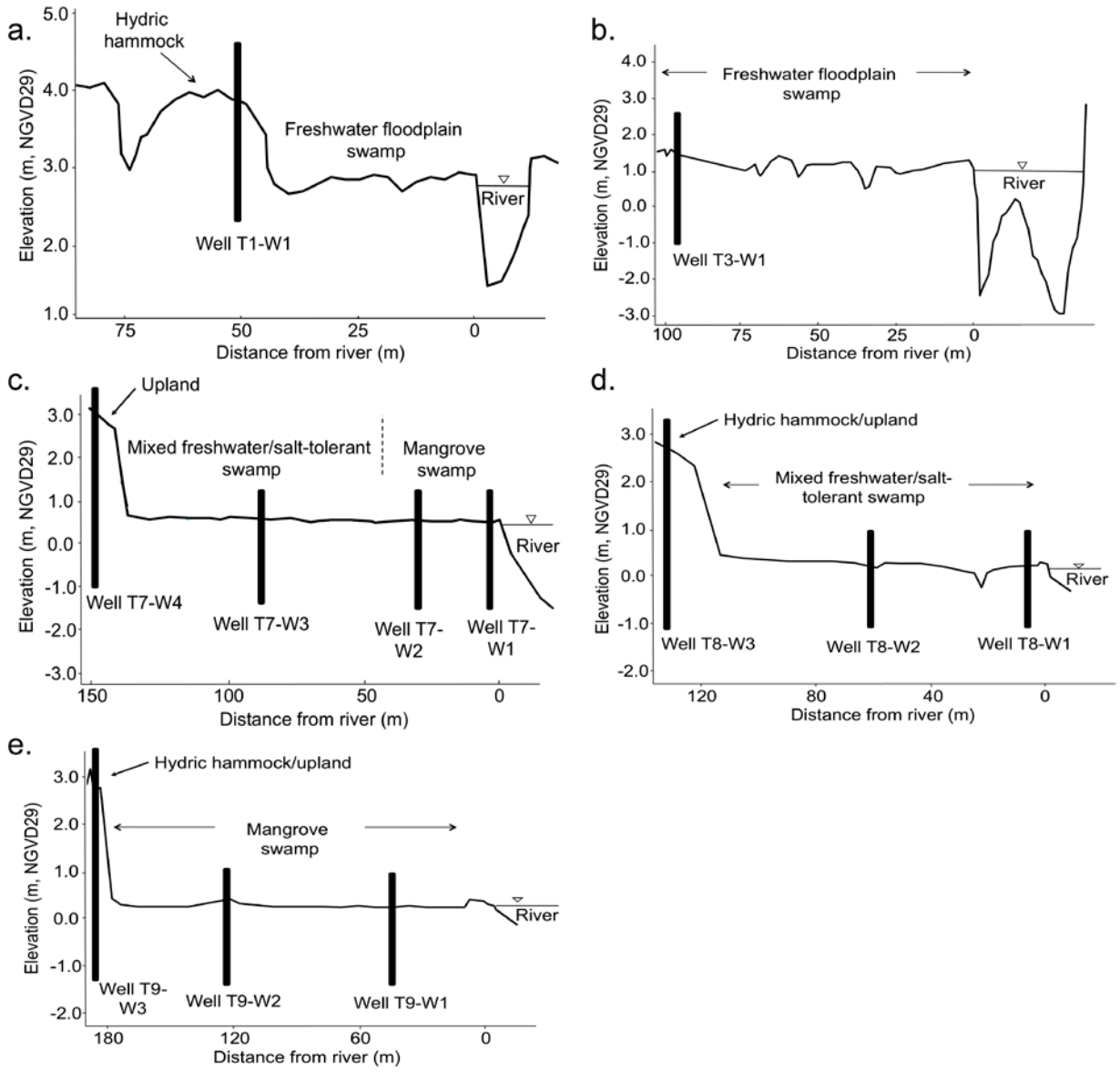

Figure 4-2. Transect topographic cross-sections, detailing well installation locations and elevations and predominant vegetation types.

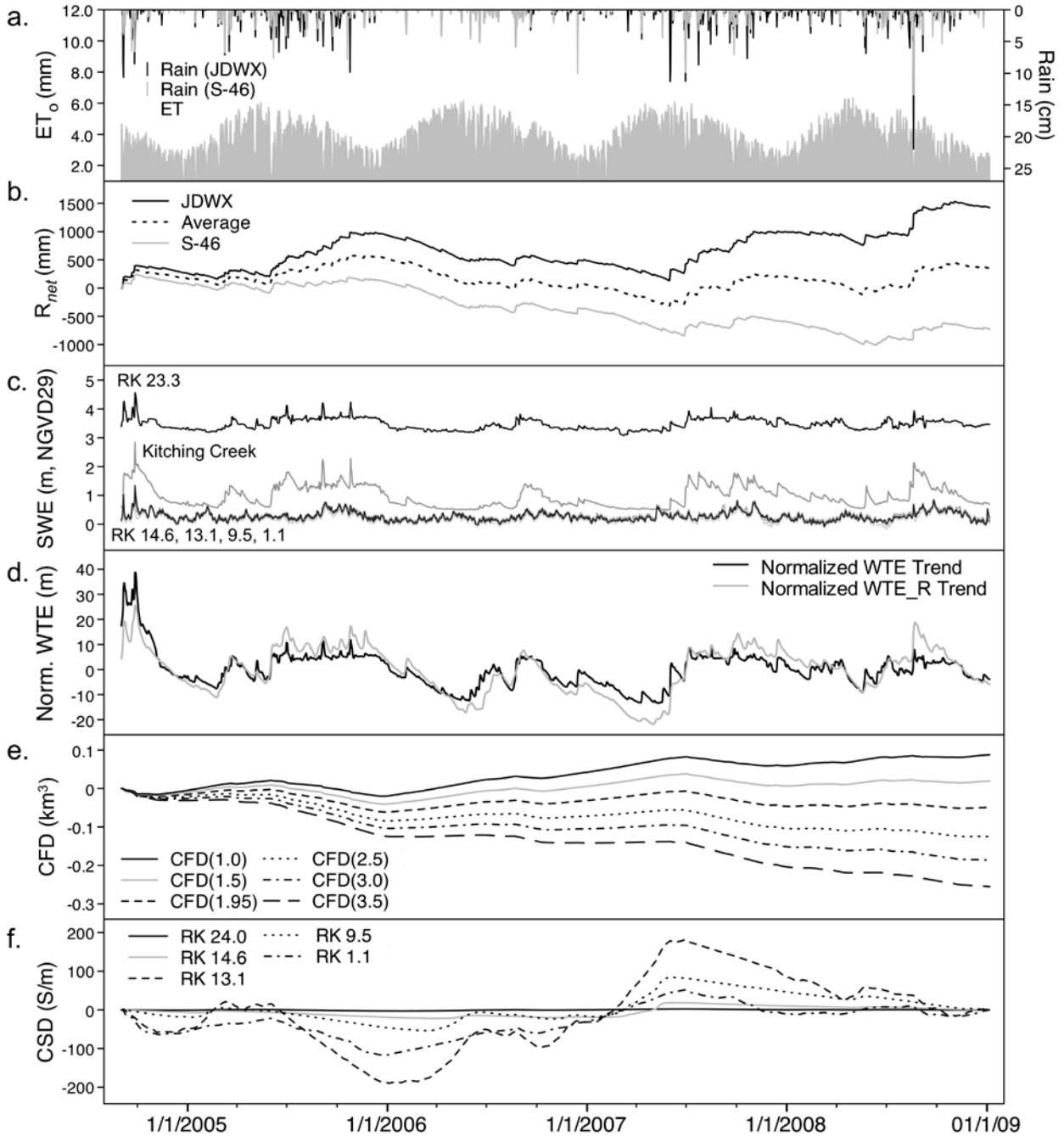

Figure 4-3. Precipitation, reference evapotranspiration (ET_0), net recharge (R_{net}), surface water elevation (SWE), normalized local and regional water table elevation, cumulative flow deficit (CFD), and cumulative salinity deviation (CSD) time series measured in and around the Loxahatchee River watershed from 2004 to 2009.

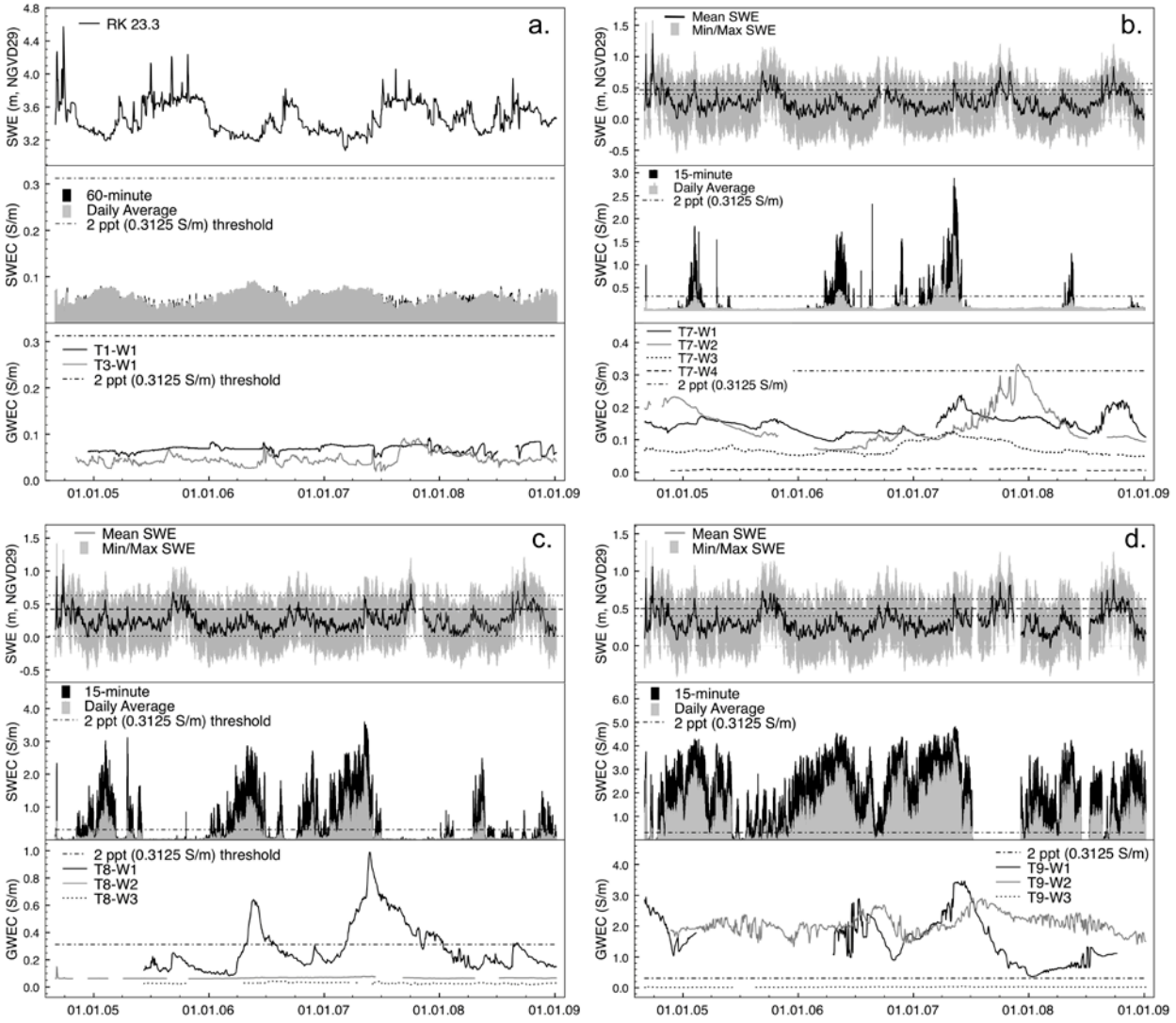

Figure 4-4. Surface water elevation (SWE), surface water electrical conductivity (SWEC), and groundwater electrical conductivity on riverine transects 1 and 3 (a), upper tidal transects 7 (b) and 8 (c), and lower tidal transect 9 (d). For transects 7, 8, and 9, which receive daily tidal flooding, SWE is plotted with mean, minimum, and maximum lower floodplain elevations (dashed and dotted horizontal lines) to illustrate floodplain flooding frequency.

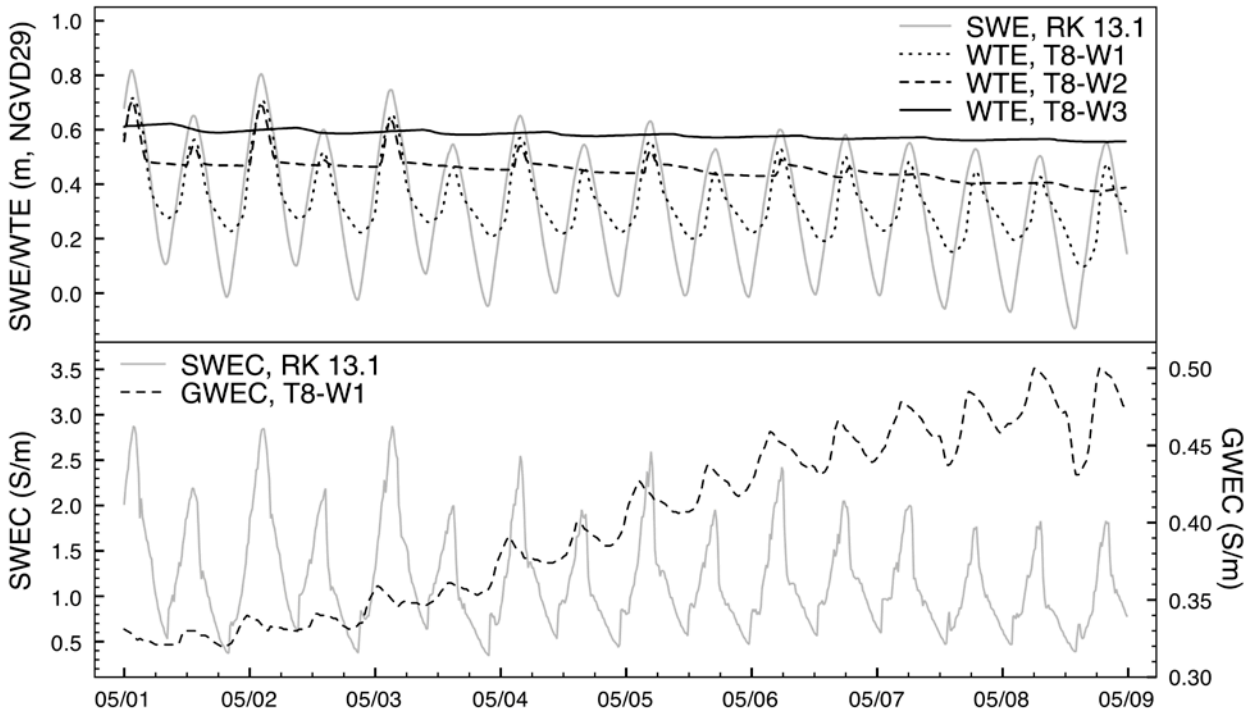

Figure 4-5. High resolution (30-minute) surface water elevation (SWE), water table elevation (WTE), surface water electrical conductivity (SWEC), and groundwater electrical conductivity data on upper tidal transect T8 over 8 days in May 2006.

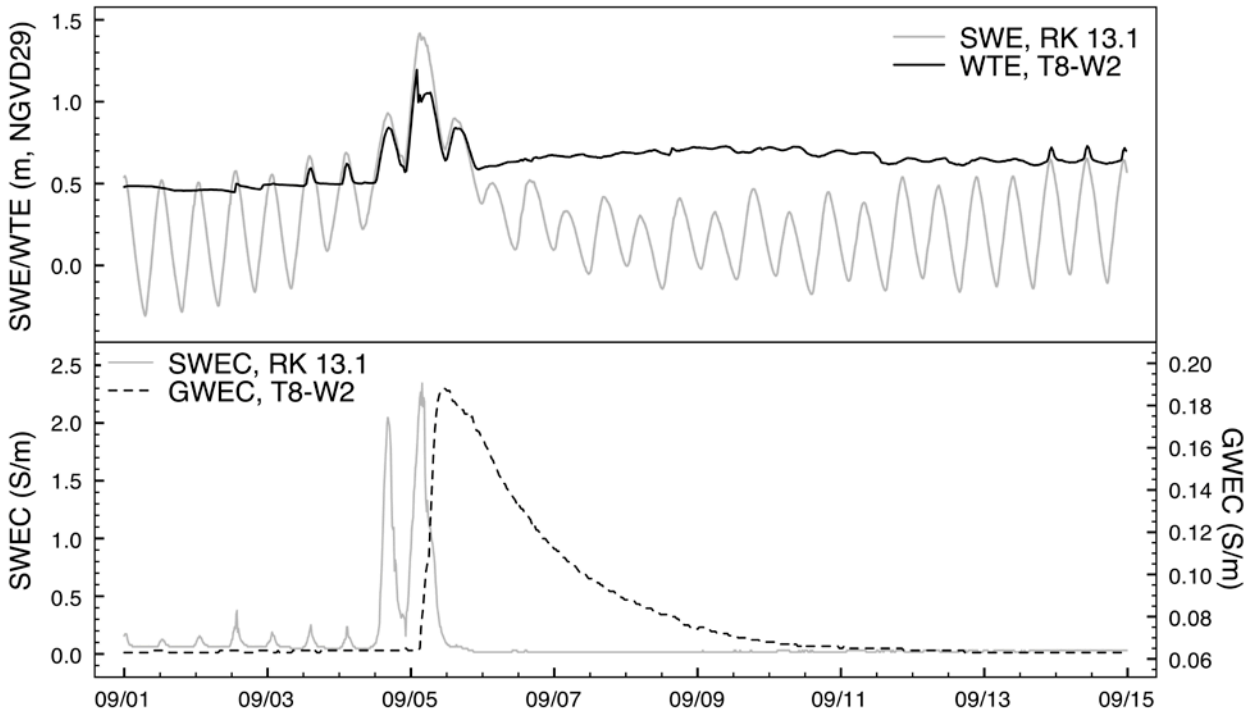

Figure 4-6. High resolution (30-minute) surface water elevation (SWE), water table elevation (WTE), surface water electrical conductivity (SWEC), and groundwater electrical conductivity data on upper tidal transect T8 over 2 weeks in September 2004 during Hurricane Frances.

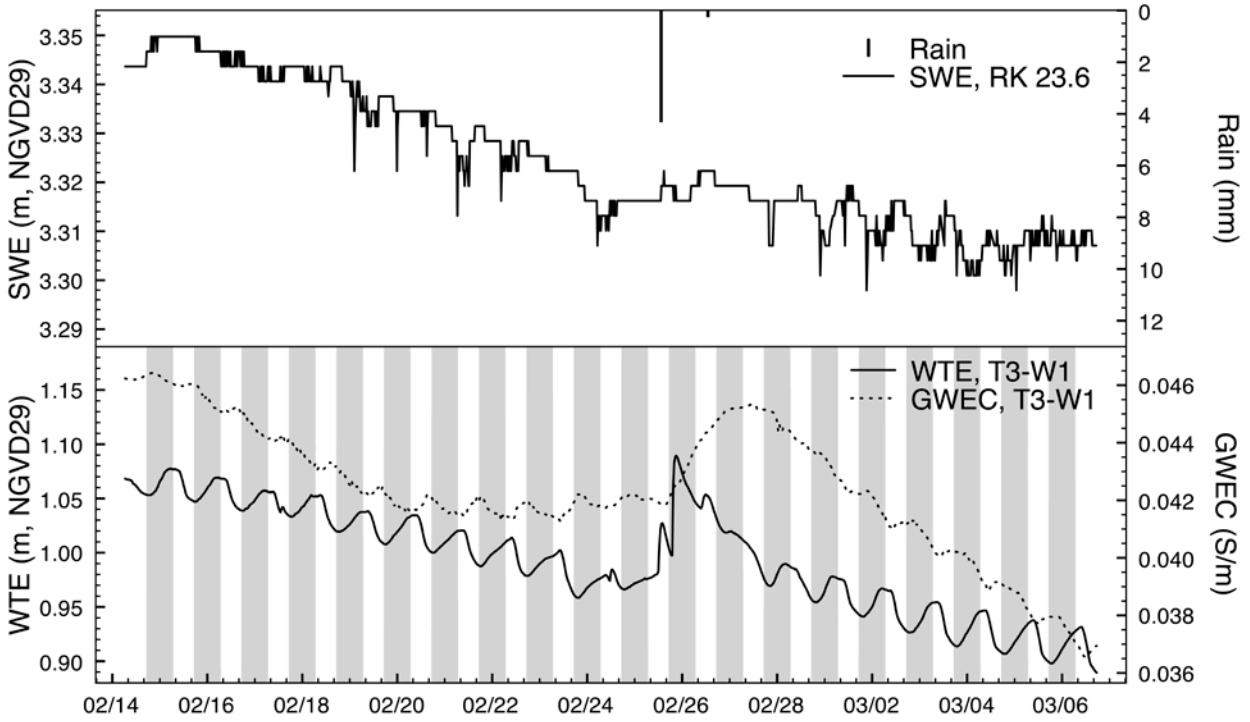

Figure 4-7. High resolution (30-minute) surface water elevation (SWE), rainfall, water table elevation (WTE), and groundwater electrical conductivity (GWEC) data on upper riverine transect T3 over 3 weeks in February 2006. Gray bars indicate nighttime hours.

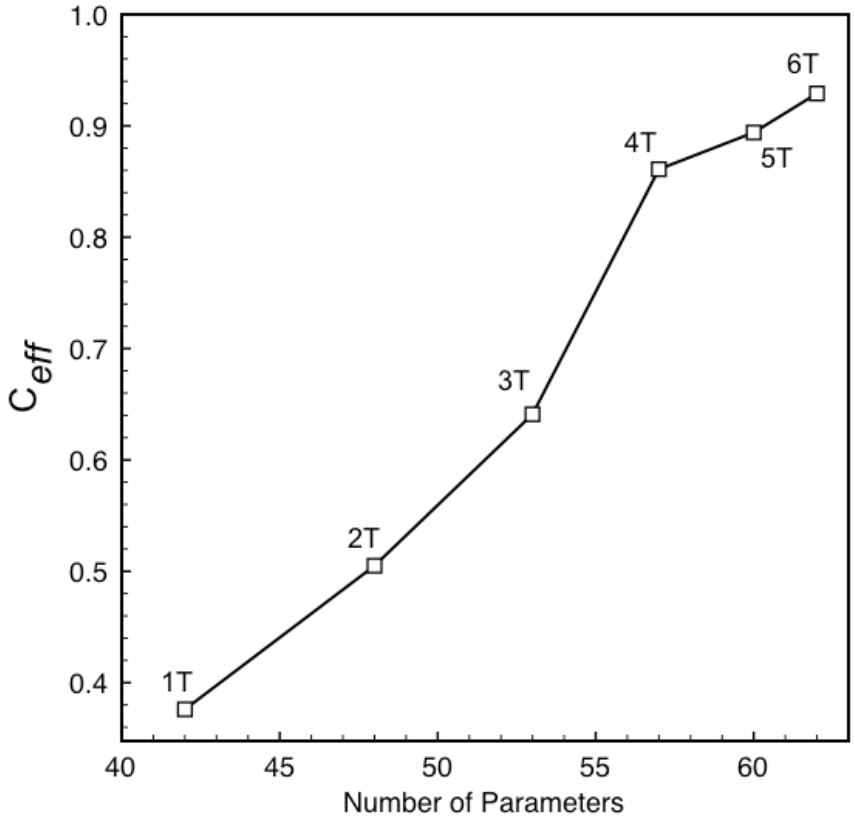

Figure 4-8. Number of parameters vs. coefficient of efficiency (C_{eff}) for DFMs with one (1T) to six (6T) common trends.

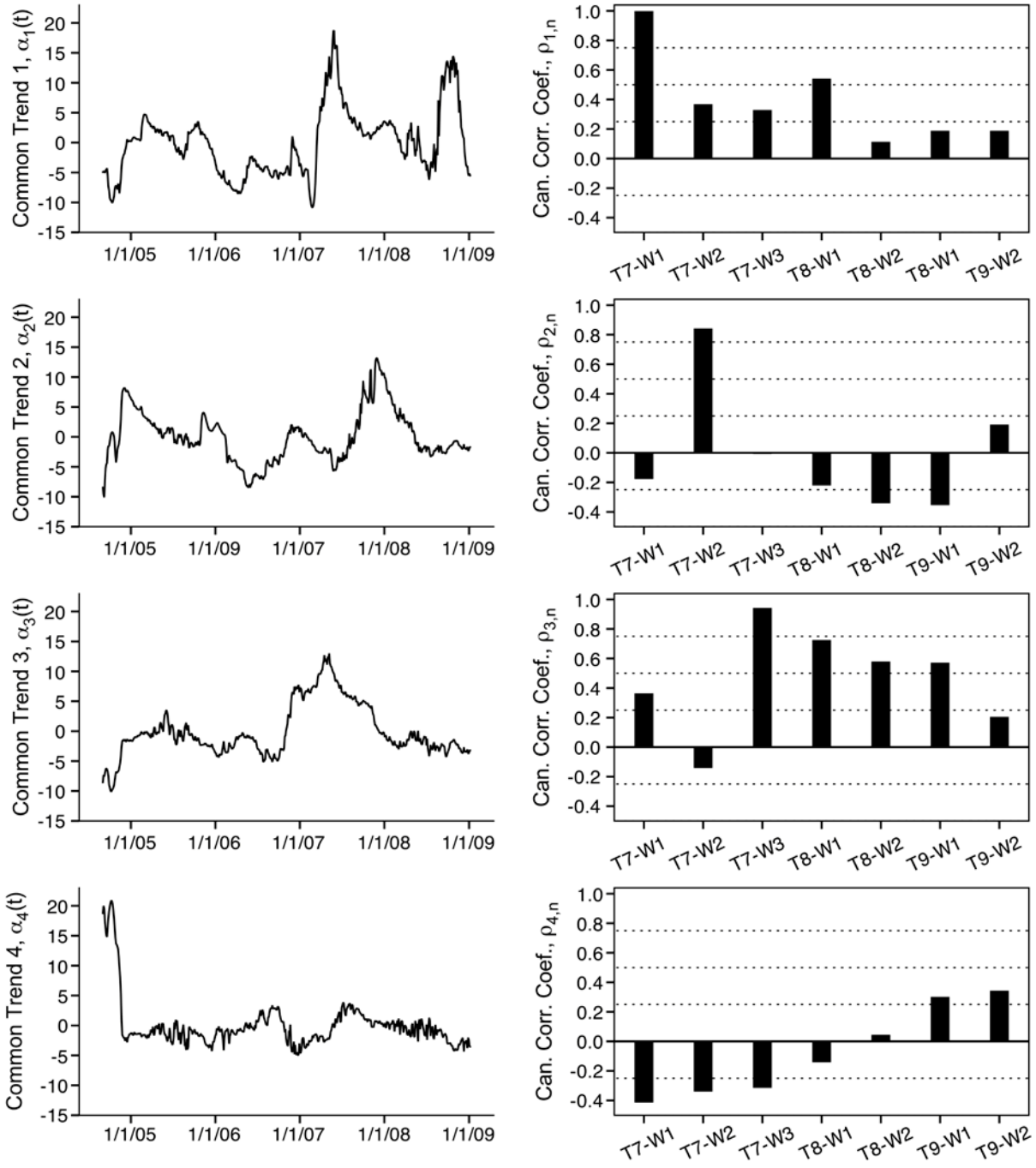

Figure 4-9. Common trends (left) and their associated canonical correlation coefficients (right) for Model I.

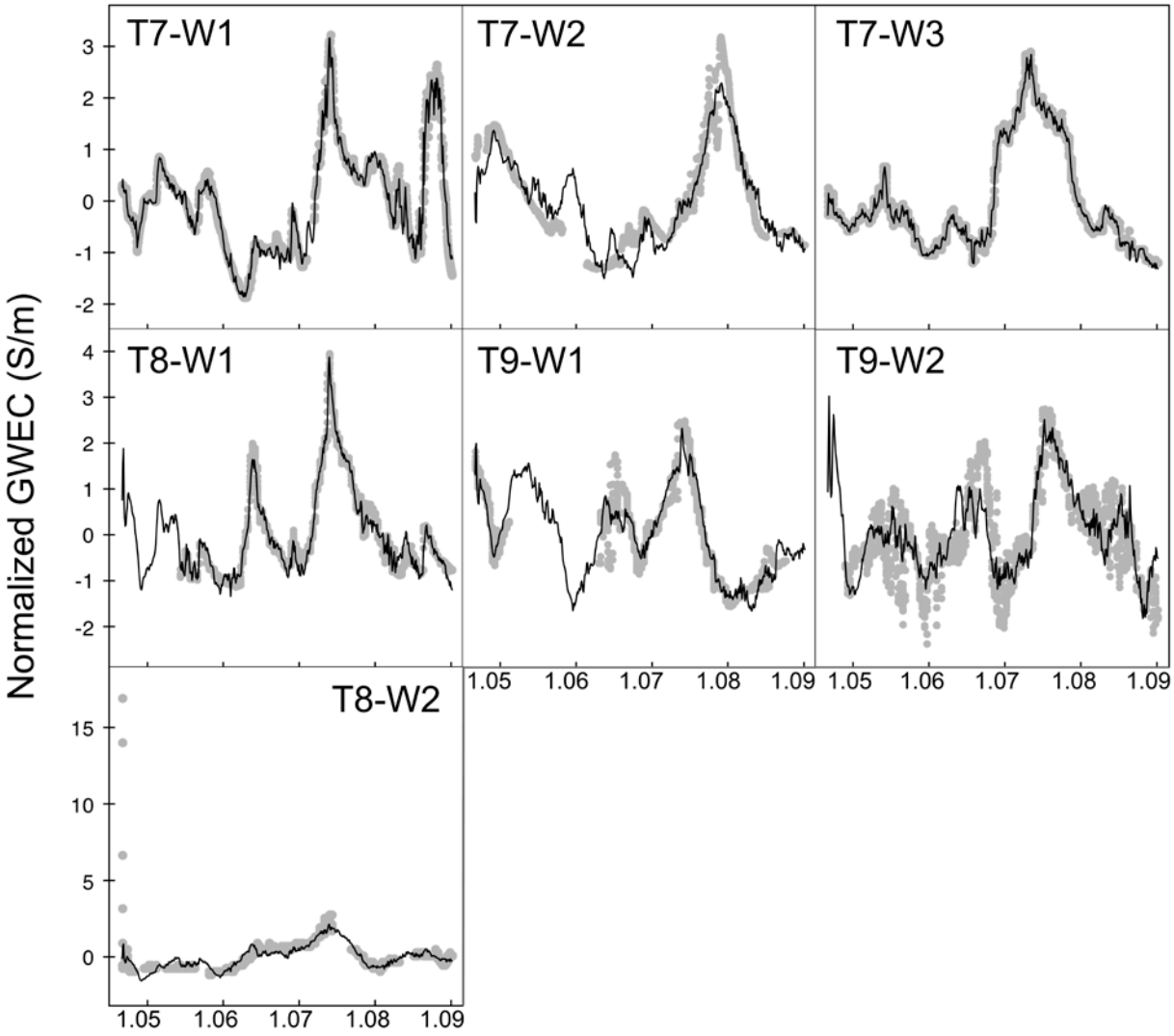

Figure 4-10. Observed (gray symbols) and modeled (black lines) normalized WTE for the twelve wells obtained from Model II using 3 common trends and 5 explanatory variables.

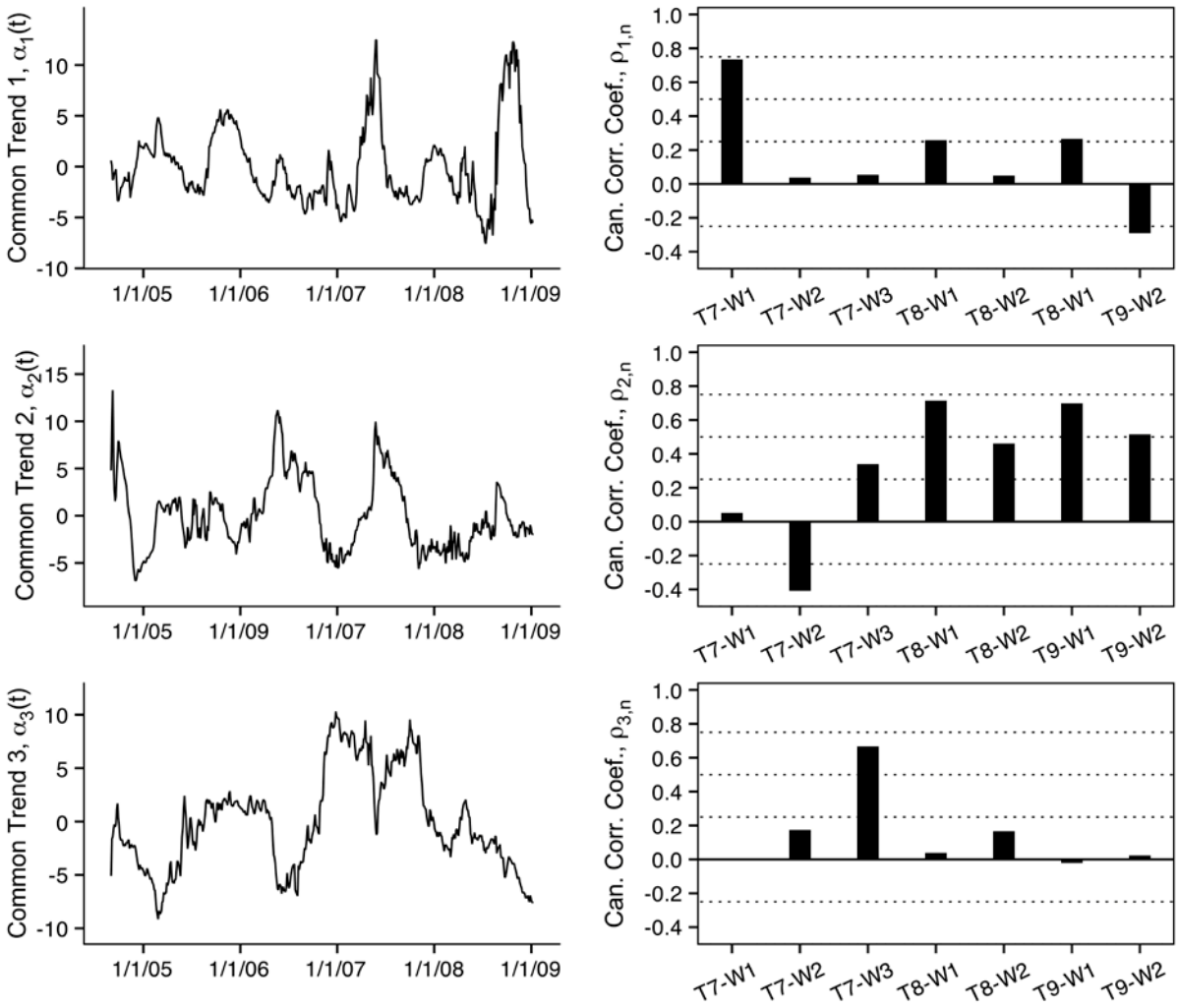

Figure 4-11. Common trends (left) and their associated canonical correlation coefficients (right) for Model II.

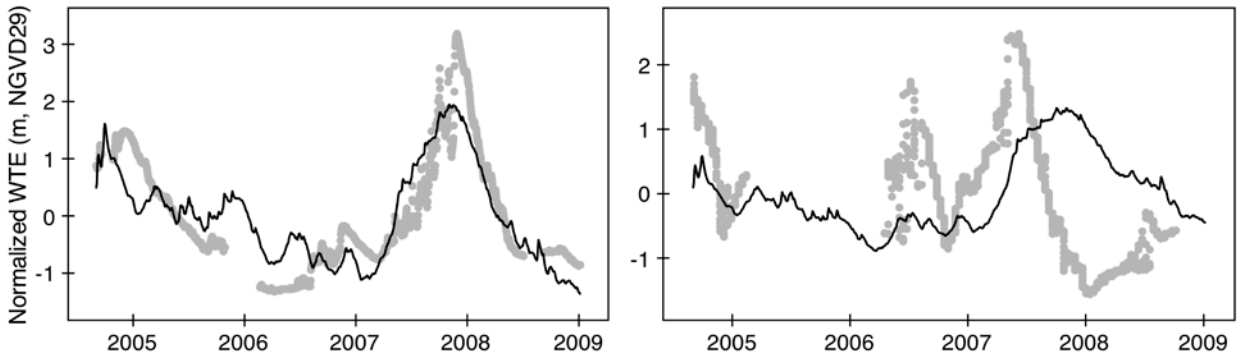

Figure 4-12. Observed (gray symbols) and modeled (black lines) normalized WTE for well T7-W2 (left) and well T9-W2 (right) obtained from Model III using 4 explanatory variables and no trends.

CHAPTER 5
EXPLORING ROOT ZONE SOIL MOISTURE DYNAMICS IN A DEGRADED BALD CYPRESS (*TAXODIUM DISTICHUM* [L.] RICH.) FLOODPLAIN FOREST

Introduction

Ecosystem restoration is often undertaken with the goal of returning a degraded (i.e., impacted, invaded, perturbed, altered, etc.) plant community to an earlier, more "natural" state (e.g., Pottier et al., 2009). Hydrological regime is often the primary environmental sieve (i.e., filter or barrier) (Harper, 1977) controlling seed germination, seedling recruitment, and long-term maintenance of plant species and communities, particularly in wetlands (van der Valk, 1981). Accordingly, wetland restoration efforts are usually built upon a foundation of hydrological restoration, whereby historical hydrological regimes and connections are reestablished in order to provide well-timed freshwater flows (Middleton, 2002), nutrients (Junk et al., 1989), and (where appropriate) the sediment required for accretion (DeLaune et al., 1994). A robust understanding of site hydrology is therefore vital for meeting restoration goals.

Hydrological monitoring and modeling efforts in support of wetland restoration usually focus on surface water (e.g., Wang, 1987), and less frequently, groundwater (e.g., Jung et al., 2004), but overwhelmingly overlook hydrological conditions in the vadose (unsaturated) zone, which largely dictate seed germination and seedling survival for many wetland plant species (Middleton, 1999). In addition to surface water performance measures like hydroperiod, restoration plans that rely on plant recruitment from existing seed banks, extant populations, or re-seeding must also ensure that restored areas experience the appropriate soil moisture regime to facilitate germination of desired species. For example, the timing and duration of flooding and drawdown in the floodplain play a critical role in the reproduction of bald cypress (*Taxodium*

distichum [L.] Rich.), a major component of floodplain swamps in sixteen U.S. states (Thompson et al., 1999).

Bald cypress seeds are dispersed primarily by water (Schneider and Sharitz, 1988; Middleton, 1999), and are relatively short-lived, with less than 40% of seeds remaining viable after 100 days and less than 5% remaining viable after 1 year (Middleton, 2000). Thus, the maintenance of viable seed banks is dependent on a regular flood pulse for distribution. Seeds settle along drift lines after floodwaters recede and require moist, but not saturated conditions to germinate (Middleton, 2000). Due to this requirement, Middleton (2000) found that the zone of germination is limited to areas that draw down during the growing season. At the other end of the moisture regime, seeds will not germinate on well-drained soils due to lack of surface moisture. Thus, a prolonged drawdown (1 to 3 months) of flooded soils to a saturated condition is required for germination (Burns and Honkala, 1990; Middleton 1999, 2002). Seedlings must also grow fast enough to keep their crowns above floodwaters for most of the growing season to survive (Conner, 1988; Conner et al., 1986, 1987). In spite of these rather rigid environmental requirements, bald cypress forests can survive with infrequent regeneration events as long as mature populations remain healthy and continue to produce seeds. Since seed germination of other swamp species is similarly restricted by the extent and timing of flooding, bald cypress is not out-competed by other long-lived tree species (Middleton, 2000).

Given this specific set of life-cycle requirements, the success of bald cypress floodplain swamp restoration efforts relies on an understanding of the relationships between vadose zone, surface water, and groundwater hydrology. However, finding

direct relationships between basic hydrological inputs can be difficult due to interactions between surface water, groundwater, and porewater in variably saturated matrices with heterogeneous soils, vegetation, and topography (e.g., Gardner et al., 2002, Langevin et al., 2005). Collection of long-term, high-resolution data can describe temporal soil moisture dynamics (i.e., magnitude, range, daily, seasonal and interannual variation, etc.) and spatial variation (e.g., Kaplan et al., 2010a), however the intrinsic stochasticity of hydrological processes complicates the identification of hydrological fluxes that contribute to this observed variation. On the other hand, physically based models of the vadose zone (e.g., reviews in Vachaud et al., 1993 and Šimůnek et al., 2003) are useful exploratory tools to improve our understanding of these complex hydrological processes (Ritter et al., 2009), but require extensive parameterization and often rely on simplifying assumptions to estimate model boundary (Kampf and Burges, 2010) and initial conditions (Rocha et al., 2006).

Given these limitations, an alternative method for identifying possible shared variation and explanatory relationships is required. In this context, we applied Dynamic Factor Analysis (DFA), a multivariate times series dimension reduction technique, to investigate observed soil moisture dynamics in the degraded bald cypress floodplain river swamps of the Loxahatchee River, a managed coastal river in southeastern Florida (USA). DFA is a statistical technique that produces alternative dynamic factor models (DFMs), driven by measured data. Since the DFMs are based on observed data, no a priori information about the physical system being modeled is required. DFA provides the means to analyze complex, non-stationary environmental systems and decomposes observed times series variation into one or more common trends (which represent

unexplained variation) and any number of explanatory variables. DFA is especially useful for assessing which explanatory variables (if any) most affect the time series of interest.

DFA was initially developed for economic time series (Geweke, 1977), but has lately been applied to groundwater systems (Kovács et al., 2004; Ritter and Muñoz-Carpena, 2006; Kaplan et al., 2010b), groundwater quality trends (Muñoz-Carpena et al., 2005; Ritter et al., 2007), and soil moisture dynamics (Ritter et al., 2009; Regalado and Ritter 2009a,b). DFA is often applied to improve conceptualization of ecological relationships, and it has been used to identify trends and environmental response variables affecting squid populations (Zuur and Pierce, 2004), Atlantic bluefish (Addis et al., 2008), and commercial fisheries (Erzini, 2005; Tulp et al., 2008).

We applied DFA to study the interactions between root zone soil moisture and other hydrological variables in the floodplain wetlands of the Loxahatchee River (Florida, USA), where watershed modifications and management over the past century have led to reduced freshwater flow, inadequate hydroperiod, and a shift towards drier plant communities (South Florida Water Management District [SFWMD], 2009). Data collection and modeling efforts in the Loxahatchee River have been directed at developing surface water management goals to maintain and restore the river's floodplain swamp (SFWMD 2002, 2006), but have largely overlooked groundwater and vadose zone hydrology in the floodplain. Monitoring in the vadose zone (Kaplan et al., 2010a) has supported the development of initial relationships between surface water management and vadose zone conditions. However, improved soil moisture predictions are required to better assess the effects of restoration implementation and to guide

adaptive management. To meet this goal, we applied DFA to 12 long-term soil moisture datasets and other hydrological variables in the watershed to: (a) identify important common trends among the soil moisture series; and (b) identify the external hydrological factors that most fully explained observed variation in the data.

Materials and Methods

Study Site

Historically part of the greater Everglades watershed, the Loxahatchee River is located on the southeastern coast of Florida, USA (26° 59' N, 80° 9' W; Fig. 5-1) and is often referred to as the "last free-flowing river in southeast Florida" (SFWMD, 2006). The river's three main branches (the North, Southwest, and Northwest Forks) join in a central embayment that connects to the Atlantic Ocean via Jupiter Inlet (Fig. 5-1). Watershed modifications and hydraulic infrastructure have decreased the effective size of the watershed from 700 km^2 to approximately 550 km^2, but much of the area is protected in public lands including Jonathan Dickinson State Park (JDSP), the Loxahatchee Slough Preserve, and the J.W. Corbett Wildlife Management Area. In 1985, the Loxahatchee River became Florida's first National Wild and Scenic River (National Park Service [NPS], 2004).

The Northwest Fork of the Loxahatchee River (NW Fork) and its watershed are unique in that they contain a diverse array of terrestrial and aquatic ecosystems in an increasingly urbanized area, including sandhill, scrub, hydric hammock (a plant community characterized by 30 to 60 days of inundation yearly and mixed, facultative hardwood species), wet prairie, floodplain swamp, estuarine swamps, seagrass beds, tidal flats, oyster beds, and coastal dunes (Roberts et al., 2006; Treasure Coast Regional Planning Council [TCRPC], 1999). Within the river channel itself, there are

four distinct aquatic environments: freshwater, oligohaline, mesohaline, and polyhaline. Since much of the NW Fork's watershed is protected, many of these ecosystems remain intact and support a diversity of protected animal and plant species including the endangered West Indian manatee (Trichechus manatus latirostris) and four-petal pawpaw (Asimina tetramera Small).

The upper watershed of the NW Fork is also home to one of the last remnants of bald cypress swamp in southeast Florida, but modified watershed hydrology and management threaten this resource. The construction of the C-18 canal in 1958 transferred a majority of flow from the NW Fork to the channelized Southwest Fork (Fig. 5-1) to aid in flood protection; major and minor canals direct water away from the historic watershed; and increasing municipal withdrawals have lowered the regional groundwater table (SFWMD, 2002). These hydrologic changes have led to inadequate hydroperiod and soil moisture in the upstream riverine floodplain, which has shifted the system towards drier plant communities (SFWMD, 2009). Similar changes in the composition of floodplain vegetation as a result of reduced flooding frequency have been observed regionally and globally (e.g., Darst and Light, 2008; Leyer, 2005). In the Loxahatchee River, data collection and modeling efforts in support of management and restoration planning have been underway for several years (e.g., SFWMD, 2002, 2006, 2009; VanArman et al., 2005; Mortl, 2006; Muñoz-Carpena et al., 2008, Kaplan et al., 2010a,b).

The experimental site is a freshwater, riverine area, 23.3 kilometers upstream of the river mouth (T1 in Fig. 5-1) and is not impacted by daily tides. Elevations range from 4.19 m to 1.66 m (Fig. 5-2; all elevations are referenced to the National Geodetic

Vertical Datum of 1929, NGVD29). Soils on the higher elevation hydric hammock consist of Winder fine sand (a fine-loamy, siliceous, superactive, hyperthermic Typic Glossaqualf; Soil Survey Staff, 1981), transitioning to sandy clay loam at depths of ~90 cm (Mortl, 2006). In the lower floodplain, soils are classified as fluvents— stratified entisols made up of interbedded layers of sand, clay, and organic matter, typical of areas with frequent flooding and deposition (Sumner, 2000)—with sand content increasing with depth (Mortl, 2006). Vegetation communities in this area consist of hydric hammock at higher elevations and mature bald cypress swamp (average diameter at breast height, DBH = 49 cm) at lower elevations. Low bald cypress recruitment and the invasion of less flood-tolerant species into the hydric hammock and riverine floodplain in this and other upstream areas have been documented (SFWMD, 2009), indicating the ecological impact of reduced moisture and shortened hydroperiod in the area.

Experimental Setup

Twelve frequency domain reflectometry (FDR) dielectric probes (Hydra Probe, Stevens Water Monitoring Systems, Beaverton, OR, USA) measuring soil moisture, bulk electrical conductivity, and temperature were installed at four locations and three depths along a previously established vegetation survey transect perpendicular to the river (Fig. 5-2). Each cluster of three probes was wired to a field data logger (CR10/CR10-X, Campbell Scientific, Logan, Utah, USA), which recorded data every 30 minutes. Every two to four weeks, system batteries were changed and data were downloaded. Data collection began in September 2004 and continued through September 2008.

The Hydra probe determines soil moisture by measuring soil dielectric properties. The probe generates a 50 MHz electromagnetic wave, most of which is absorbed by the

soil. The portion of the wave that reflects creates a standing wave, which characterizes the soil dielectric constant, K. K is a complex number composed of real (ε_r) and imaginary (ε_i) dielectric constants (Campbell, 1990) such that:

$$K = \varepsilon_r - i\varepsilon_i \tag{5-1}$$

Temperature-corrected (25° C) ε_r was used to calculate soil moisture (θ) based on calibrations developed specifically for the soils of the Loxahatchee River floodplain by Mortl (2006). When comparing θ across soils, we used the effective soil moisture, Θ_e [-], since the Winder fine sand and fluvent soils have substantially different hydraulic characteristics Table 5-1. Θ_e scales θ from zero to unity and is calculated by:

$$\Theta_e = \frac{\theta - \theta_r}{\theta_s - \theta_r} \tag{5-2}$$

where θ is the actual (measured) soil moisture content [$m^3\ m^{-3}$], θ_r is the residual soil moisture content [$m^3\ m^{-3}$], and θ_s is the saturated soil moisture content [$m^3\ m^{-3}$].

Dynamic Factor Analysis

Soil moisture time series were investigated using dynamic factor analysis (DFA) (Zuur et al., 2003b). DFA is a parameter optimization and dimension reduction technique that is useful for identifying interactions between variables of interest and possible explanatory factors. With DFA, temporal variation in a set of *N* observed time series is modeled as a linear combination of one to *M* common trends, zero to *K* explanatory variables, a constant intercept parameter, and noise (Zuur et al., 2003b):

N time series = *M* common trends + level parameter + *K* explanatory variables + noise (5-3)

In this construction, the *M* common trends represent unexplained, shared variation among the *N* measured time series, the level parameter allows for relative shifts up and

down, and the *K* are additional observed time series that represent explained variation. The goal of DFA is to identify one or more common trends in the set of observed time series that represent latent (unexplained) variation, minimizing the number of trends required to achieving a good fit with measured data. Appropriate explanatory variables may improve the model fit and point out which external factors most affect the response variables (improving conceptualization of the physical system that drives observed variation).

Mathematically, Equation 5-3 may be written as:

$$s_n(t) = \sum_{m=1}^{M} \gamma_{m,n} \alpha_m(t) + \mu_n + \sum_{k=1}^{K} \beta_{k,n} v_k(t) + \varepsilon_n(t) \quad (5\text{-}4)$$

$$\alpha_m(t) = \alpha_m(t-1) + \eta_m(t) \quad (5\text{-}5)$$

where $s_n(t)$ is a vector containing the set of *N* time series being modeled (dubbed "response variables"); $\alpha_m(t)$ is a vector containing the common trends; $\gamma_{m,n}$ are weighting coefficients that represent the relative importance of common trends to each response variable (dubbed "factor loadings"); μ_n is a constant level parameter that shifts series up or down; $v_k(t)$ is a vector containing the explanatory variables; and $\beta_{k,n}$ are weighting coefficients for the explanatory variables that indicate the relative importance of explanatory variables to each response variable (dubbed "regression parameters"). In this study, the response variables, $s_n(t)$, are the twelve □e time series. The terms $\varepsilon_n(t)$ and $\eta_m(t)$ are independent, Gaussian noise with zero mean and unknown diagonal or symmetric/non-diagonal covariance matrix. DFMs with diagonal matrices may include a smaller number of model parameters than those with symmetric, non-diagonal matrices,

but may also require a larger number of common trends to achieve adequate model fits (Zuur et al., 2003a).

Common trends, $\alpha_m(t)$, are modeled as a random walk (Harvey, 1989) and predicted with the Kalman filter/smoothing algorithm and Expectation Maximization (EM) techniques (Dempster et al., 1977; Shumway and Stoffer, 1982; Wu et al., 1996). The EM technique is also used to calculate factor loadings ($\gamma_{m,n}$) and level parameters (μ_n), while regression parameters ($\beta_{k,n}$) are modeled by linear regression (Zuur and Pierce, 2004). The $\gamma_{m,n}$ and $\beta_{k,n}$ accompanying common trends and explanatory variables allow us to identify the differential effects of common trends and explanatory variables on the soil moisture response variables. The significance of the $\beta_{k,n}$ were assessed using their magnitude and associated standard errors to compute a t-value. Relationships between response and explanatory variables were deemed significant for t-values > 2 (Ritter et al., 2009). Relationships between response variables and common trends, on the other hand, were quantified with the canonical correlation coefficient ($\rho_{m,n}$). Values of $\rho_{m,n}$ close to unity indicated high association between the common trend and response variable. We classified the strength of these correlations into four groups: "minor" ($|\rho_{m,n}| < 0.25$); "low" ($0.25 \leq |\rho_{m,n}| < 0.50$); "moderate" ($0.50 \leq |\rho_{m,n}| < 0.75$); and "high" correlations ($|\rho_{m,n}| \geq 0.75$) (Ritter, 2009).

Explanatory Variables: Meteorological, Surface Water, and Groundwater Data

Additional meteorological and hydrological variables were measured across the watershed, and a total of 31 daily time series (twelve response variables and nineteen candidate explanatory variables, each with 1589 daily values) were investigated for use in this analysis (Table 5-2). Since multi-collinearity may exist between explanatory

variables measured at nearby locations, not all candidate explanatory variables could be used simultaneously. To assess the severity of multi-collinearity, we used the variance inflation factor (VIF) of each set of explanatory variables (Zuur et al., 2007), avoiding combinations of explanatory variables that resulted in VIF > 5 (Ritter et al., 2009).

Average annual precipitation in the Loxahatchee River watershed is 1550 mm yr^{-1}, with approximately two-thirds falling during the wet season from May to October (Dent, 1997). Average annual evapotranspiration (ET) losses are 1140 mm yr^{-1} in southern Florida (SFWMD, 2002). For this study, rainfall data were recorded at the S46 hydraulic structure on the Southwest Fork and ET data were recorded at the JDWX weather station in JDSP (Fig. 5-1). These data are publicly available and were downloaded from the SFWMD online environmental database, DBHYDRO (accessed at http://my.sfwmd.gov/dbhydroplsql/; stations S46_R and JDWX) and converted to daily means. Note that soil moisture data are autocorrelated (i.e., Θ_e at time *t* is dependent on Θ_e at *t*-1), while this is not true for rainfall and ET. To make these data potentially useful to the DFA, the difference between cumulative rainfall and cumulative ET was used to calculate a net recharge time series such that:

$$R_{net,t} = \sum_{i=1}^{t} P_i - \sum_{i=1}^{t} ET_i \qquad (5\text{-}6)$$

where $R_{net,t}$ is the net recharge at time t [mm], P is precipitation [mm] and ET is evapotranspiration [mm] (Ritter et al., 2009).

Breakpoint surface water elevation (SWE) was measured at a SFWMD monitoring station on the headwater side of Lainhart Dam (0.45 km upstream of the study area; Fig. 5-1) and converted to mean daily values. These data are also available on

DBHYDRO (station LNHRT_H). Water table elevation (WTE) data were collected on T1 in a groundwater well located 50 m from the river (Fig. 5-2) using a multi-parameter water quality probe (TROLL 9000/9500, In-Situ Inc., Ft. Collins, CO, USA). The well was constructed of slotted 5.08 cm (nominally 2 in) PVC pipe housed in a 20.32 cm (nominally 8 in) PVC pipe. The screen size was 0.254 mm (nominally 0.01 in) and the slotted section length was 0.61 m (nominally 2 ft), corresponding to slotted elevations between 1.66 to 2.27 m. WTE was measured every 30 minutes from September 2004 through January 2009 and converted to mean daily values. A full description of the groundwater dataset and QA/QC procedure are available in Muñoz-Carpena et al. (2008).

Unlike SWE and WTE, Θ_e time series are bound, by definition, between zero and unity (corresponding to 0 and 100% saturation, respectively; see Equation 5-2). Physically, this means that SWE and/or WTE may continue to increase after Θ_e reaches unity, after which the response variables lose dependence on these explanatory variables. To account for this mathematically, we calculated an additional set of explanatory variables that capped measured SWE and WTE variables at fixed elevations according to:

$$SWE_{\kappa,t} = \min(SWE_t,\ \kappa) \tag{5-7}$$

$$WTE_{\kappa,t} = \min(WTE_t,\ \kappa) \tag{5-8}$$

where $SWE_{\kappa;t}$ and $WTE_{\kappa;t}$ are surface water and water table elevations (m, NGVD29) capped at fixed elevations, κ [m, NGVD29]. For this analysis we investigated values of κ ranging from 2.6 to 4.0 (in 0.1 m increments), corresponding to soil moisture monitoring elevations in the floodplain (Fig. 5-2).

Analysis Procedure

DFA was implemented using the Brodgar v. 2.6.5 statistical package (Highland Statistics Ltd., Newburgh, UK), which uses the "R" statistical software language, version 2.9.1 (R Core Development Team, 2009). To compare the relative importance of common trends and explanatory variables across response variables (Zuur et al., 2003b; Zuur and Pierce, 2004), all series were normalized (mean subtracted, divided by standard deviation). We carried out the DFA in three distinct steps, resulting in three models. Model I was developed by constructing a set of DFMs using an increasing number of common trends until model performance was deemed satisfactory according to goodness-of-fit indicators (Zuur et al., 2003a). Model II was developed by incorporating explanatory variables into the DFA until a combination of common trends and explanatory variables was identified that met or exceeded the goodness-of-fit indicators from Model I without exceeding the VIF criterion. The use of explanatory variables in Model II is intended to reduce the amount of unexplained variability and improved description of Θ_e in the floodplain. A final reduced model (Model III) was explored by using the explanatory variables identified in Model II to create a multi-linear model (Model III) without common trends. Model III was developed using a multiple regression procedure run in Matlab (2009b, The MathWorks, Inc., Natick, MA, USA).

DFM goodness-of-fit was quantified with the Nash-Sutcliffe coefficient of efficiency ($-\infty \leq C_{eff} \leq 1$, Nash and Sutcliffe, 1970) and Akaike's information criterion (AIC; *Akaike*, 1974). C_{eff} compares the variance between predicted and observed data about the 1:1 line, with C_{eff} =1 indicating that the plot of predicted vs. observed data matches the 1:1 line. The AIC is a statistical criterion that balances goodness-of-fit with model

parsimony by rewarding goodness-of-fit but including a penalty term based on the number of model parameters. Generally, the DFM with the largest C_{eff} and smallest AIC are preferred.

Finally, to assess whether model performance had been improved through this analysis, DFMs were compared with the sigmoidal model of floodplain soil moisture based solely on SWE developed by Kaplan et al. (2010a) of the form:

$$\Theta_e = \frac{1}{1 + e^{-\left(\frac{SWE - a}{b}\right)}} \tag{5-9}$$

where SWE is measured at Lainhart Dam (m, NGVD29), and *a* and *b* are local parameters. Underlying Equation 5-9 is the fundamental relationship describing θ as a function of soil water pressure head (ψ) (e.g., Brooks and Corey, 1964; van Genuchten, 1980). Under relatively hydrostatic conditions (i.e., no inflow, outflow, or redistribution of soil water above the water table), ψ can be estimated as the distance to the water table (Skaggs, 1991). Since SWE and WTE at T1 are often coupled (see results section), directly linking θ to SWE is consistent with these fundamental relationships.

Results and discussion

Experimental Time Series

Fig. 5-3 shows hydrological time series collected on and near the experimental transect (T1). Data collected during this four-year period represented a wide range of climatic conditions, including four wet/dry seasons; two years with above-average rainfall and hurricane-induced flooding (2004 and 2005); and the driest two-year period (2006 to 2007) on record in south Florida in more than 75 years (Neidrauer, 2009). Rainfall and ET (Fig. 5-3a) followed a seasonal pattern, with wet season (May to

October) rain accounting for 73 to 80% of yearly totals over the four years (mean 77%). SWE and WTE (Fig. 5-3b) were closely correlated in wet seasons (r = 0.92), but diverged during dry seasons when SWE remained impounded at a relatively constant level behind Lainhart Dam while WTE continued to decline, most notably in the summers of 2006 and 2007.

SWE and WTE dynamics were reflected in Θ_e time series (Fig. 5-3c-f). On the sandy hydric hammock (Fig. 5-3c-d), highest elevation Θ_e series (e.g., T1-60 [3.90 m]) were the most dynamic, responding quickly to rainfall and promptly draining. Middle elevation soils (T1-60 [3.80 m] and T1-50 [3.71 m]) showed a similar, but damped response to hydrological fluxes (rain, SWE, and WTE). Lowest elevation (i.e., deepest) soils (T1-60 [3.60 m] and T1-50 [3.06 m]) remained saturated for several months at a time, but all soils dried considerably during dry seasons. The lower floodplain was periodically inundated during the study period and Θ_e was at or close to saturation (i.e., $\Theta_e = 1$) at all depths for long periods, however surface soils (T1-30 [2.76 m] and T1-1 [2.71 m]) experienced considerable drying during all dry seasons (most markedly in 2006 and 2007; Fig. 5-3e-f, dark lines), with very dry conditions at surface of these highly organic and clayey soils. Lowest elevation soils (T1-30 [2.76 m] and T1-1 [2.71 m]) remained saturated for the entire study period (Fig. 5-3e-f, gray lines). As constant values, these series had zero variance and were thus removed from the DFA. Kaplan et al. (2010a) described these Θ_e datasets in further detail.

Dynamic Factor Analysis

Baseline DFA (no explanatory variables)

DFA was applied in three steps. First, different DFMs were obtained using M = 1 to 9 common trends and no explanatory variables to model the ten response variables (twelve original series minus the two constant series from lowest elevation probes). Initially, both diagonal and non-diagonal error covariance matrices were explored to identify the number of trends required to achieve a maximum C_{eff} and minimum AIC. However, when using a diagonal error covariance matrix, we found one or more common trends that exactly fit one or more of the response variables. This can occur with highly variable and noisy datasets and is referred to as a Heywood case (Highland Statistics, 2000). Since the goal of the DFA is to identify shared variation, non-diagonal error matrices were used in subsequent analyses to avoid this occurrence.

With a non-diagonal matrix, AIC continued to decrease and C_{eff} to increase with up to nine trends (M=9). As an alternative to the AIC, we also examined the Bayesian Information Criterion (BIC; Schwarz, 1978) and Consistent Akaike's Information Criteria (CIAC; Bozdogan, 1987), which penalize additional parameters more strongly than the AIC, but all metrics continued to decrease with up to nine trends (Table 5-3). That more than nine trends (representing unexplained information) were necessary to achieve the best DFM of ten response variables suggested that multiple latent effects influence the variability of Θ_e at different depths across the floodplain. Since no inflection point in AIC, BIC, or CIAC was identified, we used C_{eff} and visual inspection as a measure of a model's goodness-of-fit. Though choice of a threshold C_{eff} is necessarily arbitrary, it is common to choose an appropriate model based on the reduction in model improvement with increased parameterization (e.g., Regalado and Ritter, 2009b). This led to the

selection of the DFA with five common trends (M = 5; Table 5-3) as Model I, since addition of an extra trend had minimal impact on model performance. Model I had overall C_{eff} = 0.90 (0.46 ≤ C_{eff} ≤ 0.99) and AIC = 1292. Based on this selection, the objective of the subsequent DFA with explanatory variables (Model II) was to reduce the amount of unexplained variability in the DFM by achieving similar model performance using less than five common trends.

It is first instructive to examine common trends from Model I and their associated canonical correlation coefficients ($\rho_{m,n}$), since high $\rho_{m,n}$ values indicate high correlation with response variables. The three most important common trends from Model I (highest average $|\rho_{m,n}|$ across the ten response variables) are shown in Fig. 5-4. Though only describing latent (unknown) variability at this stage, these trends and their patterns of correlation are useful for developing ideas about how Θ_e varies in the floodplain and where to look for the most useful explanatory variables. For example, common trend 1 (Fig. 5-4a, left panel) was highly ($|\rho_{m,n}| \geq 0.75$) to moderately ($0.50 \leq |\rho_{m,n}| < 0.75$) correlated with nine of the ten Θ_e series (Fig. 5-4a, right panel), and appears to reflect large variation due to high water events associated with Hurricane Frances and Jeanne (which passed over the study site in 2004) and extended dry periods in the summers of 2006 and 2007. Correlations with common trend 2 (Fig. 5-4b) were weaker, but generally positive and highest for lower elevation Θ_e series. On the other hand, common trend 3 (Fig. 5-4c) was most correlated with Θ_e in higher elevation soils. This topographic distribution of $\rho_{m,n}$ suggested it would be useful to search for explanatory variables whose relative importance is split across lower and higher elevation response variables.

DFA with explanatory variables

Next, explanatory variables were added to the model to reduce the number of common trends required while maintaining similar goodness-of-fit metrics as those from Model I. By adding explained variability in this step, we also aim to reduce canonical correlation coefficients and factor loadings of any remaining trends, indicating reduced dependency on unknown variation. Candidate explanatory variables included surface water elevation at Lainhart Dam (SWE), water table elevation in well T1-W1 (WTE), SWE_{κ} and WTE_{κ} series calculated with elevations ranging from 2.6 to 4.0 m, and net recharge calculated as the difference between cumulative rainfall and ET series (R_{net}), for a total of nineteen possible explanatory time series (Table 5-2). When two or more candidate explanatory variables were collinear or multi-collinear (resulting in VIFs > 5), the explanatory variable resulting in the best overall model fit (highest C_{eff} and lowest AIC) was selected.

Approximately 50 DFMs were developed with different combinations of common trends and explanatory variables. Finally, the best DFM used three explanatory variables (K=3): SWE at Lainhart Dam, WTE_{κ} calculated with $\kappa = 3.10$ m, and net recharge (R_{net}) (Table 5-3). With these explanatory variables the number of required common trends was reduced from five to three (M=3), reducing the unexplained variability in the model while achieving performance similar to that of Model I. This model (Model II) yielded an AIC value of 331 (lower than the 1292 target from Model I) and an overall C_{eff} value of 0.90 across the ten Θ_e series (equal to the target of 0.90 from Model I).

Table 5-4 summarizes parameters obtained using Model II. Significant regression parameters (t-value > 2) are shown in bold. The ten Θ_e series had variable relationships to the common trends from Model II, but canonical correlations were reduced from Model I, indicating a reduced dependence of the DFM on these latent series. While the trends in Model I had five "high" and thirteen "moderate" correlations with response variables, trends in Model II had only two "high" and one "moderate" correlations. Model fits are fair to excellent ($0.67 \leq C_{eff} \leq 0.99$). Model II out-performed the empirical sigmoidal model of Kaplan et al. (2010a) for all Θ_e series (Table 5-5), although at the cost of more parameters (122 for Model II versus 20 for the sigmoidal model). Model performance is particularly improved for Θ_e series in the lower floodplain (i.e., stations T1-30 and T1-1), where bald cypress seed germination will dictate the success of proposed restoration and management scenarios.

The spatially distributed effects of the explanatory variables and common trends on Model II are compared in Fig. 5-5. Fig. 5-5a shows that SWE was most important in describing variability in high and middle elevation soils on the hydric hammock, but had a reduced effect in deeper soils, particularly in the lower floodplain. On the other hand, WTEκ had strong effects on Θ_e in lower elevation soils. This pattern follows from Model I, which identified different common trends grouped around elevation. Regression coefficients for the R_{net} series were weaker and spread across response variables, though generally positive and significant (Table 5-5). Inclusion of explanatory variables in Model II reduced factor loadings (Fig. 5-5d) slightly over those in Model I (overall average $|\gamma_n|$ for the five trends in Model I was 0.08 ± 0.08 compared to 0.05 ± 0.05 in Model II). While these trends are important for improving model fits for some response

variables, this suggests that the Θ_e patterns observed in the Loxahatchee River floodplain may be adequately described using only the selected explanatory variables (see following section).

The remaining three trends in Model II and their associated $\rho_{m,n}$ values are shown in Figure 6. These common trends represent remaining unexplained (latent) variability among the Θ_e. Trend 1 (Fig. 5-6a) has low or minor correlations with all response series; trends 2 and 3 (Fig. 5-6b-c) are each highly associated with just one response variable, improving model fits for these series with little effect on other series. No additional spatial or physical interpretations were clear from these three remaining trends, suggesting that shared variation is being accounted for with explanatory variables.

Multilinear regression model (DFA with no common trends)

Finally, common trends were removed from the model to assess model performance model using only explanatory variables. The three explanatory variables identified in Model II were used to create a multi-linear model of the response variables, Model III. As expected, Ceff values for Model III were somewhat reduced from Model II (overall Ceff = 0.79, 0.59 ≤ Ceff ≤ 0.93; compared to Ceff = 0.90, 0.67 ≤ Ceff ≤ 0.99 for Model II), but are adequate for most measurement locations (Table 5-5). The distribution of model parameters in Model III are similar to the regression coefficients from Model II, with SWE most important to high and middle elevation soils and WTE_κ most important in lower elevation soils. Model fits are fair to excellent and are illustrated in Fig. 5-7. Model III out-performed the sigmoidal model for eight of the ten Θe series and had only slightly inferior performance for the remaining two series, T1-60 (3.90 m)

and T1-50 (3.41 m). Model improvements for response variables in the lower floodplain realized in Model II were retained. Although empirical by nature, these results indicate that Model III may be useful for assessment of restoration scenarios for the floodplain wetlands of the Loxahatchee River, particularly in light of the wide range of climatic conditions captured in the experimental period.

Conclusions

Long-term multivariate hydrological time series, measured in and around the Loxahatchee River watershed in south Florida, were studied in order to model soil moisture variation along a floodplain transect using dynamic factor analysis (DFA). The method proved to be a useful tool for the study of interactions among 29 long-term, non-stationary hydrological time series (ten effective soil moisture [Θ_e] series and nineteen candidate explanatory variables). We found a minimum of five common trends (representing unexplained variability) were necessary to adequately describe observed Θ_e variation in the ten response variables (Model I). Dependence on this unexplained variability was reduced by including appropriate explanatory variables selected from hydrological data measured in the area. The resulting model (Model II) required fewer trends, and those that remained were less important to the model (reduced canonical correlations and factor loadings). Model II also identified the most useful explanatory variables for describing Θ_e variation: surface water elevations (SWE), capped water table elevation (WTE$_\kappa$), and cumulative net recharge (R_{net}). The analysis also quantified the spatial distribution of the importance of explanatory variables to Θ_e in each location, highlighting the differential effects of surface water and groundwater on floodplain soil moisture. Finally, we found variation in Θ_e series to be adequately

described using just these explanatory variables after removing the trends (overall C_{eff} = 0.79, $0.59 \leq C_{eff} \leq 0.93$). The complex variability observed in these multivariate hydrological datasets was simplified using DFA, and the resulting models are useful for assessing the effects of proposed ecological restoration and management scenarios on Θ_e dynamics in the floodplain. Next, we aim to incorporate these and other hydrological relationships into an ecohydrological model to predict long-term effects of restoration scenarios on floodplain vegetation.

Table 5-1. Loxahatchee River floodplain soil characteristics described by Mortl (2006).

Soil Category	ρ_b (g cm^{-3})[†]	K_s (cm/hr)[‡]	θ_r[§]	θ_s[§]	%C[¶]
Sand	1.36 ± 0.18[#]	37.04 ± 7.70	0.04	0.40	0.45
	(1.06 - 1.55)	(29.26 - 48.42)			(0.10 - 0.48)
Fluvent	0.69 ± 0.38	84.33 ± 83.52	0.20	0.90	11.0
	(0.30 - 1.22)	(0.81 - 166.17)			(1.00 - 15.0)

[†]Field bulk density
[‡]Saturated hydraulic conductivity
[§]Residual (θ_r) and saturation (θ_s) soil moisture
[¶]Percent carbon
[#]Mean ± standard deviation (range in parenthesis)

Table 5-2. Hydrological time series used in the DFA.

Variable	Series Type	No. of series	Description
Θ_e	Response	12	Effective soil moisture (-) in the floodplain root zone
SWE	Explanatory	1	Surface water elevation in the river (m, NGVD29) measured 0.45 km upstream of the experimental transect
WTE	Explanatory	1	Water table elevation (m, NGVD29) measured on the experimental transect, 50 m from the river
SWE$_\kappa$	Explanatory	8	Capped SWE (m, NGVD29), see explanation in text
WTE$_\kappa$	Explanatory	8	Capped WTE (m, NGVD29), see explanation in text
R_{net}	Explanatory	1	Cumulative net recharge (cumulative rainfall – cumulative ET, mm) calculated from rain gauge at the S-46 structure and weather station in Jonathan Dickinson State Park (JDWX).

Table 5-3. Number of parameters, Nash-Sutcliffe coefficients of efficiency (C_{eff}), Akaike's information criteria (AIC), Bayesian Information Criterion (BIC), and Consistent Akaike's Information Criteria (CIAC) for selected dynamic factor models (DFMs). The best DFM for each model type are highlighted in italics (i.e., trends and no explanatory variables; trends and explanatory variables; and just explanatory variables).

DFM	Explanatory variables†	No. of trends	AIC	BIC	CIAC	C_{eff}	No. of parameters
Model I	0	1	15,585	16,140	16,215	0.61	75
	0	2	11,114	11,736	11,820	0.79	84
	0	3	7,459	8,140	8,232	0.83	92
	0	4	4,172	4,906	5,005	0.85	99
	0	*5*	*1,292*	*2,070*	*2,175*	*0.90*	*105*
	0	6	-1,949	-1,135	-1,025	0.91	110
	0	7	-3,625	-2,781	-2,667	0.93	114
	0	8	-4,603	-3,736	-3,619	0.95	117
	0	9	-6,214	-5,333	-5,214	0.97	119
Model II	2 (SWE, $WTE_{\kappa=3.10}$)	3	2,587	---	---	0.86	112
	3 (SWE, WTE, R_{net})	3	5,796	---	---	0.84	122
	3 (SWE, $WTE_{\kappa=3.00}$, R_{net})	3	2,724	---	---	0.88	122
	3 (SWE, $WTE_{\kappa=3.10}$, R_{net})	*3*	*331*	---	---	*0.90*	*122*
Model III	*3 (SWE, $WTE_{\kappa=3.10}$, R_{net})*	*0*	*11,188*	---	---	*0.79*	*40*

† SWE, surface water elevation at Lainhart Dam; WTE, water table elevation; $WTE_{\kappa=x}$, water table elevation capped at κ=x; R_{net}, net recharge

Table 5-4. Constant level parameters (μ_n), canonical correlation coeficents ($\rho_{m,n}$), factor loadings ($\gamma_{m,n}$), regression coefficients ($\beta_{k,n}$), and coefficients of efficiency from Model II ($C_{eff,n}$) and sigmoidal model ($C_{eff,sig}$). Significant regression parameters in bold.

		Canon. Corr. Coef.			Factor loadings			Regression coefficients				
s_n	μ_n	$\rho_{1,n}$	$\rho_{2,n}$	$\rho_{3,n}$	$\gamma_{1,n}$	$\gamma_{2,n}$	$\gamma_{3,n}$	$\beta_{SWE,n}$	$\beta_{WTE(\kappa=3.1),n}$	$\beta_{Rnet,n}$	$C_{eff,n}$	$C_{eff,sig}$
T1-60 (3.90 m)	-0.03	0.38	0.27	-0.03	0.08	0.02	-0.02	**0.81**	**-0.16**	-0.03	0.67	0.64
T1-60 (3.80 m)	-0.06	0.31	0.86	-0.01	-0.02	0.21	0.03	**0.41**	**-0.13**	**0.18**	0.98	0.72
T1-60 (3.60 m)	-0.05	0.14	0.16	0.74	-0.04	0.02	0.15	**0.24**	**0.50**	**0.08**	0.99	0.78
T1-50 (3.71 m)	0.03	0.30	0.46	-0.11	0.03	0.07	-0.02	**0.71**	**-0.10**	**0.24**	0.87	0.77
T1-50 (3.41 m)	-0.09	-0.32	0.48	0.17	-0.14	0.04	0.03	**0.50**	**0.20**	**0.29**	0.97	0.82
T1-50 (3.06 m)	0.00	0.17	0.18	0.32	0.01	0.03	0.03	**-0.05**	**0.93**	**0.04**	0.94	0.65
T1-30 (2.76 m)	0.24	0.11	-0.07	0.57	0.01	-0.01	0.06	**0.10**	**0.63**	**0.20**	0.93	0.54
T1-30 (2.51 m)	-0.04	-0.13	-0.36	0.34	0.01	-0.07	-0.03	-0.03	**0.93**	**0.03**	0.86	0.33
T1-1 (2.71 m)	0.07	0.48	0.12	0.46	0.06	0.05	0.11	-0.02	**0.63**	**-0.07**	0.89	0.51
T1-1 (2.46 m)	0.09	0.24	-0.32	0.32	0.06	-0.08	-0.02	**0.11**	**0.76**	**-0.11**	0.89	0.34
										Overall:	0.90	0.68

Table 5-5. Constant level parameters (μ_n), model parameters, and coefficients of efficiency (C_{eff}) from Model III (no trends, 3 explanatory variables) and empirical sigmoidal model ($C_{eff,sig}$). Significant model parameters in bold.

		Model parameters				
s_n	μ_n	$\beta_{SWE,n}$	$\beta_{WTE(k=3.1),n}$	$\beta_{Rnet,n}$	$C_{eff,n}$	$C_{eff,sig}$
T1-60 (3.90 m)	-0.04	**0.80**	**-0.15**	0.03	0.59	0.64
T1-60 (3.80 m)	-0.11	**0.78**	0.00	**0.20**	0.76	0.72
T1-60 (3.60 m)	-0.07	**0.27**	**0.72**	**0.00**	0.84	0.78
T1-50 (3.71 m)	0.03	**0.86**	**-0.17**	**0.23**	0.79	0.77
T1-50 (3.41 m)	-0.09	**0.69**	**0.21**	**0.13**	0.77	0.82
T1-50 (3.06 m)	0.00	0.01	**0.95**	**0.02**	0.93	0.65
T1-30 (2.76 m)	0.26	**0.05**	**0.72**	**0.27**	0.90	0.54
T1-30 (2.51 m)	-0.07	**-0.22**	**1.06**	**0.06**	0.82	0.33
T1-1 (2.71 m)	0.05	0.00	**0.75**	**-0.05**	0.73	0.51
T1-1 (2.46 m)	0.11	**-0.17**	**0.83**	0.02	0.78	0.34
				Overall:	0.79	0.68

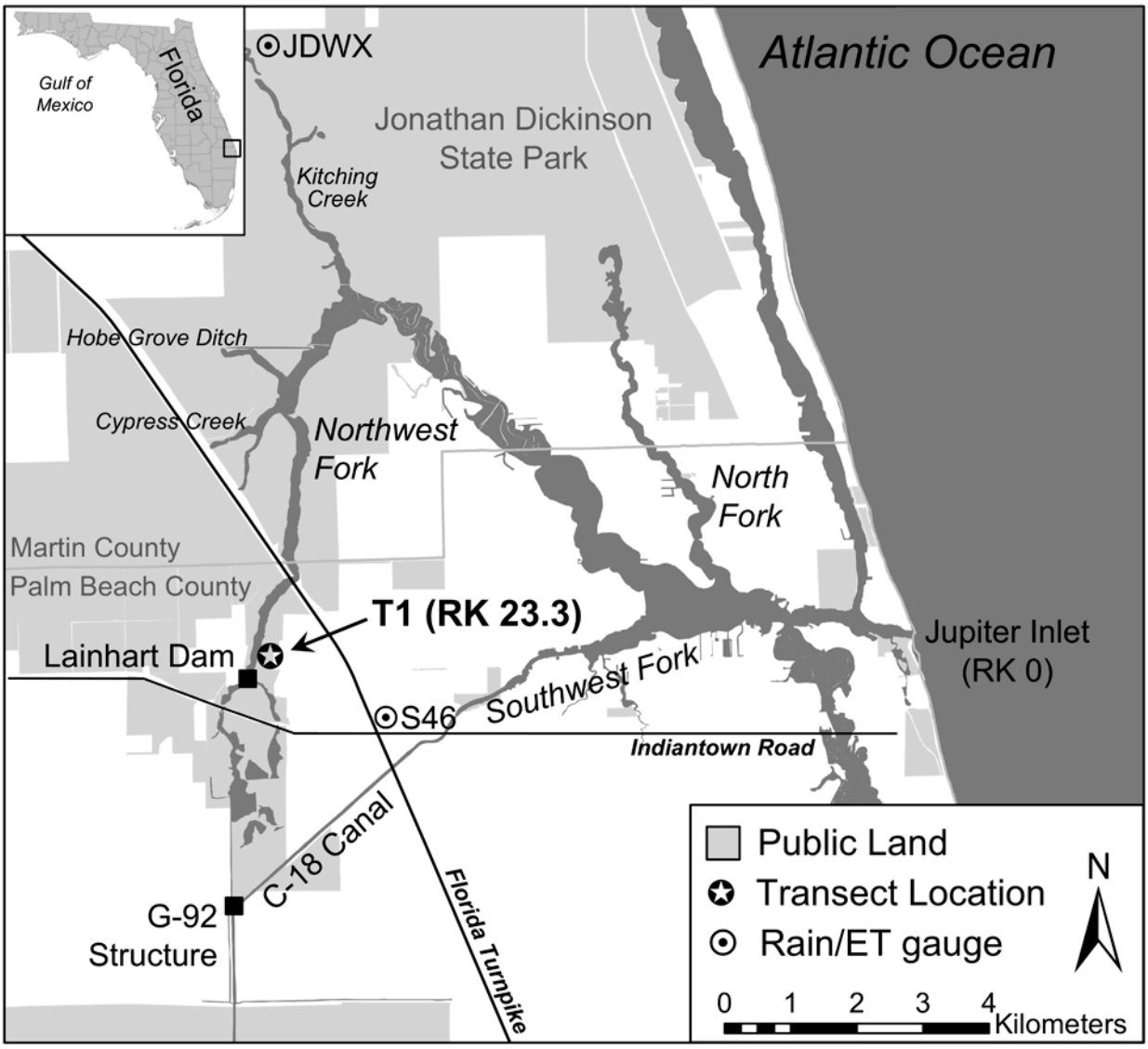

Figure 5-1. The Loxahatchee River and surrounding area with experimental transect (T1), meteorological measurement locations (JDWX and S46), and major hydraulic infrastructure. Distance from river mouth indicated by river kilometer, RK.

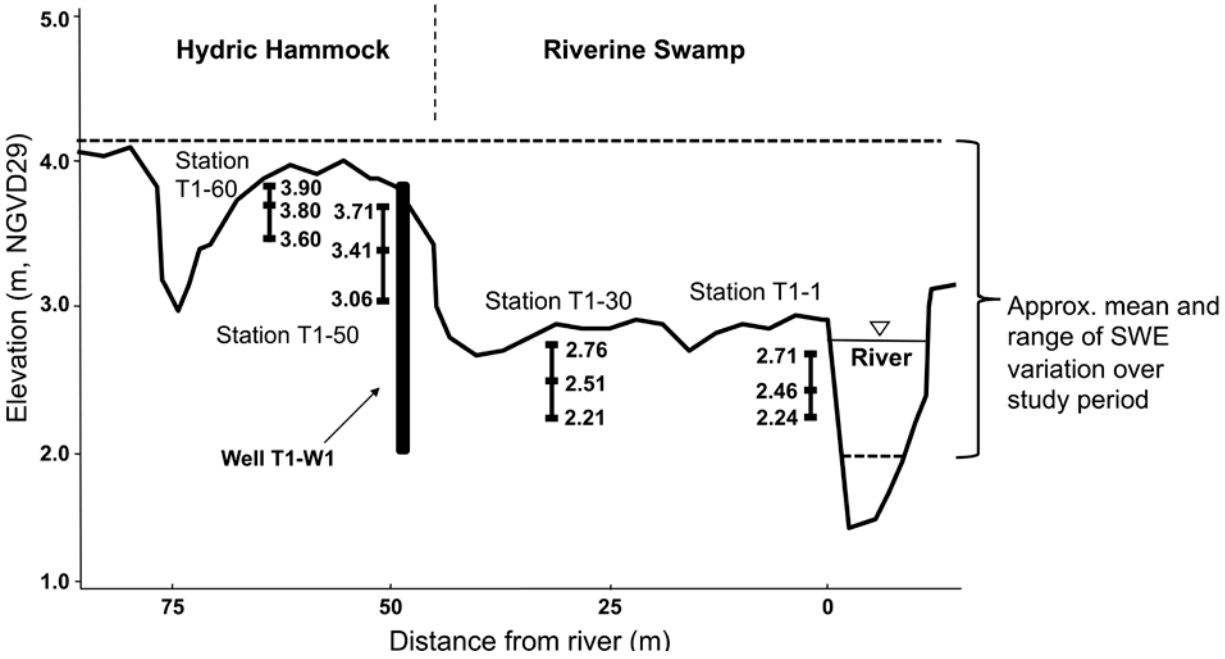

Figure 5-2. Topographic cross-section of experimental transect with layout of vadose zone and groundwater monitoring instrumentation. Station names denote transect name (T1) and distance from the river (m). Probe installation elevations (m, NGVD29) listed below each station. Vertical scale exaggerated ~10x.

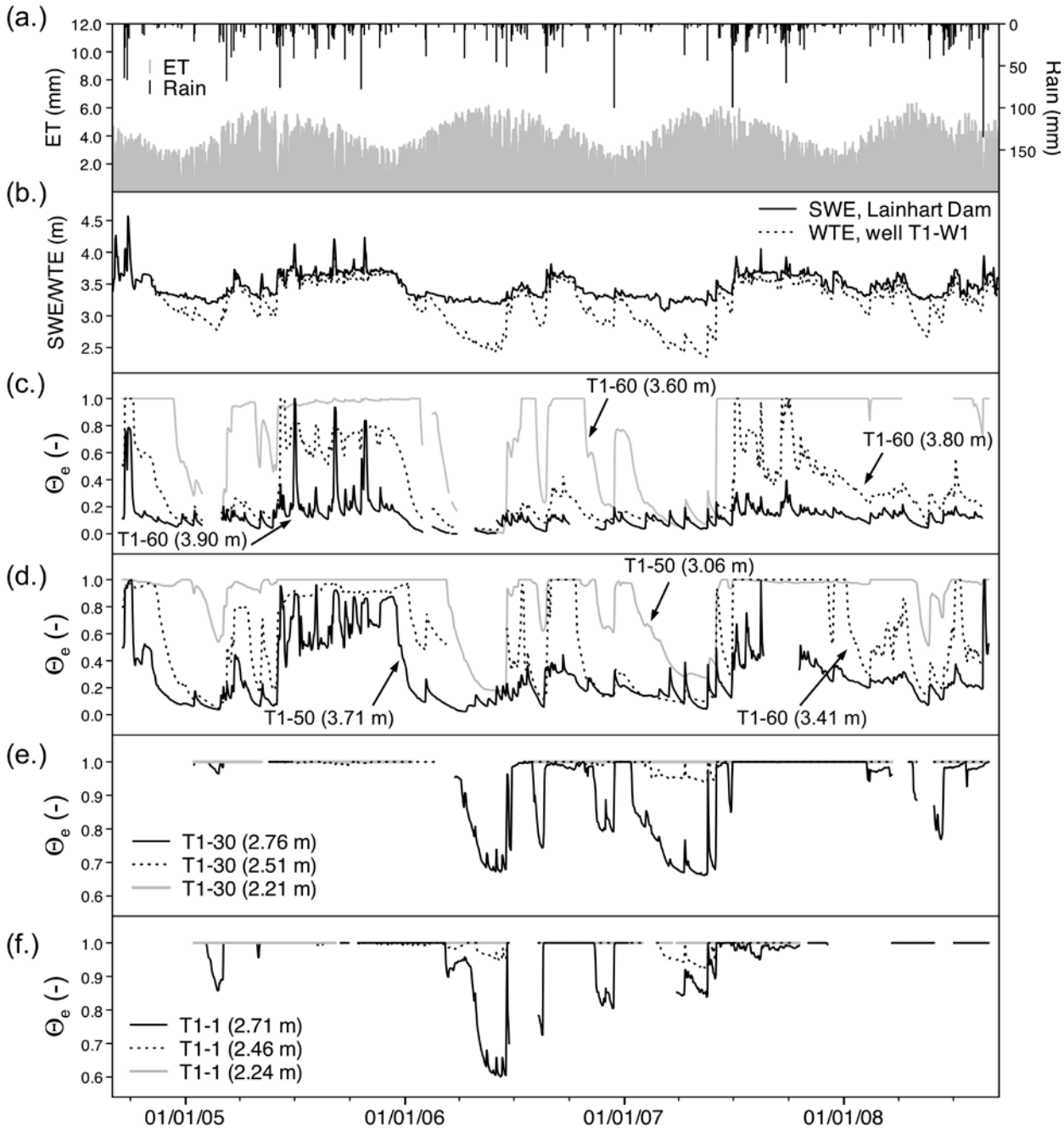

Figure 5-3. Precipitation, evapotranspiration (ET), surface water elevation (SWE), water table elevation (WTE), and effective soil moisture (Θ_e) measured in and around the experimental site. Θ_e series names indicate experimental transect 1 (T1), distance from river (m) and installation elevation (m, NGVD29)

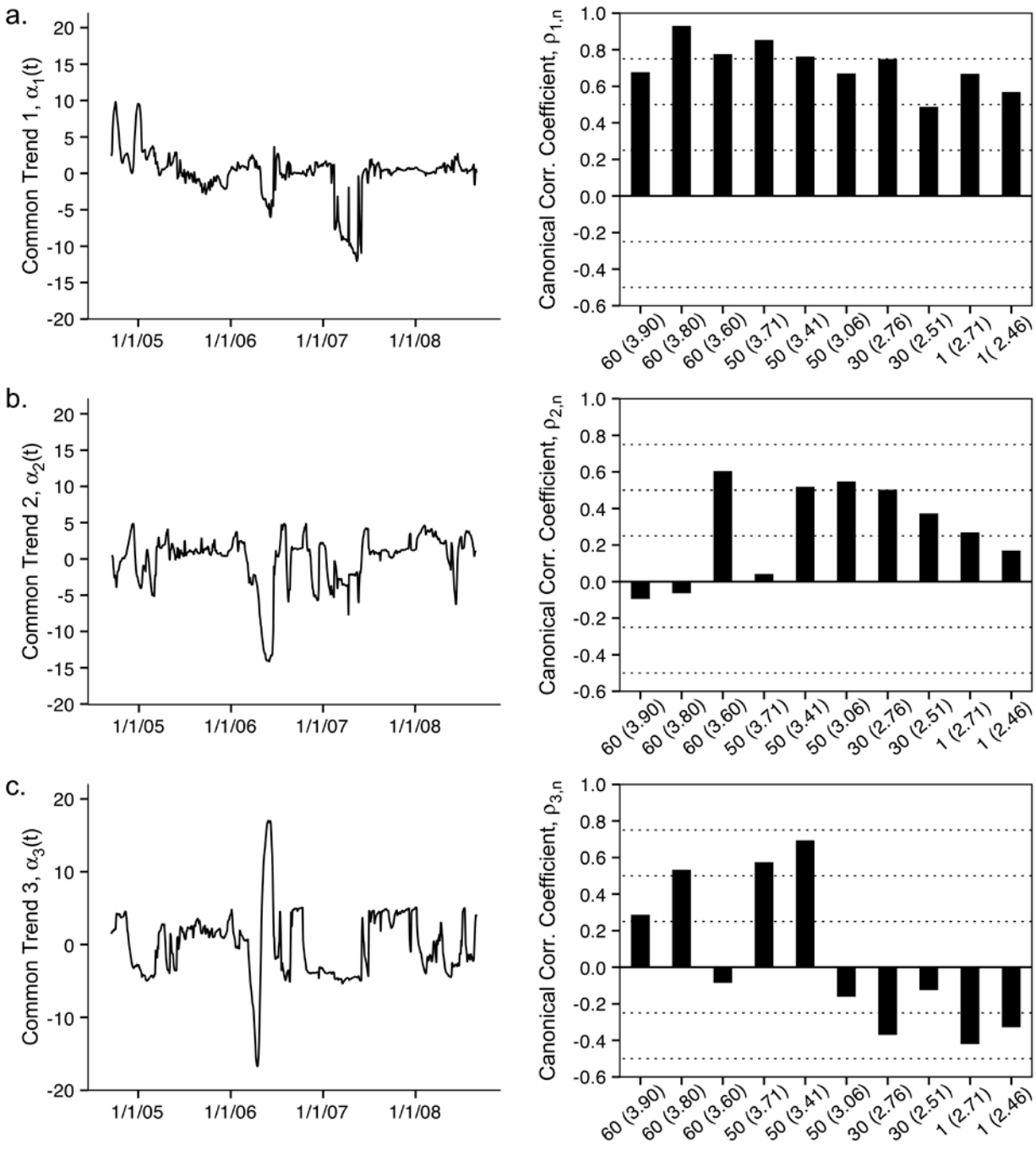

Figure 5-4. The three most important trends from Model I (left) and their associated canonical correlation coefficients (right). Trend 1 (a) has high or moderate correlations with all response series; trend 2 (b) is most associated with middle and lower elevation series; trend 3 (c) is positively correlated with the four highest elevation series and negatively correlated with lower elevation series.

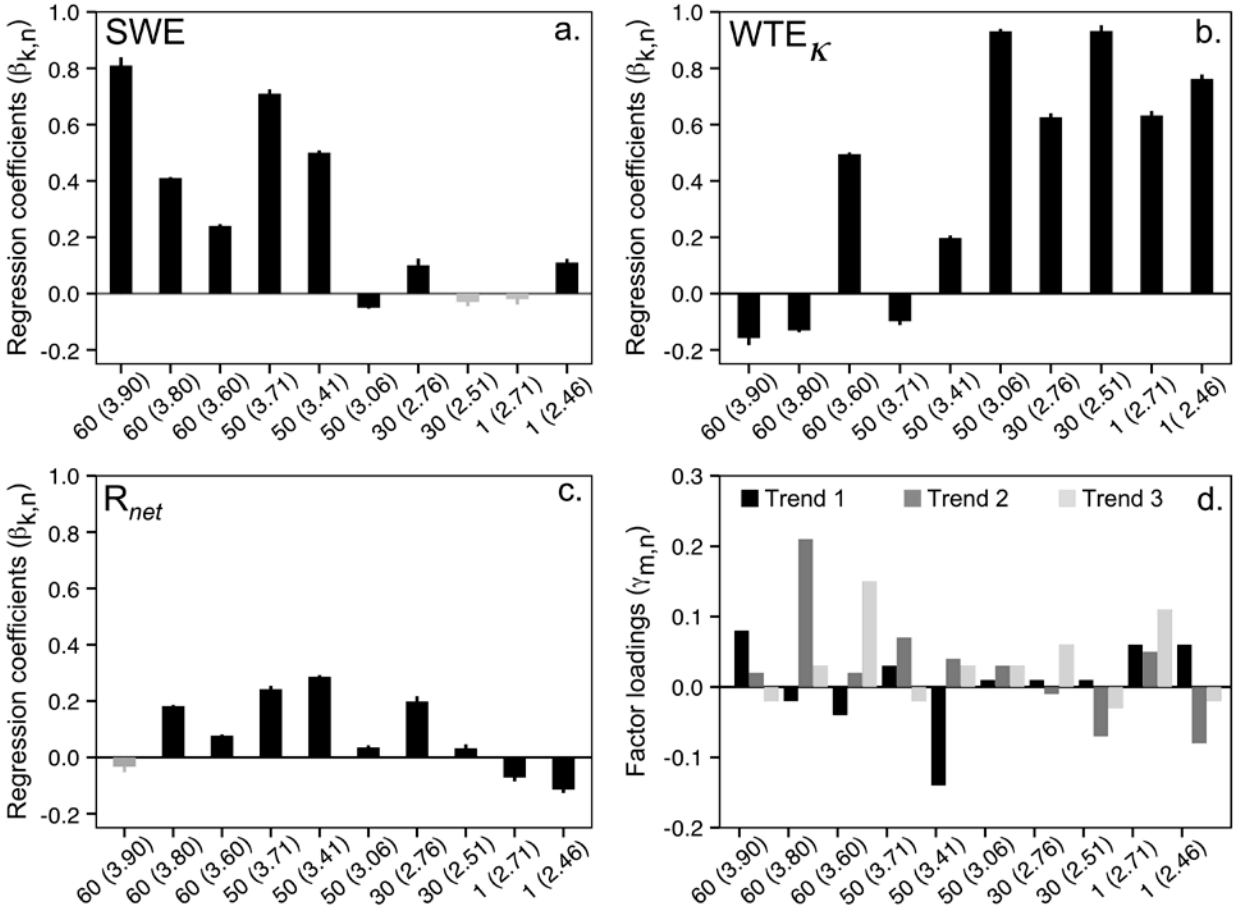

Figure 5-5. Regression parameters (a-c) and factor loadings (d) for Model II (3 common trends and 3 explanatory variables). Regression parameters (a-c) are shown with their standard errors, with black bars indicating significance. Note different y-axis scale on factor loadings panel (d).

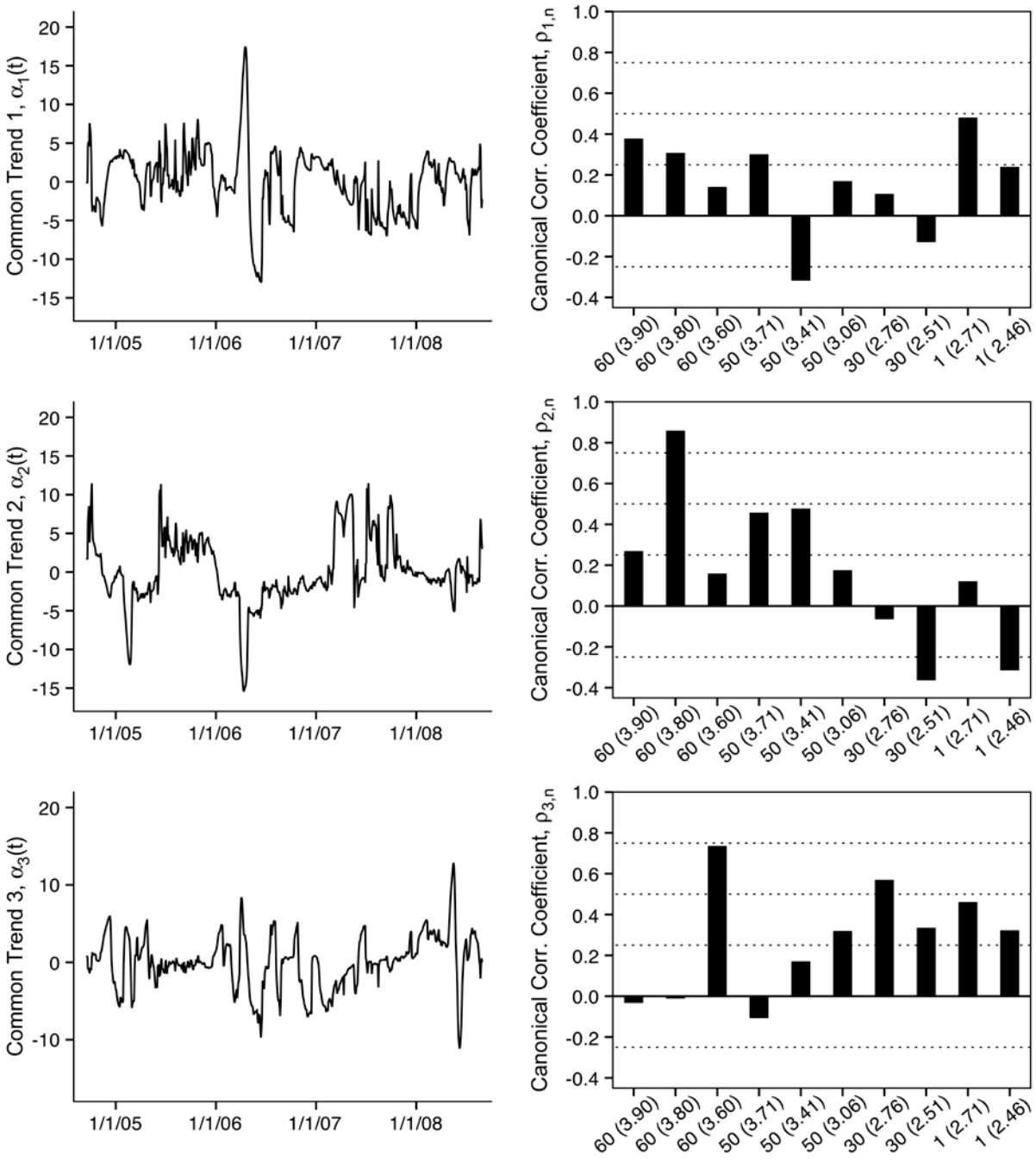

Figure 5-6. Common trends from Model II (left) and their associated canonical correlation coefficients (right).

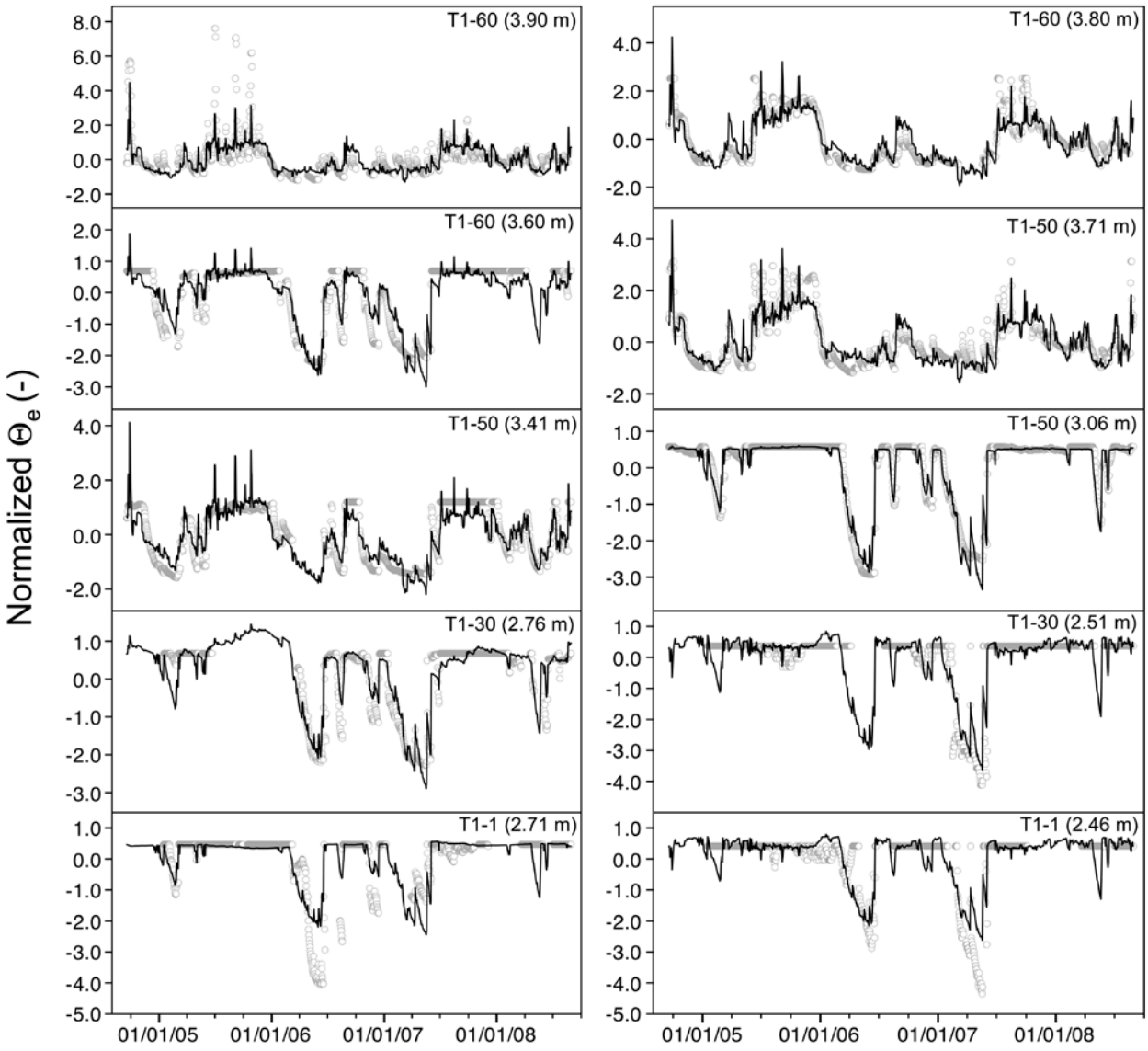

Figure 5-7. Observed (gray symbols) and modeled (black lines) normalized Θ_e for the ten response variables obtained from multilinear Model III using 3 explanatory variables and no common trends.

CHAPTER 6
A SIMPLE ECOHYDROLOGICAL MODEL TO ASSESS THE POTENTIAL FOR RESTORATION SUCCESS IN A DEGRADED BALD CYPRESS (*TAXODIUM DISTICHUM* [L.] RICH.) FLOODPLAIN SWAMP

Introduction

The Loxahatchee River is located on the southeastern coast of Florida, USA (26° 59' N, 80° 9' W; Fig. 6-1) and is often referred to as the "last free-flowing river in southeast Florida" (SFWMD, 2006). The river's three main branches (the North, Southwest, and Northwest Forks) join in a central embayment that connects to the Atlantic Ocean via Jupiter Inlet (Fig. 6-1), and in 1985, a 15.3-km stretch of the Northwest Fork (NW Fork) became Florida's first National Wild and Scenic River (National Park Service [NPS], 2004). Over the past century, however, watershed modifications for flood control and agricultural and residential development have reduced the effective size of the watershed from over 700 km2 to approximately 550 km2, reduced freshwater flow and wetland hydroperiod, and caused the intrusion of saline water upriver into historically freshwater ecosystems. Altered hydroperiods and encroaching salinity in the NW Fork have been linked to undesired changes in the vegetative composition of the floodplain, where studies have documented the upriver retreat of bald cypress (*Taxodium distichum* [L.] Rich.) since at least the turn of the 20th century (General Land Office [GLO], 1855; Alexander and Crook, 1975; McPherson, 1981; Ward and Roberts, 1996; Roberts et al., 2008). Of primary concern are: 1) the transition from bald cypress floodplain swamp to mangrove-dominated communities (primarily *Rhizophora mangle* L.) in the tidal floodplain as salinity increased; and 2) inadequate hydroperiod in the upstream riverine floodplain, which has shifted the

system towards drier plant communities (SFWMD, 2009). Further descriptions of the river's hydrological and ecological history are given in SFWMD (2002, 2006, 2009).

Despite these challenges, the Loxahatchee River has a high potential for ecological restoration (SFWMD, 2002, 2006; VanArman, 2005) for several reasons. Firstly, although the Loxahatchee River is located in an increasingly urbanized landscape (SFWMD, 2002; Zwick and Carr, 2006), its watershed includes several large, publicly owned areas including Jonathan Dickinson State Park (JDSP), the Loxahatchee Slough and Grassy Waters Preserves, and the J.W. Corbett Wildlife Management (among others; Fig. 6-1). Thus, future land use planning for a large portion of the watershed lies with local and state agencies. Secondly, the health of the Loxahatchee River and its adjacent ecosystems is a priority for many residents, visitors, agencies, and political leaders. As such, several protection and restoration planning efforts have been initiated over the past twenty years, including the Loxahatchee River National Wild and Scenic River Management Plan, the North Palm Beach County Comprehensive Everglades Restoration Plan (CERP) Project, and the Minimum Flow and Levels (MFL) Rule, which requires Florida's Water Management Districts to protect ecological and water resources from "loss of water resource functions which result from a change in surface or groundwater hydrology that takes more than two years to recover" (Section 373.042[1], Florida Statues). Finally, although halting saltwater intrusion due to climate change-induced sea-level rise is beyond the scope of local management (i.e., at the global scale), much of the ecological change observed in the Loxahatchee River has been attributed to local, anthropogenic drivers (SFWMD, 2006). Thus, some amount of restoration and management is likely achievable (e.g., Scruton, 1992)

Intensive data collection and modeling efforts in support of management and restoration planning for the Loxahatchee River have been underway for several years (SFWMD, 2002, 2006, 2009; VanArman et al., 2005; Mortl, 2006; Muñoz-Carpena et al., 2008, Kaplan et al., 2010a,b). In 2006, the SFWMD released a Restoration Plan for the Northwest Fork of the Loxahatchee River ("Restoration Plan"; SFWMD, 2006), which proposed a preferred restoration flow scenario (PRFS) based on evaluations of the anticipated ecological effects of several flow scenarios to each of the following zones and associated valued ecosystem components (VECs): riverine floodplain (bald cypress swamp and hydric hammock); tidal floodplain (mangrove swamp); low salinity zone (fish larvae); mesohaline zone (oysters); and polyhaline zone (sea grasses).

Like most hydrological monitoring and modeling efforts initiated in support of wetland restoration (e.g., Wang, 1987), the Restoration Plan focused on surface water performance measures (PMs) for VECs (i.e., hydroperiod and surface water salinity), but did not explicitly consider hydrological conditions in the vadose (unsaturated) zone, which largely dictate seed germination and seedling survival for many floodplain wetland plant species (Middleton, 1999). For example, the PM identified for bald cypress swamp in the Restoration Plan is a hydroperiod of 4 to 8 months. While the Restoration Plan notes that "during the dry season, water levels…will drop and allow cypress seed germination" and "…the occasional very dry season will provide good conditions for freshwater tree seedling and sapling production and germination to rebuild the forest…" (SFWMD, 2006), germination and recruitment are not directly addressed. Additionally, while thorough in its evaluation of impacts to VECs across the river's four distinct aquatic environments (freshwater, oligohaline, mesohaline, and

polyhaline), analysis of the likely impacts of restoration scenarios on floodplain vegetation was limited in spatial extent. For example, impacts to bald cypress swamp and hydric hammock were evaluated along a single vegetation transect (Transect 1 [T1]; Fig. 6-1), and changing salinity regimes with distance from the river towards the upland were not considered.

The ecohydrological modeling effort described here draws on hydrological and water quality monitoring and modeling results used in the Restoration Plan—adding vadose zone relationships and a spatially-distributed framework—with the goal of assessing the long-term impacts of management decisions on vegetative communities. In this chapter, the concepts and structure used to develop this initial model (EcoLox v1.0) are introduced, and the model is used to compare the effects of restoration scenarios described in the SFWMD Restoration Plan. While still a preliminary tool, the EcoLox model can serve as a platform for future analyses to improve our understanding of how other long-term, stochastic scenarios—sea-level rise, hurricanes, fire, and frost—will impact restoration efforts for the NW Fork of the Loxahatchee River.

Materials and Methods

Modeling Concept

Hydrological regime is often the primary environmental sieve (Harper, 1977) controlling seed germination, seedling recruitment, and long-term maintenance of plant species and communities, particularly in wetlands (van der Valk, 1981). Accordingly, ecological restoration efforts in wetlands are usually built upon a foundation of hydrological restoration, whereby historical hydrological regimes and connections are reestablished in order to provide well-timed freshwater flows (Middleton, 2002), nutrients (Junk et al., 1989), and (where appropriate) the sediment required for

accretion (DeLaune et al., 1994). Applying the environmental sieve concept to the NW Fork is helpful for assessing the potential for restoration success.

The NW Fork of the Loxahatchee River can be broken into three reaches based on hydrology, soils, and vegetation (SFWMD, 2006; modified from USGS 2002): riverine, upper tidal, and lower tidal. In the upstream, riverine reach of the NW Fork, the chief ecological consequence of altered watershed hydrology has been the conversion of bald cypress swamp and hydric hammock to drier vegetation communities due to insufficient hydroperiod and moisture regime (SFWMD, 2006). Bald cypress seeds are dispersed primarily by water (Schneider and Sharitz, 1988; Middleton, 1999), and are relatively short-lived, with less than 40% of seeds remaining viable after 100 days and less than 5% remaining viable after 1 year (Middleton, 2000). Seeds settle along drift lines after floodwaters recede and require moist, but not saturated conditions to germinate (Middleton, 2000). Due to this requirement, Middleton (2000) found that the zone of germination is limited to areas that draw down during the growing season, a "rare and unpredictable event in the Southeast" (IFAS, 2004). At the other end of the moisture regime, seeds will not germinate on well-drained soils due to lack of surface moisture. Thus, a drawdown of flooded soils to a saturated condition is required for germination (Burns and Honkala, 1990; Middleton 1999, 2002). Seedlings must also grow fast enough to keep their crowns above floodwaters for most of the growing season to survive (Conner, 1988; Conner et al., 1986, 1987).

Given these specific life-cycle requirements, the restoration of bald cypress floodplain swamp in the riverine reach of NW Fork relies on a series of environmental sieves to maintain mature bald cypress floodplain swamps and achieve periodic

recruitment. To facilitate germination from existing seed banks and extant populations, restoration flows must ensure an appropriate soil moisture regime when seeds are available for germination. Restoration flows must also provide the appropriate hydroperiod to allow seedlings to grow tall enough to avoid overtopping by floodwaters for extended periods while young. Finally, restoration flows must provide an overall maintenance hydroperiod to prevent transition to a shorter hydroperiod vegetation community such as bottomland hardwood swamp—dominated by red maple (*Acer rubrum* L.), buttonbush (*Cephalanthus occidentalis* L.), swamp bay (*Persea palustris* [Raf.] Sarg.), and other flood-tolerant hardwoods—over the long term. On the other hand, species that make up the hydric hammock community—i.e., cabbage palm (Sabal palametto [Walter] Lodd. ex Schult. & Schult. f.) and swamp laurel oak *(Quercus laurifolia* Michx.)—do not require the same distinct flooded-to-drawdown hydrology to achieve good recruitment years, but are generally characterized by 30 to 60 days of yearly inundation (Roberts et al., 2006).

In the upper tidal reach of the NW Fork, the primary ecological consequence of altered watershed hydrology has been the conversion of bald cypress swamp to mangrove swamp due to saltwater intrusion caused by reduced freshwater flow. Bald cypress seeds and seedlings have limited salt tolerance (Allen et al., 1996) and the combined negative effects of flooding and salinity are greater than either alone, and are more pronounced at higher salinities. A general bald cypress seedling salinity tolerance threshold of 2 parts per thousand (ppt) has been established by Liu et al. (2006) using seedlings collected from the study area. This is in agreement with Chabrek (1972) who found that bald cypress stands rarely occur naturally in areas with salinity exceeding

1.98±1.40 (std) ppt and Wicker et al. (1981) who concluded that bald cypress forests are limited to areas where salinity does not exceed 2 ppt greater than 50% of the time that trees are inundated.

Building on these findings, Zahina (2004) proposed a characteristic salinity regime (Ds:Db ratio), defined as the ratio of the average length of salinity "events" (consecutive days above a critical salinity threshold; Ds), divided by the average length of time between these events (Db). Zahina found the surface water Ds:Db ratio calculated with a critical salinity value of 1 ppt correlated well with floodplain vegetation in the NW Fork, with a Ds:Db ratio > ~0.3 indicating a transitional point between freshwater and salt-tolerant vegetation. While monitoring and modeling of surface water salinity (SWS) in the Loxahatchee River described the long-term salinity dynamics in the river channel, they did not fully explain the observed zonation of vegetation in the upper tidal floodplain, which changes from salt-tolerant mangrove swamp at the river's edge to bald cypress swamp closer to the floodplain-upland border (SFWMD, 2009). Groundwater salinity (GWS) was also a poor indicator of floodplain vegetation (Kaplan et al., 2010b). On the other hand, porewater salinity (PWS) in the root zone did a better job of explaining the distribution of freshwater and salt-tolerant plant species in the upper tidal reach (Kaplan et al., 2010a). Thus, we used relationships between SWS and PWS developed in the Loxahatchee River floodplain (see Kaplan et al. [2010a] and vadose zone section, below) to calculate the porewater Ds:Db ratio (after Zahina, 2004) and used this metric to assess the potential for restoration success. We tested different values of the porewater Ds:Db ratio porewater and CritSal by comparing spatial distribution of the Ds:Db ratio with observed vegetation on T7 (SFWMD, 2009). We

found the best representation of floodplain vegetation at this location using CritSal = 3 ppt, with a Ds:Db ratio of 0.12 indicating a transitional point between freshwater and salt-tolerant vegetation.

In general, soils in the floodplain in the upper tidal reach of NW Fork do not experience significant drawdown beyond saturated conditions, but are subject to inundation with tidal floodwaters of varying salinity much of the time (Kaplan et al., 2010a). For example, a large number of bald cypress seedlings were observed on T7 (Fig. 6-1) in late 2003 and early 2004, but had died by August 2004 (SFWMD, 2006), although it is unclear whether their mortality was caused by extended overtopping, high salinity, or a combination of the two. Thus the restoration of bald cypress floodplain swamp in the upper tidal reach of NW Fork relies on the maintenance of appropriate hydroperiod, and salinity conditions to allow for periodic recruitment events. Finally, vegetation in the lower tidal reach of the NW Fork is dominated by red and white mangroves (*Laguncularia racemosa* [L.] Gaertn.f.) due to high salinity and high tidal surface water elevation (SWE) relative to floodplain elevation. In this reach, restoration of historic freshwater communities is likely impossible, even with large increases in freshwater flow, since germination and recruitment would still be limited due to low elevations and projected sea-level rise.

Based on these ecohydrological relationships, the EcoLox model predicts the most likely vegetation communities by keeping track of long-term inundation, moisture, and salinity conditions in the floodplain and assessing their effects on vegetation (i.e., germination, recruitment, and survival). While the model represents the effects of hydrology and salinity on seeds and seedlings—and thus keeps track of “seeds” and

“seedlings”—it is not a population model, but fundamentally a habitat suitability model (e.g., review in Sklar et al., 2001). The Restoration Plan recognizes a total of sixteen floodplain ecological communities across the riverine, upper tidal, and lower tidal reaches of the NW Fork (delineated based on canopy tree species; modified from Darst et al. [2003]), separating areas of red and white mangroves, for example. For simplicity in assessing restoration impacts, EcoLox 1.0 considers five floodplain ecological community types based on hydrological and water quality conditions: upland, hydric hammock, bottomland hardwood forest (BLH forest), bald cypress swamp, and mangrove swamp. Additional community types (i.e., tidal hammock or mixed tidal) can easily be added by refining performance measures in the HABITAT subroutine of the EcoLox model (see subsequent sections).

Model Domain

The model domain includes the river floodplain and adjacent upland and was created by overlaying classified GIS maps of historic floodplain vegetation (SFWMD, 2006) over a recent Light Detection and Ranging (LiDAR) raster (1.524 m [nominally 5 ft] resolution; data acquired from SFWMD staff). A preliminary QA/QC of the LiDAR dataset using field-surveyed benchmarks at the landward end of vegetation transects revealed a consistent bias, with an average overestimation of approximately 20 cm. Accordingly the raw LiDAR data was adjusted by -20 cm. Next, a floodplain vegetation map drawn from interpretation of 1940 aerial photography (data acquired from SFWMD staff) was buffered 50 m on all sides and the LiDAR raster was clipped to this buffered layer, converted from ft to m and re-sampled at 10 m resolution in ArcInfo (ESRI, Redlands, CA) using the cubic convolution method. Distance to the river from each grid in the model domain was calculated using the straight-line distance tool in Spatial

Analyst with the river as the target and an output size of 1.254 m. The centerline of the Loxahatchee River was represented as a line shapefile using publically-available surface water feature layers for Martin and Palm Beach Counties (Florida Geographic Data Library, University of Florida GeoPlan Center; accessed at accessed at www.fgdl.org), modified based on visual inspection of digital orthophoto quarter quadrangle (DOQQ) and LiDAR images. The resulting elevation and distance to river grids were converted to shapefiles and linked using a spatial join.

In order to apply the results of simulated hydrology and water quality across the EcoLox model domain, the river was classified into 29 sub-reaches (including tributaries) of ~200 to 500 m, and each model grid was assigned to a sub-reach. The riverine and tidal reaches of the NW Fork were broken into 14 and 15 sub-reaches, respectively, and tributaries were assigned to nearby sub-reaches of the NW Fork with similar elevations. Finally, where the river width was discernable from DOQQs (downstream of ~RK 17), its footprint was removed from the domain (the river is less than 10 m wide in the upstream, riverine portion of the NW Fork but widens to ~80 m in the downstream, lower tidal reach). The EcoLox model domain contained 46,697 cells, each containing elevation, distance to river, and reach number.

General Model Structure and Logic

A flowchart of the EcoLox model structure is given in Fig. 6-2. The model was written in the FORTRAN 77 programming language and developed in the XCode programming environment (v. 3.2.1, Apple, Inc., Cupertino, CA). The model runs from the UNIX command line from a project file (*.prj) that defines the input files to be used in the simulation (input and output files are described in the following section). EcoLox runs on a daily time step over a user-defined interval and performs operations in each of

the model cells, which are independent (i.e., cells do not have spatial relationships with other cells). Model subroutines and logic are summarized below. Source code is provided in Appendix B.

Initial subroutines

The FINPUT, INPUTS, INI, and INICALC subroutines are performed once at the initiation of a model run (green boxes in Fig. 6-2). FINPUT sets up command line operation and defines input and output files. The INPUTS subroutine structures the time series over which the model is run (e.g., calculates leap years, beginning and ending days of each year, etc.), reads the input files specified in the .prj file into model variables, and writes these values to an output file. The INI subroutine sets appropriate variables and arrays to their initial values (usually zero).

INICALC performs initial calculations that are used across years and cells throughout the model, including setting seedling growth parameters, seed availability, and calculating porewater salinity time series (see calculation details in vadose zone section). Bald cypress seedlings reach heights of 20 to 75 cm their first year of growth (Bull, 1949) and their rate of growth is seasonally dependent (i.e., they grow faster in spring and summer, slower or not at all in fall and winter). To account for variable seasonal and interannual growth rates, we applied seasonal seedling growth rates after Liu et al. (2006), which were randomly set for each simulation year between minimum and maximum values from the literature (Table 6-1). Examples of minimum and maximum seedling growth over one year (along with field data collected from seedlings in the Loxahatchee River by Liu et al. [2006]) are shown in Fig. 6-3. While the growth functions applied here are simple, we recognize the importance of a number of other factors on seedling growth (hydroperiod, salinity, nutrients, and shade, for example) and

the modular design of EcoLox allows for simple modifications or substitutions to these algorithms in future versions.

The potential for seed germination is limited not just by moisture and hydroperiod, but also by the availability of seeds, which is also variable between years and seasons. In south Florida, bald cypress seeds drop in early fall (Brown, 1984) and are viable for only a short period (Middleton, 2000). Thus, we model seed availability as a function of month, with seed availability probabilities (Table 6-1) based on an exponential decay in seedling availability after seed drop (modeled after seed viability field data in Middleton [2000]). For example, the likelihood of seed availability is highest in October (95%) and quickly declines (Table 6-1). Monthly probabilities of seed availability are tested against a random number to determine seed availability each year, and the resulting time series of seed availability is stored in an array. The NEWCELL and NEWYEAR subroutines reset appropriate model variables and arrays when switching between cells and years, respectively.

Period of record subroutines

After these initialization subroutines, EcoLox moves into loops for cells, years, and days, and is structured such that it performs calculations over the entire period of record (POR) in each cell before moving to the next cell. Within each year, EcoLox uses input and calculated data to determine inundation (INUND), salinity (SALINITY), germination (GERMINATION), and seedling growth (SEEDLINGGROW) conditions. In the INUND subroutine, SWE in the reach assigned to each cell is used to calculate water depth. If water depth is greater than zero, the cell is inundated and the number of days and consecutive days of inundation in the current year are incremented (if not inundated, days of consecutive inundation is set to zero). Next, the SALINITY subroutine

calculates the number of days/consecutive days that the critical salinity threshold (CritSal; Table 6-1) is exceeded in porewater and surface water and stores records of all salinity events for calculation of the surface water and porewater D_s:D_b ratios at the end of the POR.

The number of days and consecutive days of moist soil conditions are calculated in the GERMINATION subroutine based on SWE and the vadose zone relationships developed in Kaplan et al. (2010a) (see vadose zone section). The cell can also be moist if the daily rainfall is greater than the threshold daily rainfall depth required for moist surface soil conditions under otherwise low SWE conditions (CritRainDepth). If the number of consecutively moist days is equal to or greater than the number of days of favorable germination conditions required to induce seed germination (CritConsecGermDays) and salinity < 1 ppt, then the cell has good germination conditions. If salinity is greater than 1 ppt, germination likelihood is reduced according to the seedling germination studies of Krauss et al. (1998) who found germination to decrease with increasing salinities, with mean germination rates of 26.3%, 22.9%, 15.4%, and 10.2% based on salinity treatments of 0, 2, 4, and 6 ppt, respectively (Fig. 6-4).

Next, if seeds are available and germination conditions are good, a “germination event” occurs and the SEEDLING subroutine initiates seedling growth based on seasonal seedling growth rates calculated at the beginning of the year. A germination event does not specify the *number* of seeds that germinated, but indicates that the hydrological conditions were favorable for seed germination. Similarly the resulting “seedling” does not represent one (or more) seedlings, but represents a “seedling

event," which may be thought of as a cohort of seedlings. As such, a new cohort is initiated for each day with a germination event. For simplicity, hereafter we refer to these seedling events as "seedlings."

Within each cell, a seedling array keeps track of each seedling's age, height, the number of days it is submerged (i.e., SWE > seedling height), and the number of salt-days (i.e., the cumulated magnitude of salinity above CritSal, a metric that allows for dynamic salinity conditions; Table 6-1) that seedlings accumulate during their first and second years. The subroutine "grows" the seedlings for two years, and thus there are between zero and 730 seedlings in the array at any one time. If seedlings reach an age two years without having been overtopped longer than the critical thresholds or accumulating too many salt-days in both their first and second years, a "recruitment event" is recorded for the cell in the current simulation year. Splitting accumulated stresses into seedlings' first and second years allows for the simulation of the increased sensitivity of younger seedlings to flooding and salinity stresses (e.g., Souther and Shaffer, 2000).

Summary and reporting subroutines

At the end of the last simulation year, the OUTMAP subroutine writes yearly records of days/consecutive of inundation, salinity, moisture, germination, and recruitment conditions to output files. Finally, the HABITAT subroutine sets the likely habitat type for each cell based on the long-term records written in OUTMAP. EcoLox uses long-term hydroperiod and the porewater D_s:D_b ratio as the primary indicators of likely habitat type. For hydroperiod, we use the PMs identified in the Restoration Plan (SFWMD 2006) for bald cypress swamp (180 to 365 days of continuous inundation per year) and hydric hammock (30 to 60 days of inundation per year). Cells inundated less

than 30 days in a year are considered upland, and cells with 61 to 179 days of inundation are considered BLH forest. For salinity, we used a porewater D_s:D_b ratio of 0.12 (calculated with CritSal = 3 ppt) as the transitional point between freshwater and salt-tolerant vegetation.

The HABITAT subroutine begins by reading the number of continuous inundation days in each year and assigning the yearly value to a hydroperiod type (1 for upland; 2 for hydric hammock; 3 for BLH Forest; and 4 for bald cypress swamp) based on the hydroperiod PMs described above. The cell is then assigned a habitat type based on the most common hydroperiod type experienced over the POR (i.e., the mode of the yearly hydroperiod types). Next, the habitat values are modified by long-term salinity conditions in the cells. Cells with a Ds:Db ratio > 0.12 and habitat type of bald cypress based on inundation are modified to mangroves. Future versions may include additional categories and combinations of salt and hydroperiod (i.e., mixed tidal and tidal hammock). Finally, for cells that are predicted to have bald cypress habitat, the HABITAT subroutine reads yearly germination and recruitment records from the OUTMAP subroutine and calculates the total number of years with at least one germination and recruitment events (i.e., each cell with bald cypress will have from zero to 40 germination years and zero to 40 recruitment years).

Input Files and Data

The EcoLox model runs on a set of four user input files detailing: 1) global model parameters (.igp file); 2) a rainfall time series (.irn file); 3) surface water elevation (SWE) time series for each river reach (.isw file); and 4) surface water salinity (SWS) time series for each river reach (.iss file). Keeping parameters as user-input variables allows us to update the model as new information becomes available and to perform sensitivity

and uncertainty analysis on the model given the known range and uncertainty of input parameters (e.g., Muñoz-Carpena et al., 2007). Input file structure and the specific input data used in this analysis are described below.

Parameters required in the *.igp file are summarized in Table 6-1 along with default parameter values selected from the literature or expert opinion. These include information about the model domain (i.e., number of cells, number of river reaches); length of the simulation; and parameters describing seed availability, seedling growth, and critical salinity thresholds. The *.irn data file contains daily rainfall data over the POR. For this analysis, hourly rainfall data used as an input to the WaSh model were collected from a gauging station in Jonathan Dickinson State Park (Fig. 6-1) and converted to daily sums for this study (data acquired from SFWMD staff).

The *.isw and *.iss files contains daily SWE and SWS data for each river reach. Several hydrological models have been developed to support the development of the MFL and Restoration Plan for the NW Fork, including a watershed-scale model of freshwater inflows, hydrodynamic and salinity models of surface water elevation and salinity, and a long-term salinity management model that integrated watershed and hydrodynamic model results for use in assessing proposed restoration scenarios. We used selected outputs from these models as inputs to the EcoLox model as described below.

Surface water elevation

SFWMD staff used a restructured version of the Hydrologic Simulation Program-Fortran model (HSPF) (Donigian et al., 1984) to simulate freshwater inflows to the NW Fork from the contributing watershed (the WaSh model). WaSh was implemented using hydrography, 2000 land use, soil, and the 0.308-m (nominally 1-ft) contour. Rainfall and

evapotranspiration (ET) data from 1965 to 2004 were used to calibrate and validate the model. A complete description of model structure, calibration, and validation process is given in SFWMD (2006). After calibration and validation, the model was used to create a long-term simulation of daily freshwater flows into the NW Fork over a 40-year period of record from 1965 to 2003 (POR).

From these simulations, we used modeled flow at Lainhart Dam (Fig. 6-1) to calculate SWE at transect locations in the riverine portion of the river (from Lainhart Dam downstream to T4; Fig. 6-1) using flow-stage relationships developed for the dam itself (Fig. 6-5a); in support of the restoration plan (Fig. 6-5c,d,f); and from subsequent field monitoring (Fig. 6-5b,e; SFWMD, unpublished data). In the reaches between transect locations, SWE was interpolated linearly based on the river distance between reaches.

Below T4 (~RK 18), SWE is increasingly influenced by tidal forcing and loses strong dependence on upstream inputs of freshwater flow. SWE in these reaches was not modeled over the long term for restoration planning efforts, nor were measured data available prior to 2004. Furthermore, while the effect of upstream flows diminishes with distance towards the river outlet, predicted tides (based on NOAA's long-term harmonic tide predictor algorithm) do not incorporate the effects of variable upstream flows (which can be important during large storm events, for example) and are not gauged to a local datum. In order to simulate SWE in these reaches over the 39-year POR, we developed a multilinear model of daily maximum tidal SWE as a function of upstream flow and the predicted tide of the form:

$$SWE = \alpha * SWE_{NOAA} + \beta * \text{LD Flow} + \gamma \qquad (6\text{-}1)$$

where SWE is surface water elevation (m, NAVD88); SWE_{NOAA} is the predicted tide (meters above mean low water over the 19-year tidal epoch); LD Flow is the modeled flow over Lainhart Dam ($m^3\ s^{-1}$); and α, β, and γ are fit parameters. Using Equation 6-1, we estimated SWE at three locations where measured tidal SWE were available after 2004: the downstream limit of the model domain at RK 10.5; at the outlet of Kitching Creek (RK 13.1); and at RK 14.6 (Fig. 6-1). We chose to model maximum daily tidal SWE in order to best represent the inundation of the floodplain due to twice-daily tidal flooding. The model simulated the measured data well (Figs. 6-6a-c) and was used to estimate long-term tidal SWE series. SWE in reaches between modeled locations was interpolated linearly and the modeled tidal SWE successfully predicted the number of days that each cell was inundated from 2004 to 2008 (Fig. 6-7).

Surface water salinity

With freshwater inflows from the WaSh model as inputs, SFWMD staff used the RMA-2 and RMA-4 models (USACE, 1996) to calculate surface water elevation and salinity conditions. RMA-2 is a 2-D, depth-averaged hydrodynamic model that computes water surface elevations and horizontal velocity components using a finite element solution of the Reynolds form of the Navier-Stokes equations for turbulent flows. Solutions from RMA-2 were used as inputs to RMA-4 to calculate salinity distributions. After calibration and verification (SFWMD, 2006), RMA-4 was used to simulate salinities in the NW Fork under twelve freshwater flow scenarios ranging from 1.13 to 198.21 $m^3\ s^{-1}$ (nominally 40 to 7000 $ft^3\ s^{-1}$), based on simulations from the WaSh model. Regression of the freshwater flow versus salinity relationship revealed a strong

exponential relationship, allowing estimation of depth-averaged surface water salinity as a function of freshwater inflow and location in the river of the form:

$$Y = Y_0 + ae^{-bx} \quad (6\text{-}2)$$

where x is total freshwater flow ($ft^3\ s^{-1}$) to the NW Fork from Lainhart Dam and from three tributaries (Kitching Creek, Cypress Creek, and Hobe Grove Ditch; Fig 6-1), Y is salinity (ppt), and Y_0, *a*, and *b* are parameters. The SFWMD developed these relationships for 15 locations from ~RK 1.1 to ~RK 14.6. To apply this equation to the river reaches in the EcoLox model domain, we examined relationships between river location (RK) and the model parameters in Equation 6-2 and interpolated model parameters for each EcoLox river reach (Fig. 6-8a-b). We then used these relationships with modeled flow to calculate surface water salinity (SWS) time series for each reach.

Vadose Zone Relationships

In a parallel study of vadose zone conditions in the Loxahatchee River floodplain, Kaplan et al. (2010a) developed a general model for effective soil moisture (Θ_e) in the floodplain as a function of surface water elevation (SWE) at T1 (Fig. 6-1). To extend this relationship to other areas of the floodplain, we calculated the distance between the floodplain ground elevation and adjacent SWE elevation at which modeled effective soil moisture at the surface was equal to a critical moisture threshold (e.g., Θ_e = 0.90, equivalent to 90% saturation) for all surveyed elevations on T1. The average of these distances was then used as the critical moisture depth for germination. This method assumes a relatively flat water surface profile between groundwater and surface water across the floodplain. While the slope of the groundwater table is variable, changes in the water surface profile are generally small over the width of the floodplain (Kaplan et

al., 2010a). This method also assumes similar soil hydraulic characteristics in the lower floodplain soils of the riverine reach of the NW Fork. A soils survey of the Loxahatchee River by Li et al. (2004) found lower floodplain soils in the riverine reach to be primarily fluvaquents, made up of interbedded layers of sand, clay, and organic matter (Sumner, 2000). While soil composition and layering in this type of fluvial system is characteristically heterogeneous, soil descriptions at T1 and throughout the riverine floodplain reach were similar.

Regarding salinity, Kaplan et al. (2010a) observed a time lag between peaks in SWS and PWS and the maintenance of high PWS after SWS had decreased. High levels of PWS were then flushed out of the root zone slowly by lower salinity surface water during the wet season. Notably, SWS peaks were always higher than SWS peaks, and the magnitude of these peaks decreased with increasing distance from the river. To more explicitly simulate PWS in the EcoLox model, we developed a lagged multivariate time series model based on measured SWS and PWS of the form:

$$PWS_t = PWS_{t-1} + \alpha(SWS_{t-lag} - PWS_{t-1}) + \beta \quad (6\text{-}3)$$

where PWS_t is the porewater salinity in the current time step (ppt), PWS_{t-1} is the porewater salinity from the previous time step (ppt), SWS_{t-lag} is the lagged surface water salinity [ppt], and α and β are parameters (unitless and ppt, respectively). The model was fit to PWS time series collected over four years on T7 at four distances from the river, with excellent results (Fig. 6-9) and was used to calculate long-term PWS time series in the floodplain at 10 m intervals, based on modeled SWS in each reach (see example in Fig. 6-10).

Model Scenarios

Based on the modeling efforts described in the previous sections, the SFWMD developed five constant-flow and three variable-flow restoration scenarios for comparison with the base flow conditions simulated over the POR. The eight scenarios include flow augmentation over Lainhart dam, flow augmentation from other tributaries (Cypress Creek, Hobe Grove Ditch, and Kitching Creek), and a combination of both. Table 6-2 summarizes these scenarios, with "LD" scenarios signifying flow over Lainhart Dam and "LD/TB" scenarios signifying flow from Lainhart Dam (LD) and other tributaries (TB) to the NW Fork. For variable flow scenarios, flow augmentations over Lainhart Dam are calculated using a set of logic-based rules (using monthly median flows a flood pulse intended to simulate flow conditions after a rainfall event), but tributary flows are added as a constant when total flow to the NW Fork falls below the appropriate threshold.

Results and Discussion

EcoLox results for the BASE case versus 1995 observed vegetation

Figure 6-11a shows modeled floodplain vegetation under the BASE case (historic conditions) compared with the interpretation of aerial photography of vegetation communities in 1995. In general, the EcoLox model does a good job of estimating the spatial distribution of habitat types in the floodplain. In particular, the model is able to closely match the upstream extent of mangrove encroachment and recreate the observed change in vegetation types with increasing distance to the river in some locations (i.e., in the upper tidal zone and at the outlet of Kitching Creek). This effect is limited, however, and a sharp line exists, upstream of which the gradient in floodplain vegetation is no longer observable. Accordingly, the model misses some areas of

mangroves observed in the 1995 aerial survey. This line corresponds to a sharp gradient in estimated SWS between reaches (Fig. 6-12a), which limits the extent to which the effect of changing PWS with distance from the river can be correlated with vegetation across reaches (Fig. 6-12b). Increasing the number of reaches in the model domain may improve the "smoothness" of these results.

Modeled vegetation shows a mix of bald cypress and BLH Forest habitats in the riverine reach. While the interpretation of aerial photography classifies sections of floodplain vegetation large enough to differentiate visually, the EcoLox model results are based on 10 m cells, and the pixilated results represent the spatially variable impacts of reduced hydroperiod as a function of elevation. Despite this difference, the modeled and observed vegetation are similarly dominated by BLH Forest in the riverine reach (at least where these data are available for the observed vegetation). Upstream of I-95 (i.e., south of the road that crosses over the river in Fig. 6-11a), the EcoLox model predicts an increase in the proportion of bald cypress habitat (relative to BLH habitat), which may or may not be indicative of field conditions.

The model predicts small amounts of hydric hammock, mostly in the upper tidal zone. Although not explicitly classified as hydric hammock, the interpretation of aerial photography does classify small areas of cabbage palm in the upper tidal reach (though the modeled hydric hammock does not match their exact location). Finally, the model domain is bordered (as expected) by upland. Isolated cells of upland also appear throughout the domain, sometimes in the middle of otherwise long-hydroperiod cells. It is unclear whether these cells accurately represent localized microsites of higher

elevation or are artifacts of the LiDAR survey. A complete QA/QC of the LiDAR dataset will help to answer this question.

Overall, the simulated vegetation results represented the observed conditions in the floodplain well, and the EcoLox model was used to estimate likely vegetation under the eight restoration scenarios proposed in the Restoration Plan.

Restoration scenarios

Modeled floodplain vegetation for the five constant flow and three variable flow scenarios described in Table 6-2 are shown Figs. 6-13 to 6-20. These results are based on long-term hydroperiod and salinity conditions and do not consider germination and recruitment conditions, which are discussed in subsequent sections. Increasing freshwater flow into the NW Fork pushes mangroves downriver in all scenarios from their current (modeled) upriver extent at RK ~15 to ~RK 12 for the scenario with the smallest amount of added flow (LD65; Fig. 6-13) and past the edge of the modeling domain (~RK 9.5) for the scenario with the largest amount of added flow (LD200/TB200; Fig. 6-17). As expected, additional flows over Lainhart Dam also increase the area of bald cypress in the riverine reach of the river—with the highest flow scenarios showing considerable conversion of BLH Forest to bald cypress in the riverine reach—while additional tributary flows increase bald cypress area only in tidal reaches, but have no effect on the riverine reach.

The total area of modeled floodplain vegetation under each of the nine scenarios is summarized in Fig. 6-21 and vegetation change from the BASE case are visualized in Fig. 6-22 as the percent change in area of each habitat type for each scenario. This figure shows, for example, that the increase in bald cypress habitat for scenarios LD65 and LD65/TB65 are primarily to a decrease in mangrove habitat area, whereas

increasingly higher flows (LD90/TB100, LD200, and LD200/TB200) increase bald cypress area by reducing both mangrove area in the upper tidal reach and BLH Forest area in the riverine reach. While small, increases in the area of hydric hammock occur across all scenarios. Finally, all scenarios decreased the amount of upland, though the changes were also small.

Germination and recruitment

The predicted floodplain vegetation distributions presented in the previous section were modeled according to long-term hydroperiod and salinity conditions in the floodplain. Examining how hydroperiod, moisture, and salinity affect germination and recruitment conditions gives a more nuanced view of the likelihood of achieving these conditions and potential barriers to restoration. In this context, we looked at recruitment likelihoods in cells classified as bald cypress in the previous section, as quantified by the number of years over the POR that at least one recruitment event occurred. It is first instructive to look at the existing recruitment conditions under the BASE case as a basis for comparing the results of restoration scenarios.

Fig. 6-23 is a histogram showing the distribution of the number of recruitment years across all cells in the model domain under the BASE scenario. Of the 65.8 ha of bald cypress swamp predicted by the EcoLox model, nearly half (44%) did not experience a single recruitment event over the 40-year POR. The remainder of the bald cypress area had between one and 20 recruitment events with an exponentially decreasing frequency. Two (or more) interpretations of these results exist. The first is that one or more recruitment years over 40 years is an indication of ecosystem health, since bald cypress forests can survive with infrequent regeneration events as long as mature populations remain healthy and continue to produce seeds. For example,

Duever et al. (1983) suggest that a good bald cypress recruitment season take occur as infrequently as every 30 to 40 years. This interpretation would indicate that approximately half of the bald cypress forest in the floodplain of the NW Fork is sustainably regenerating under historic flow conditions. The second interpretation is that the likelihood of achieving a recruitment event over the POR ranged from zero to 50% depending on location (i.e., zero out of 40 years for the 29.0 ha of bald cypress with no recruitment years and 20 out of 40 years for the 0.28 ha that had 20 recruitment years).

It may be expected that adding additional flow to the NW Fork would improve recruitment conditions, however results from the EcoLox model show that outcomes are mixed. For example, Fig. 6-24 is a histogram showing the distribution of the number of recruitment years under the LD65 scenario. While this scenario shows a large increase in the area of bald cypress swamp (see Fig 6-22), an overwhelming majority (87%) of this area does not experience a single recruitment year over the POR. Fig. 6-25 summarizes the percentage of bald cypress area that experiences one or more germination and recruitment events over the POR for all scenarios. The difference between the germination and recruitment bars is an indication of areas where germination conditions were met, but no seedlings survived due to hydroperiod or salinity stresses. Surprisingly, the BASE scenario has the greatest area experiencing one or more germination and recruitment events as a proportion of total bald cypress area, while the highest flow scenarios show the smallest percentage of areas with germination and recruitment.

Examining the total area (as opposed to the percentage of area) experiencing one or more years of germination and recruitment (Fig. 6-26) provides a partial explanation of these results. While all restoration scenarios increase the area expected to have bald cypress habitat based on hydroperiod and salinity, all five constant flow scenarios dramatically reduce the bald cypress area with good germination and recruitment conditions. On the other hand, the three variable flow scenarios slightly increase the total area with good germination and recruitment conditions, providing a quantitative validation of the qualitative expectation that ecological communities "…require a… range of natural variation or disturbance to maintain viability or resilience" (SFWMD, 2006). While this is heartening, model results suggest that the great majority of the potentially restored cypress swamp area do not meet the necessary ecohydrological conditions to sustainably maintain a healthy, regenerating cypress swamp community. For example, Fig. 6-27 shows the spatial distribution of modeled recruitment years for the BASE and LV90-TV60 scenarios (the LV90-TV60 was chosen as the preferred restoration scenario in the Restoration Plan). Under this scenario, large areas of potentially restored bald cypress swamp—particularly in the upper tidal reach—do not experience recruitment events over the 40-year POR.

Since restoration flows under this scenario push the saltwater downriver, it is unlikely that this lack of recruitment is due to salinity, and Fig. 6-28 confirms that high tidal surface water relative to floodplain elevation may restrict germination and recruitment to localized, high-elevation microsites (blue line indicates average floodplain elevation at T7 [RK 14.6]), which may not be captured at the 10 m resolution. This is supported by vegetation surveys, which have found the presence of hummocks,

stumps, and fallen logs to increase floodplain plant diversity, and permit the survival and recruitment of drier or less salt-tolerant species (SFWMD, 2009).

Another possibility is that the LiDAR data does not accurately represent the floodplain elevation. As noted in the Materials and Methods section, a preliminary QA/QC of the LiDAR data revealed a consistent bias of overestimation of ~20 cm, however these points were taken at survey benchmarks (located at the end of survey transects) and a globally-applied 20 cm adjustment may not fully correct the elevation. For example, SWE at RK 14.6 is often below the unadjusted average elevation at T7 (red line in Fig. 6-28). While the accuracy of the elevation dataset may be in question, it is clear that restoration of bald cypress habitat in the tidal section of the river may be tenuous in light of predicted climate change-induced sea-level rise (i.e., 18 to 59 cm by 2100; IPCC, 2007).

Conclusions

In spite of its rather rigid environmental requirements, bald cypress forests can survive with infrequent regeneration events as long as mature populations remain healthy and continue to produce seeds. The initial EcoLox model is a useful tool for assessing the likely impacts of restoration and management scenarios on the floodplain vegetation of the Loxahatchee River. The initial model described here was used to successfully simulate historic conditions and examine the likely results of proposed restoration. In general, the model predicts the possibility of restoring large areas of bald cypress habitat, but raises concerns about the natural regeneration potential of these areas. Additional work is required to improve the model structure (particularly the selection of the best porewater D_s:D_b ratio) and refine model inputs (above all, the LiDAR dataset needs to be thoroughly QA/QC'ed before making management decisions

based on model results). The next step in the development of the EcoLox model will be to perform a global uncertainty and sensitivity analysis (UA/SA), which will help point out the most important model parameters and variables. With UA/SA results as guidance, future work may include more detailed simulations of surface water elevation and salinity, improved subroutines for seedling growth, and incorporation of the impacts of sea-level rise, fire, and frost.

Table 6-1. Global model parameters in the EcoLox model and the source for the value used in this application (where applicable).

Parameter	Description	Value	Source(s), if applicable
IDayRec	Num. of days in simulation	14275	---
IYearRec	Num. of years in simulation		---
IReach	Num. of river reaches	38	---
CritRainDepth	Min. rainfall depth (mm) for moist conditions	10	D. Kaplan (unpublished data)
CritMoistureDepth	Maximum depth of water below ground surface for moist conditions (cm)	20	Kaplan et al. (2010a)
CritConsecGermDays	Consec. num. of days with moist soil conditions to initiate germination (if seeds available)	7	G. Liu (pers. comm.)
YearZeroSeedlingSubmergedCrit	Num. of consec. days of submergence required to kill a seedling < 1 yr old	50	Souther and Shaffer (2000)
YearOneSeedlingSubmergedCrit	Num. of consec. days of submergence required to kill a seedling > 1 yr old	120	
YearZeroSaltDaysCrit	Cumulated salt exposure necessary to kill a seedling < 1 yr old	60	Estimated from: Pezeshki (1990); Allen et al. (1994, 1996); Connor (1994); Connor and Inabinette (2004); Krauss et al. (1998); Liu et al. (2006)
YearOneSaltDaysCrit	Cumulated salt exposure necessary to kill a seedling > 1 yr old (all in mm day^{-1})	120	
YearZeroWinterGrowthMin	Min. Jan and Feb growth rates for seedlings < 1 yr	0.0423	Bull (1949); Liu et al. (2006)
YearZeroWinterGrowthMax	Max. Jan and Feb growth rates for seedlings < 1 yr	0.1501	
YearZeroSpringGrowthMin	Min. Mar, Apr, May, Jun, and Jul growth rates for seedlings < 1 yr	0.1018	
YearZeroSpringGrowthMax	Max. Mar, Apr, May, Jun, and Jul growth rates for seedlings < 1 yr	0.3637	
YearZeroFallGrowthMin	Min. Sep, Oct, Nov, and Dec Jul growth rates for seedlings < 1 yr	0.0222	
YearZeroFallGrowthMax	Max. Sep, Oct, Nov, and Dec Jul growth rates for seedlings < 1 yr	0.1129	
YearOneWinterGrowthMin	As above, for seedlings > 1 yr	0.0423	
YearOneWinterGrowthMax		0.1501	
YearOneSpringGrowthMin		0.1018	
YearOneSpringGrowthMax		0.3637	
YearOneFallGrowthMin		0.0222	
YearOneFallGrowthMax		0.1129	
CritSal	Critical salinity threshold for calculating characteristic salinity regime and salt days	3.0	This study
JanSeedIndex	Monthly likelihood of seed availability for Jan	0.22	Modified from Middleton (2000) based on Brown (1994)

Table 6-1. Continued.

Parameter	Description	Value	Source(s), if applicable
FebSeedIndex	Monthly likelihood of seed availability for Feb	0.14	Modified from Middleton
MarSeedIndex	Monthly likelihood of seed availability for Mar	0.08	(2000) based on Brown
AprSeedIndex	Monthly likelihood of seed availability for Apr	0.05	(1994)
MaySeedIndex	Monthly likelihood of seed availability for May	0.03	
JunSeedIndex	Monthly likelihood of seed availability for Jun	0.02	
JulSeedIndex	Monthly likelihood of seed availability for Jul	0.01	
AugSeedIndex	Monthly likelihood of seed availability for Aug	0.01	
SepSeedIndex	Monthly likelihood of seed availability for Sep	0.25	
OctSeedIndex	Monthly likelihood of seed availability for Oct	0.95	
NovSeedIndex	Monthly likelihood of seed availability for Nov	0.61	
DecSeedIndex	Monthly likelihood of seed availability for Dec	0.37	

Table 6-2. Constant flow restoration scenarios (adapted from SFWMD, 2006). Flow in $m^3 s^{-1}$ ($ft^3 s^{-1}$). POR indicates modeled flow over period of record.

Source of Flow	Base condition	LD65	LD65TB65	LD90TB110	LD200	LD200TB200
Lainhart Dam (LD)	POR	1.84 (65)	1.84 (65)	2.55 (90)	5.66 (200)	5.66 (200)
Other tributaries (TB)	POR	POR	1.84 (65)	3.11 (110)	POR	5.66 (200)
Total Flow	1.42 (50)	2.69 (95)	3.68 (130)	5.66 (200)	6.51 (230)	11.33 (400)
Approximate saltwater front position (RK)	15.3	13.7	12.9	12.1	11.3	9.7

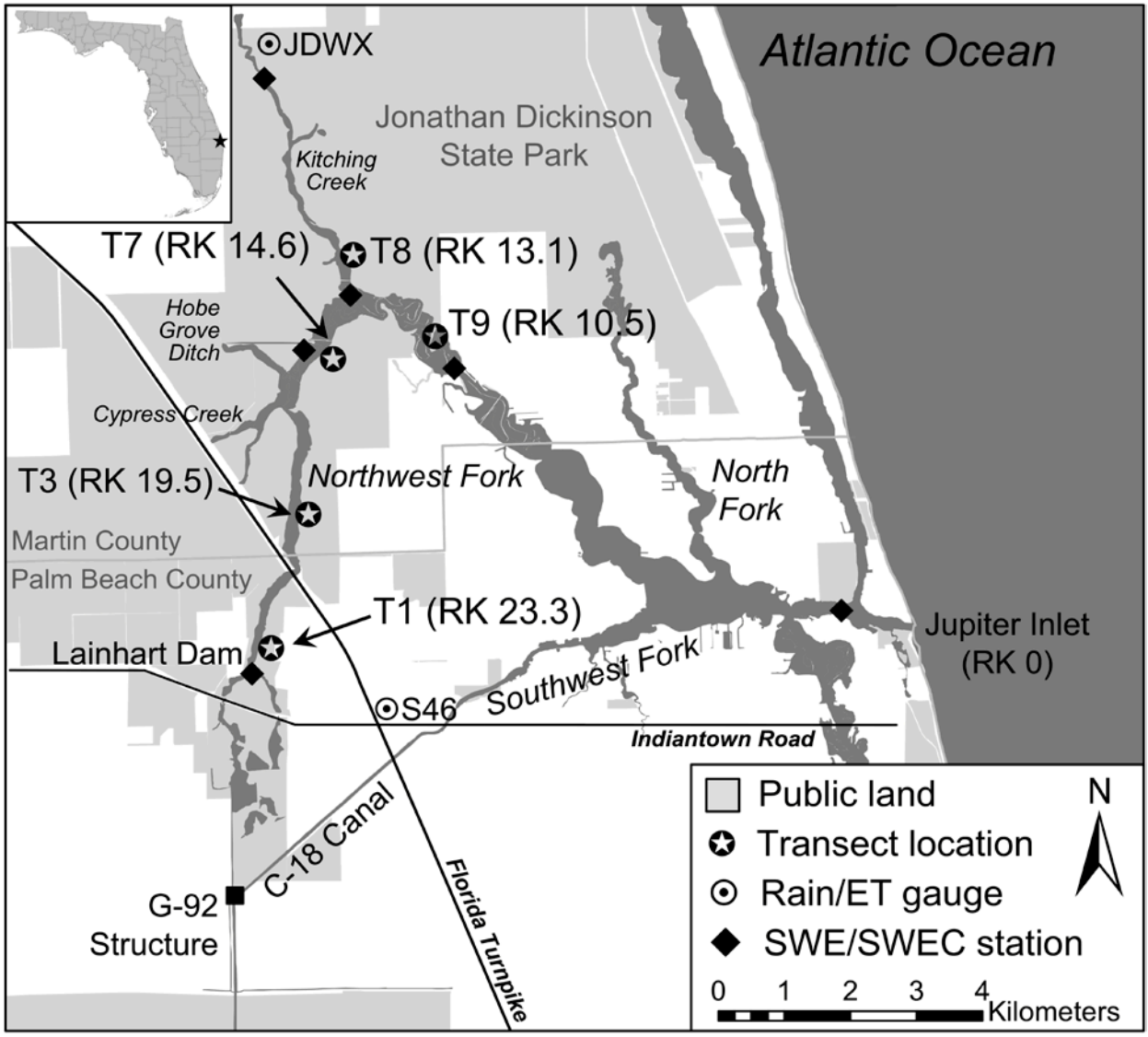

Figure 6-1. The Loxahatchee River and surrounding area with transect locations (T1, T3, T7, T8, and T9). Transect notation is followed by distance from river mouth (river kilometer, RK).

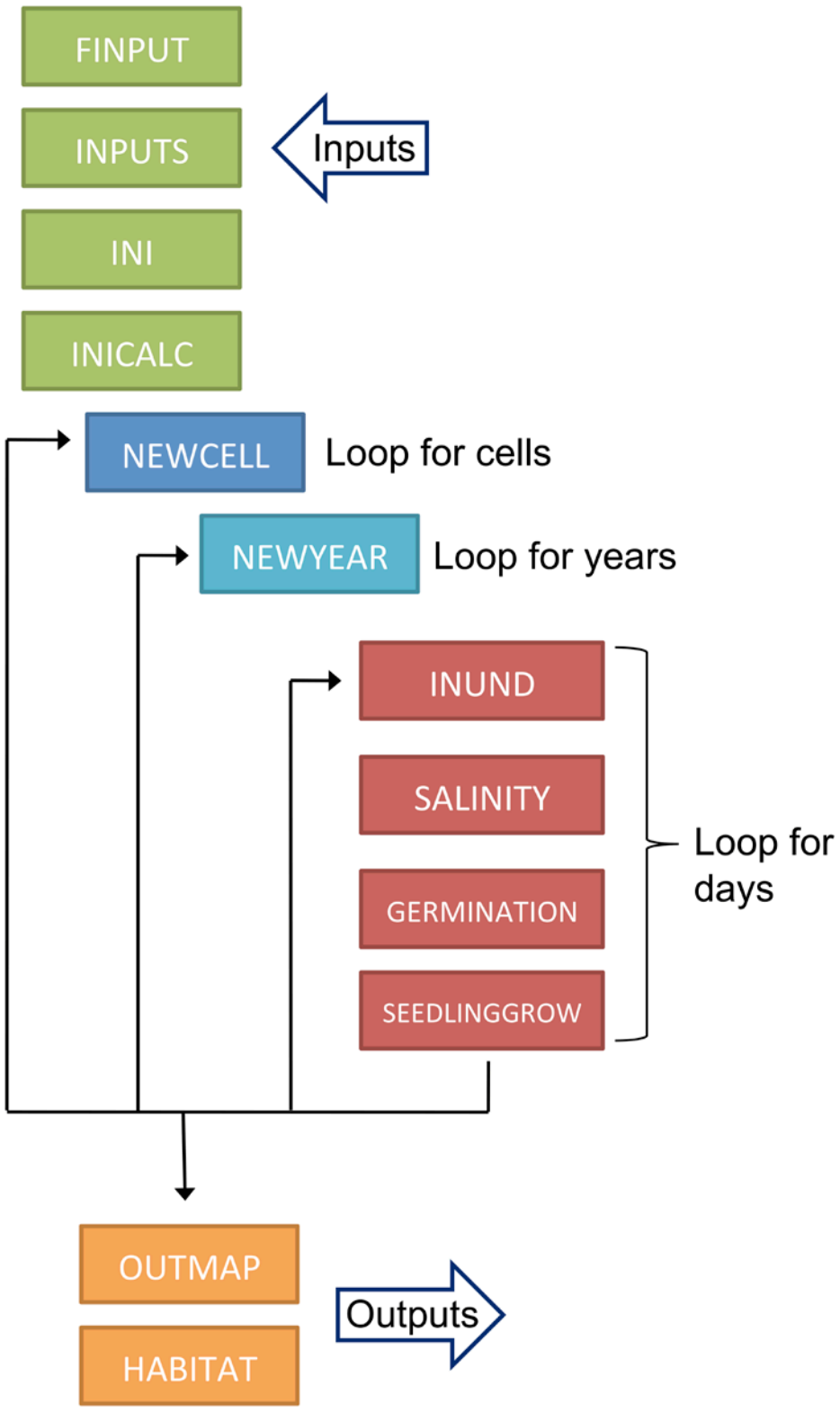

Figure 6-2. Flowchart of the structure and subroutines that make up the EcoLox model.

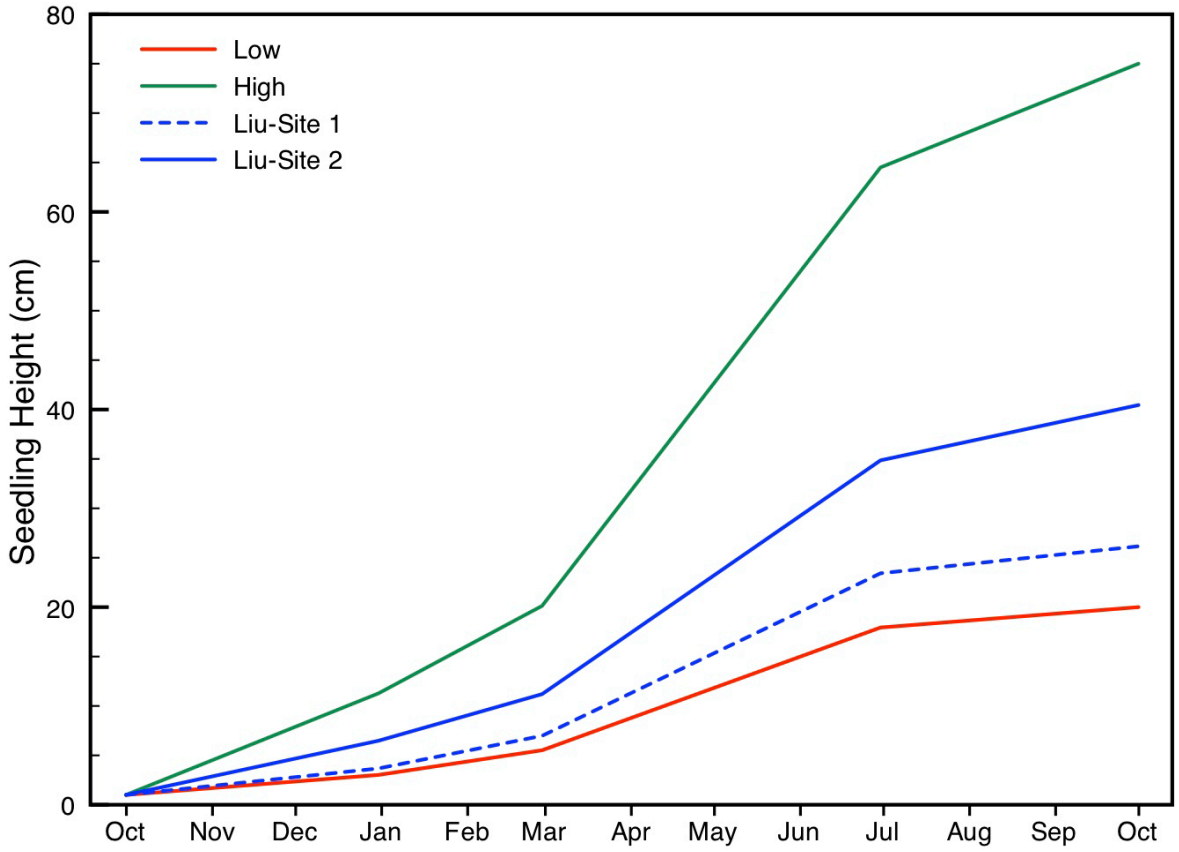

Figure 6-3. Example simulated seedling heights over one year using low and high values from the literature compared with measured data from seedlings in the floodplain of the Loxahatchee River in 2006 (after Liu et al., 2006).

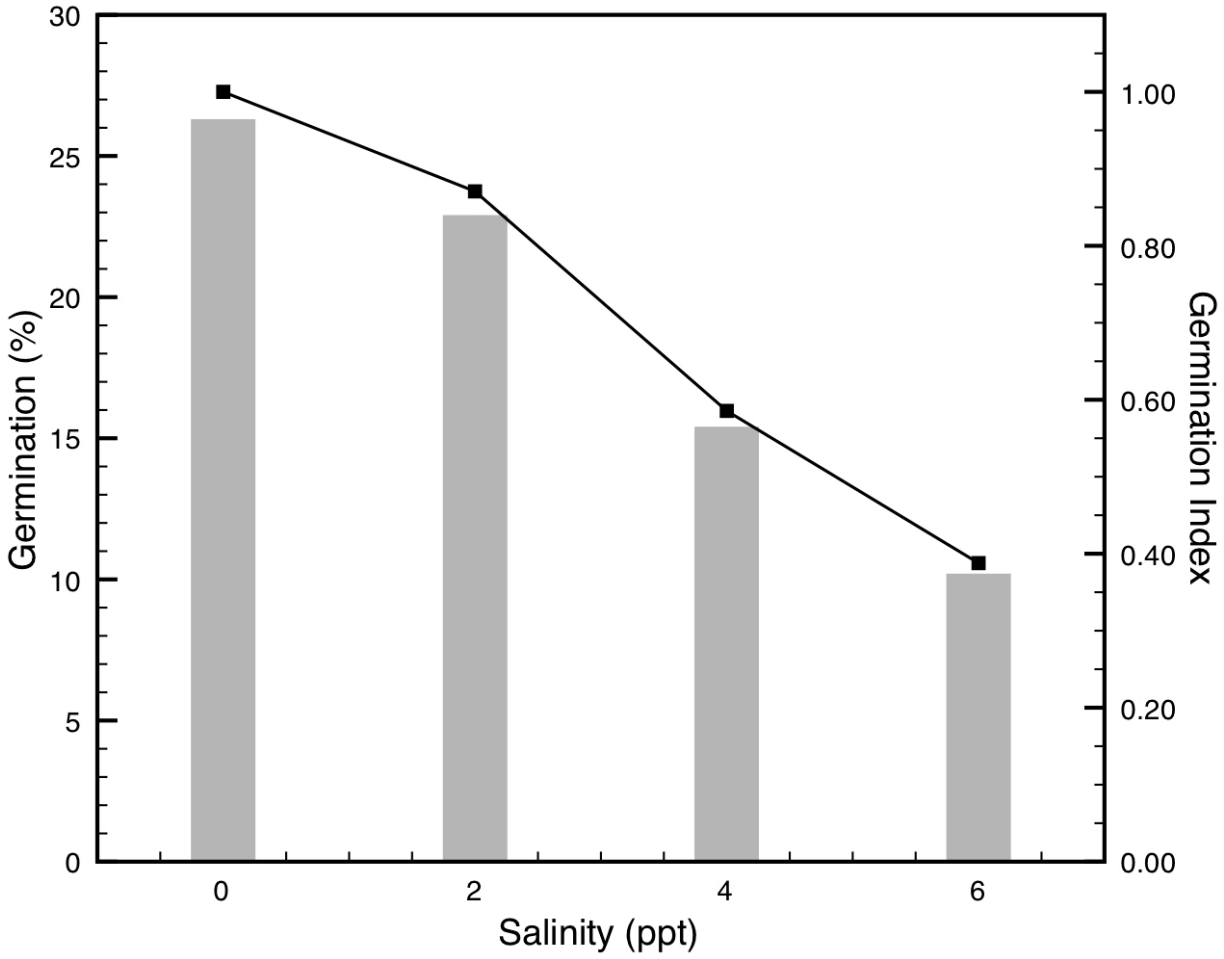

Figure 6-4. Reduction in germination percentage with salinity reported by Krauss et al. (1998) was used to create a germination index, which modified the likelihood of germination events according to the relative reduction in germination from 0 ppt treatment.

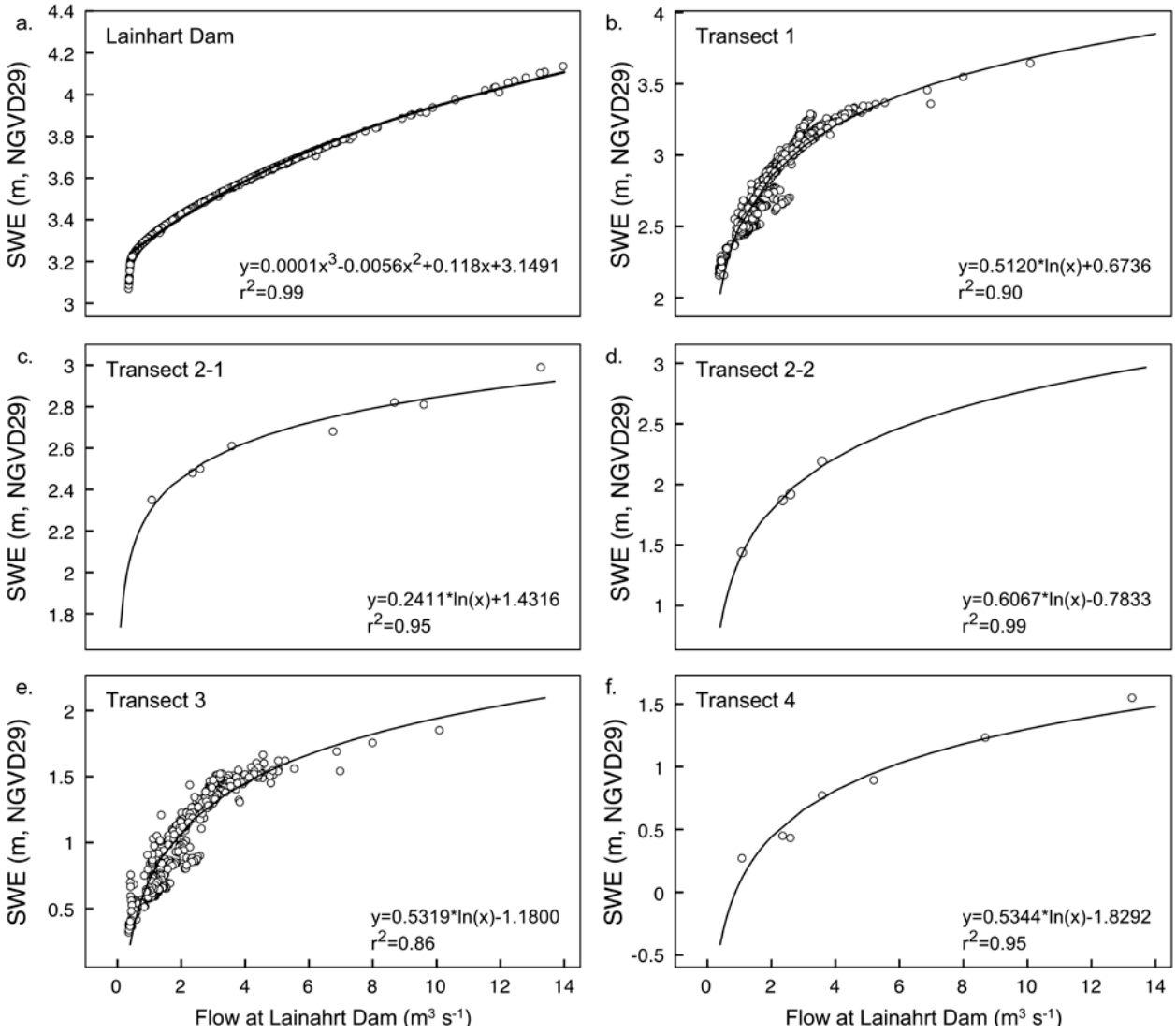

Figure 6-5. Relationships between flow at Lainhart dam and surface water elevation (SWE) at six locations in the riverine reach of the NW Fork of the Loxahatchee River (modified and expanded from SFWMD, 2006).

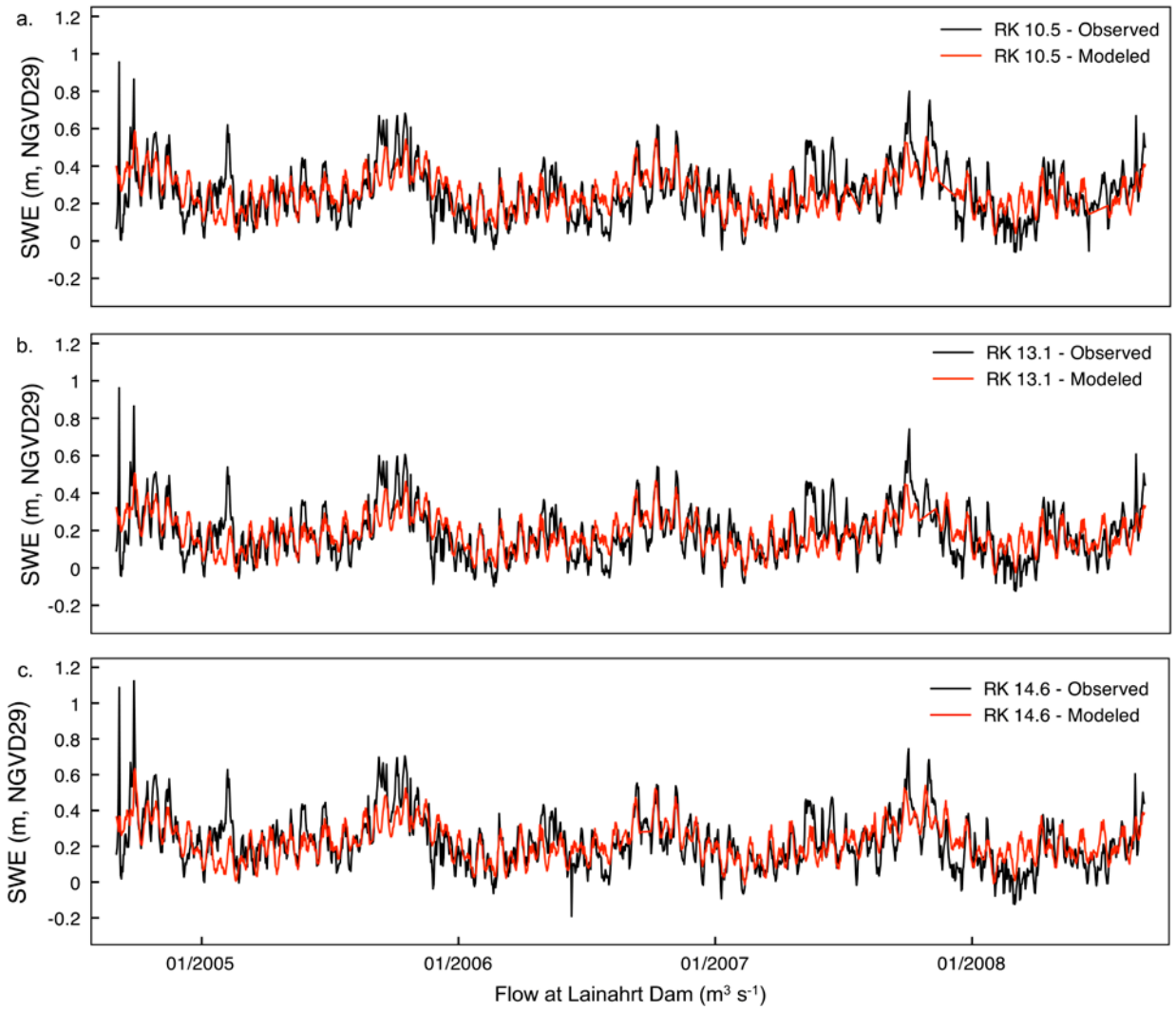

Figure 6-6. Observed (black lines) and modeled (red lines) surface water elevation (SWE) at (a): RK 10.5 (Boy Scout Dock); (b) RK 13.1 (at the mouth of Kitching Creek); and (c) RK 14.6 (adjacent to transect 7).

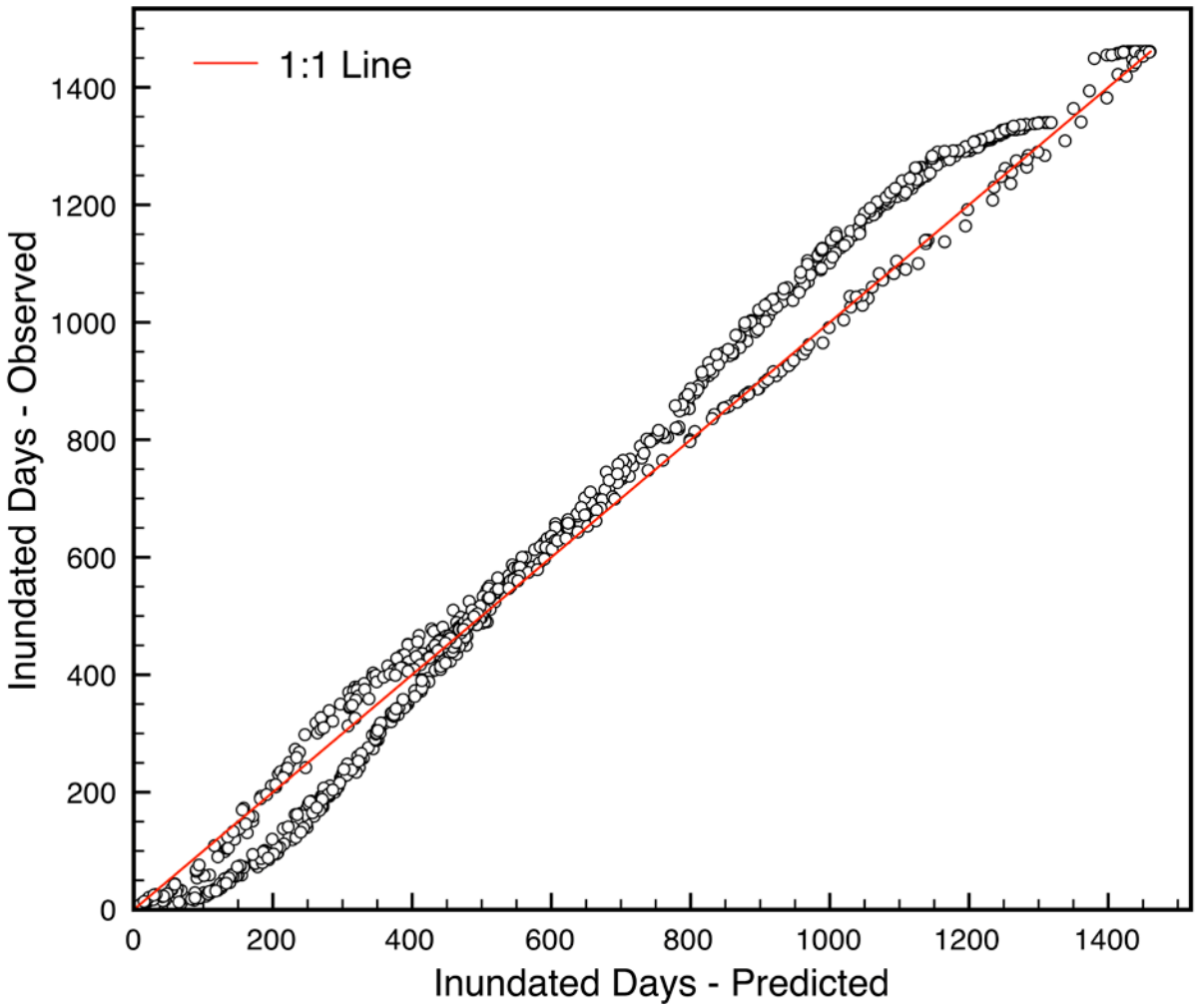

Figure 6-7. Observed vs. predicted days of inundation from 2004 to 2008 over the tidal portion of the EcoLox model domain using maximum daily surface water elevation values.

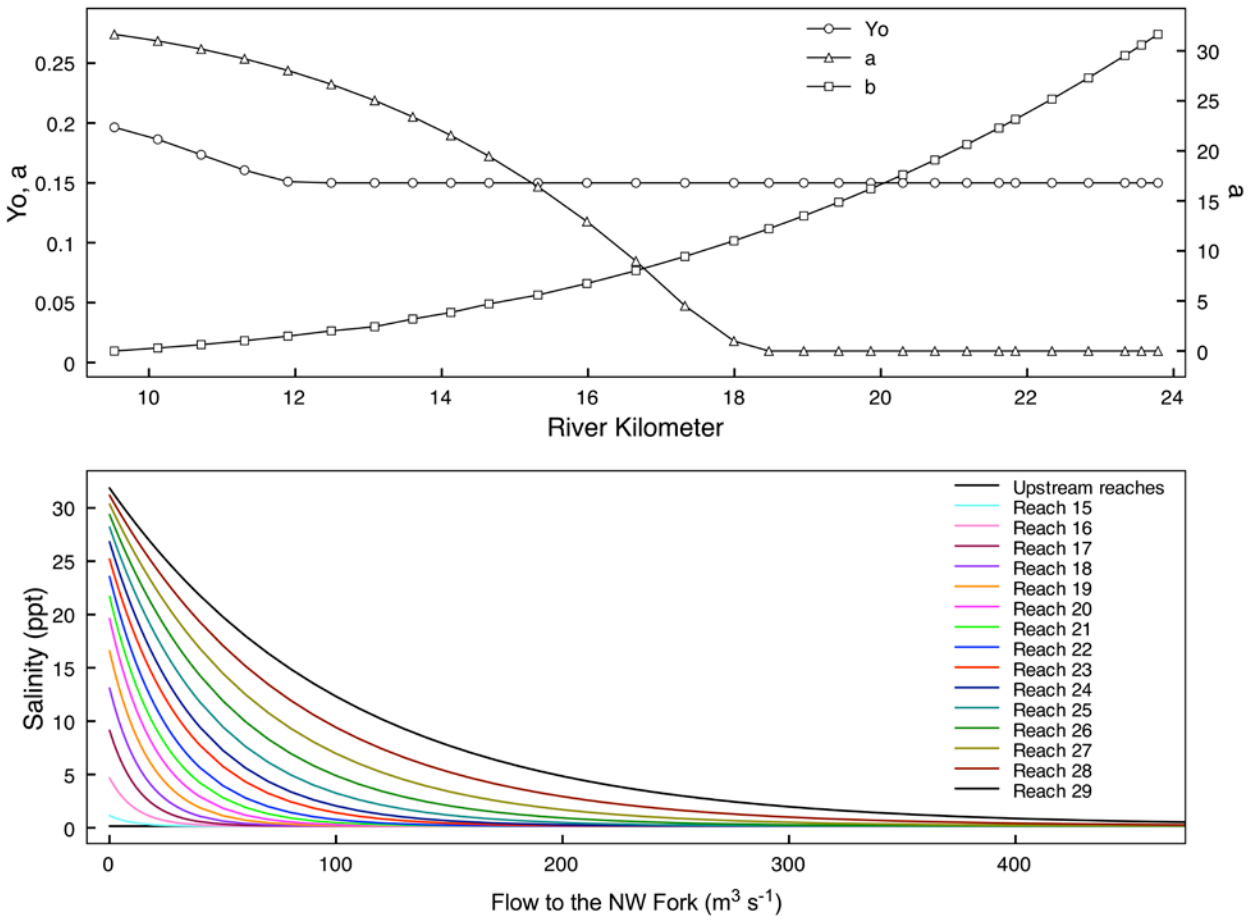

Figure 6-8. Interpolated parameters for Equation 6-2 (upper panel) and (b) exponential relationships between total freshwater flow to the NW Fork and salinity applied to the 29 reaches used in the EcoLox model (lower panel).

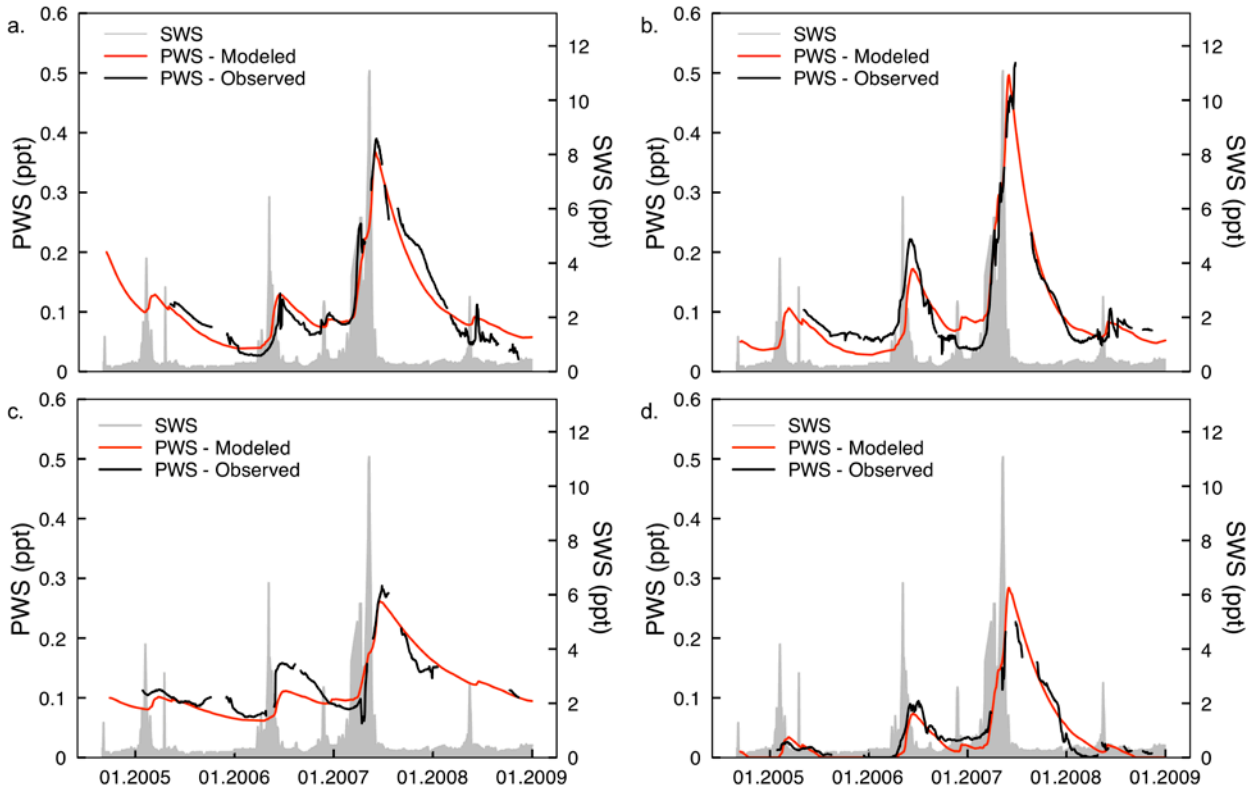

Figure 6-9. Observed (black lines) and modeled (red lines) porewater salinity (PWS) and observed surface water salinity (SWS; grey lines) at four locations on transect 7 from 2005 to 2008: (a) 2 m from river; (b) 25 m from river; (c) 90 m from river; and (d) 135 m from river.

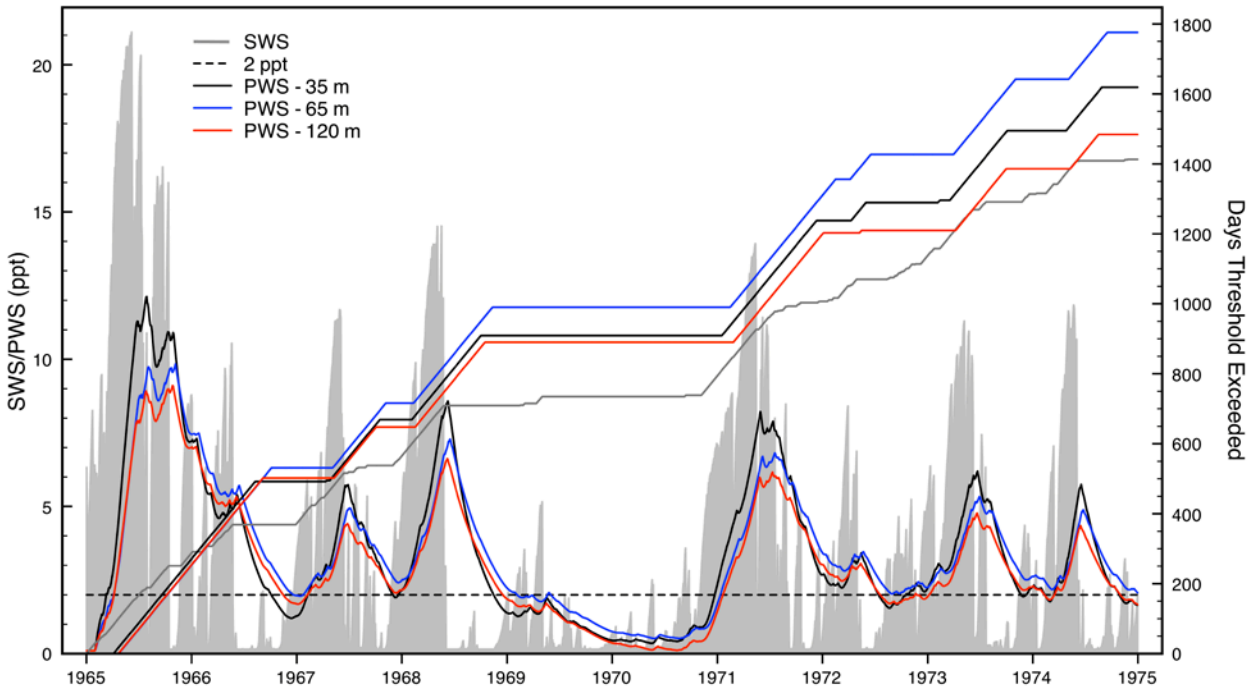

Figure 6-10. Modeled porewater salinity (PWS) at 35 (black line), 65 (blue line), and 120 m (red line) from the river based on Equation 6-3 and modeled surface water salinity (SWS) (grey line) in the floodplain at ~RK 13 (Reach 23, near the outlet of Kitching Creek) from 1965 to 1975. Cumulative lines show accumulated days of exceedance of the critical salinity for each series on the secondary axis. Note greatest number of days exceeded for middle distance series (65 m), despite lower peak concentrations (blue lines).

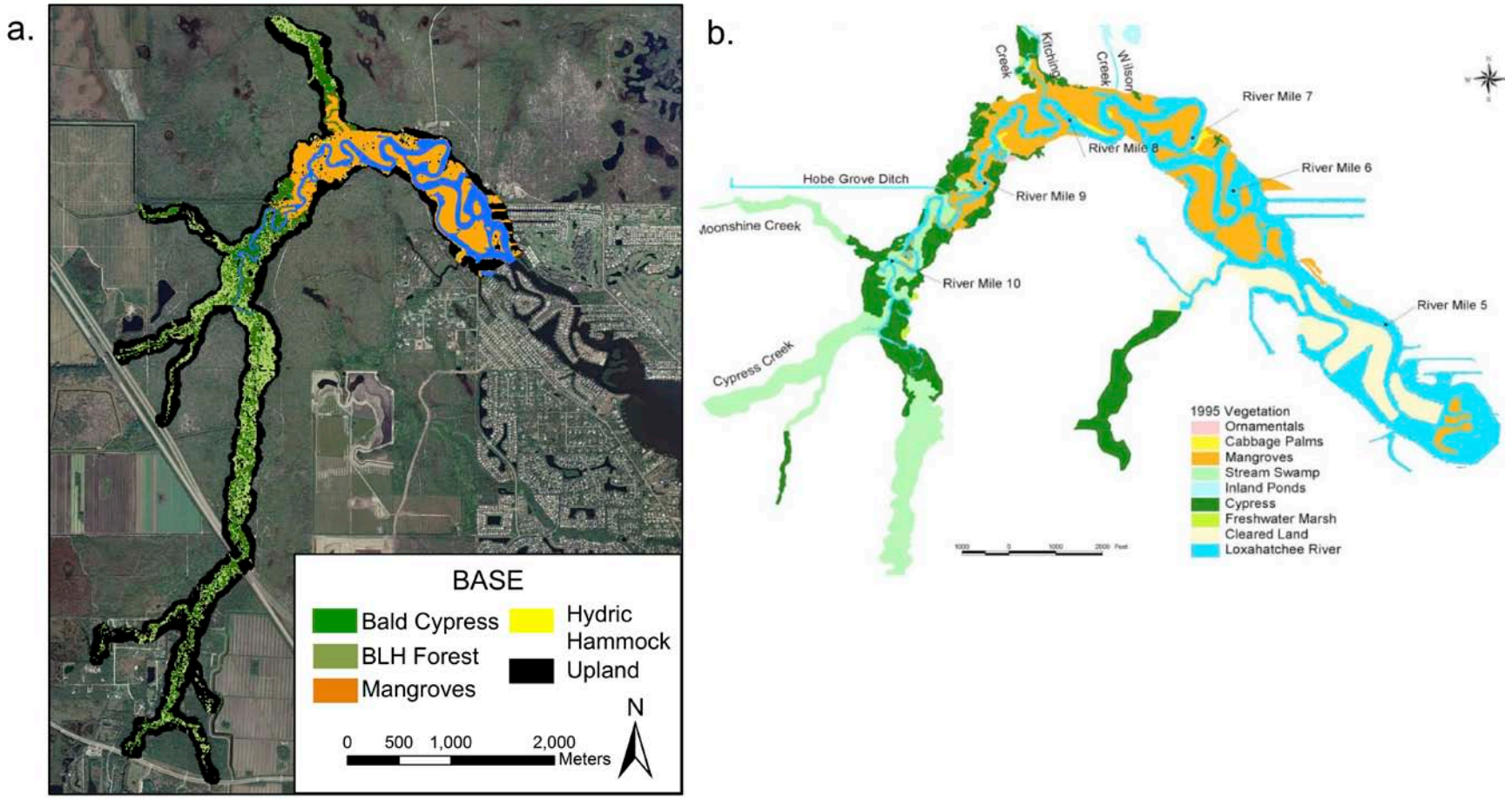

Figure 6-11. (a) Modeled floodplain vegetation results from the EcoLox model using the BASE case (modeled historic data) and (b) Interpretation of aerial photography of vegetation communities in the floodplain of the NW Fork of the Loxahatchee River in 1995. River Miles 5 to 10 in (b) correspond to River Kilometers (RK) 9.7, 11.3, 12.9, 14.5, 16.1, and 17.7

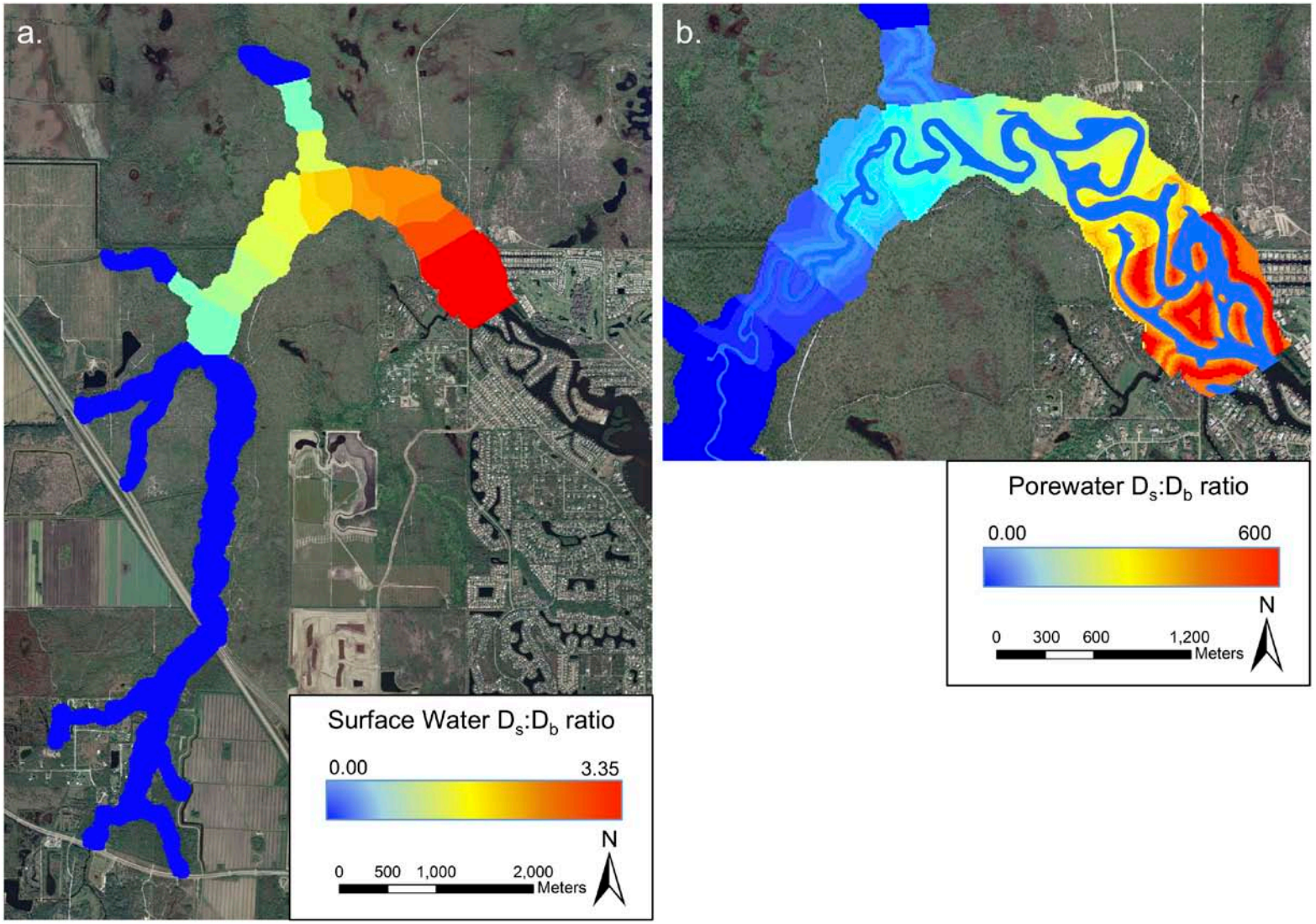

Figure 6-12. (a) The characteristic salinity regime (Ds:Db ratio) in (a) surface water and (b) porewater calculated with a critical salinity of 3 ppt. The range of values for porewater Ds:Db ratio is considerably larger than for surface water (capped at 600) because PWS in some areas of the floodplain is rarely (if ever) below the threshold.

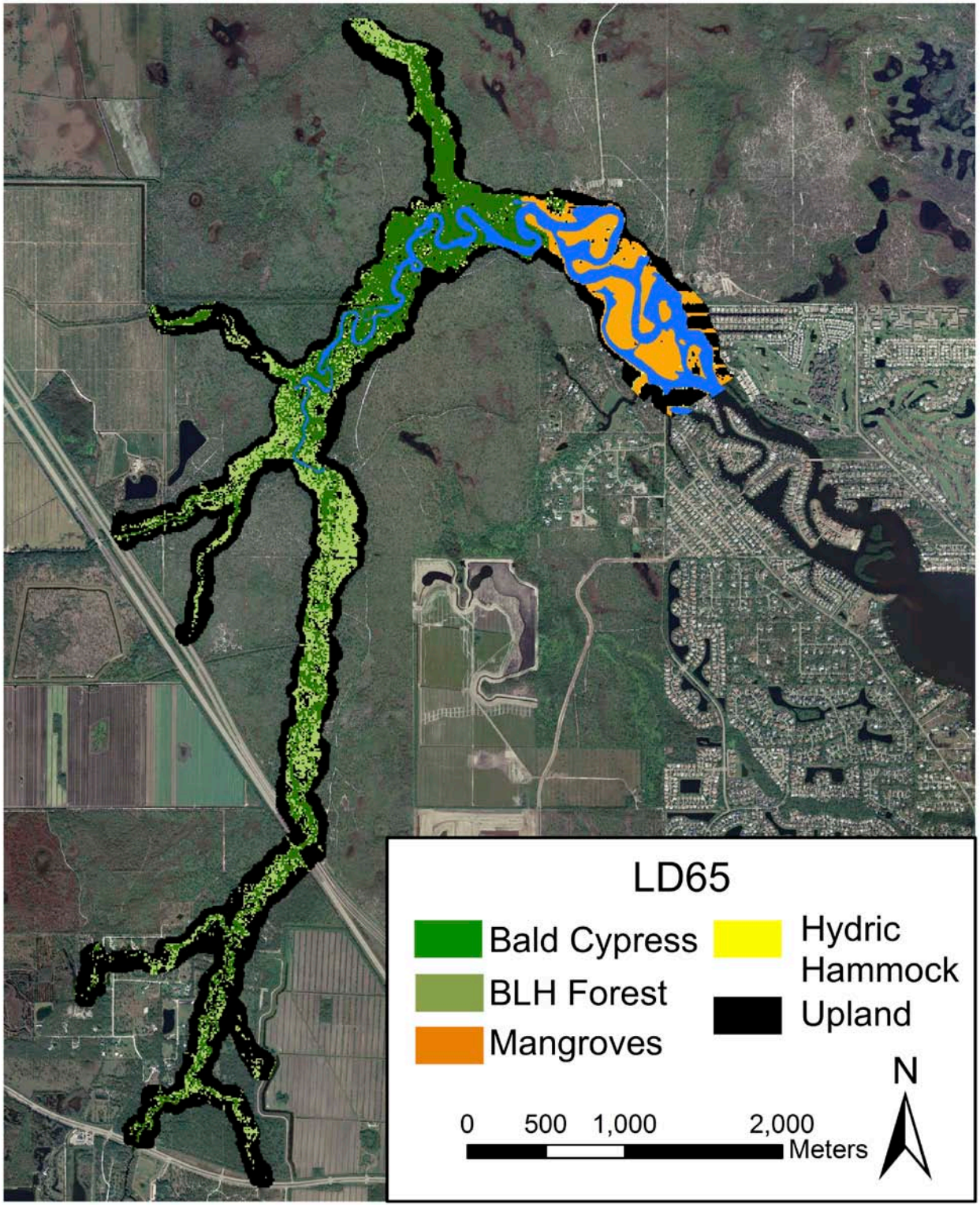

Figure 6-13. Modeled floodplain vegetation results from the EcoLox model under the LD65 restoration scenario.

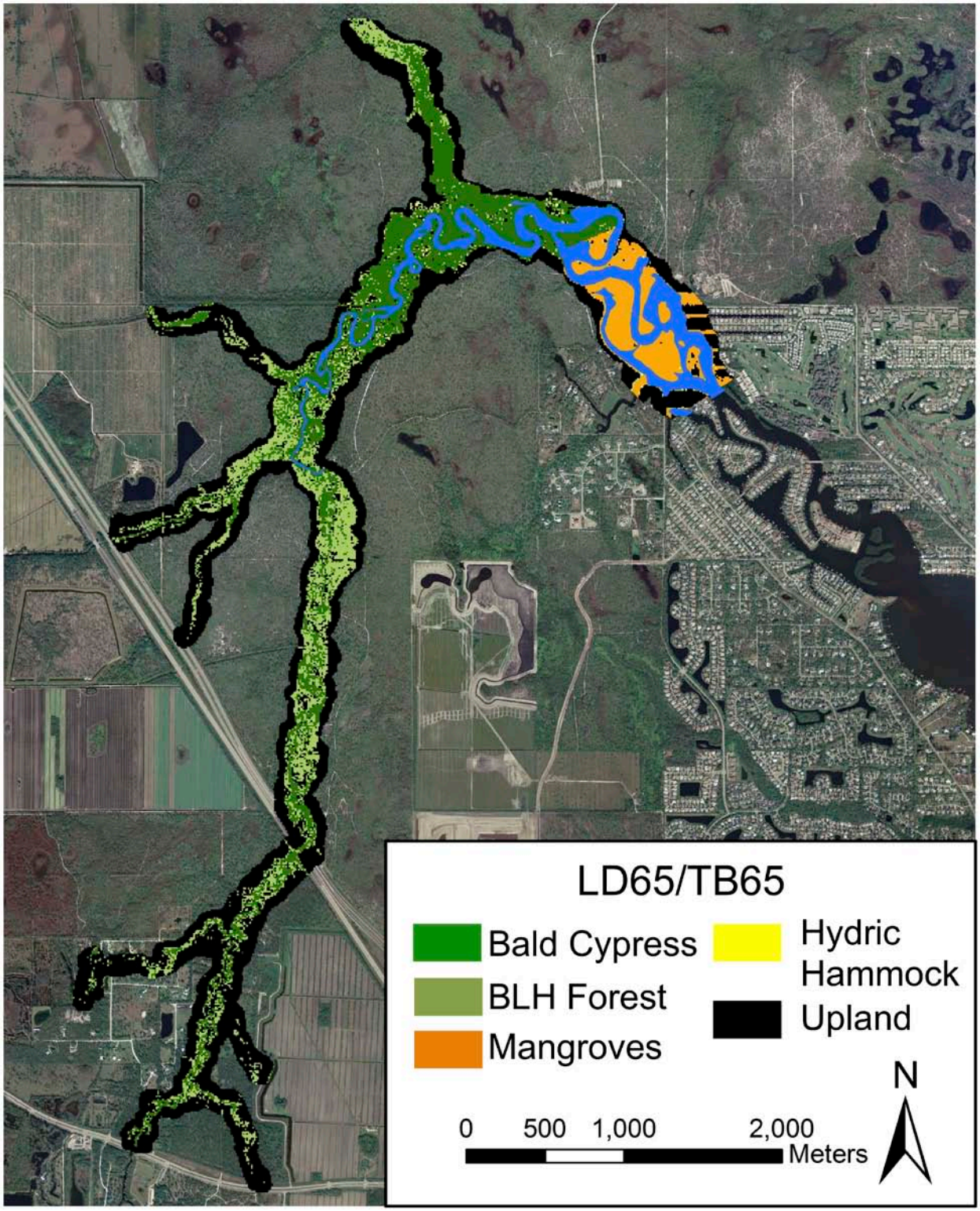

Figure 6-14. Modeled floodplain vegetation results from the EcoLox model using the LD65/TB65 restoration scenario.

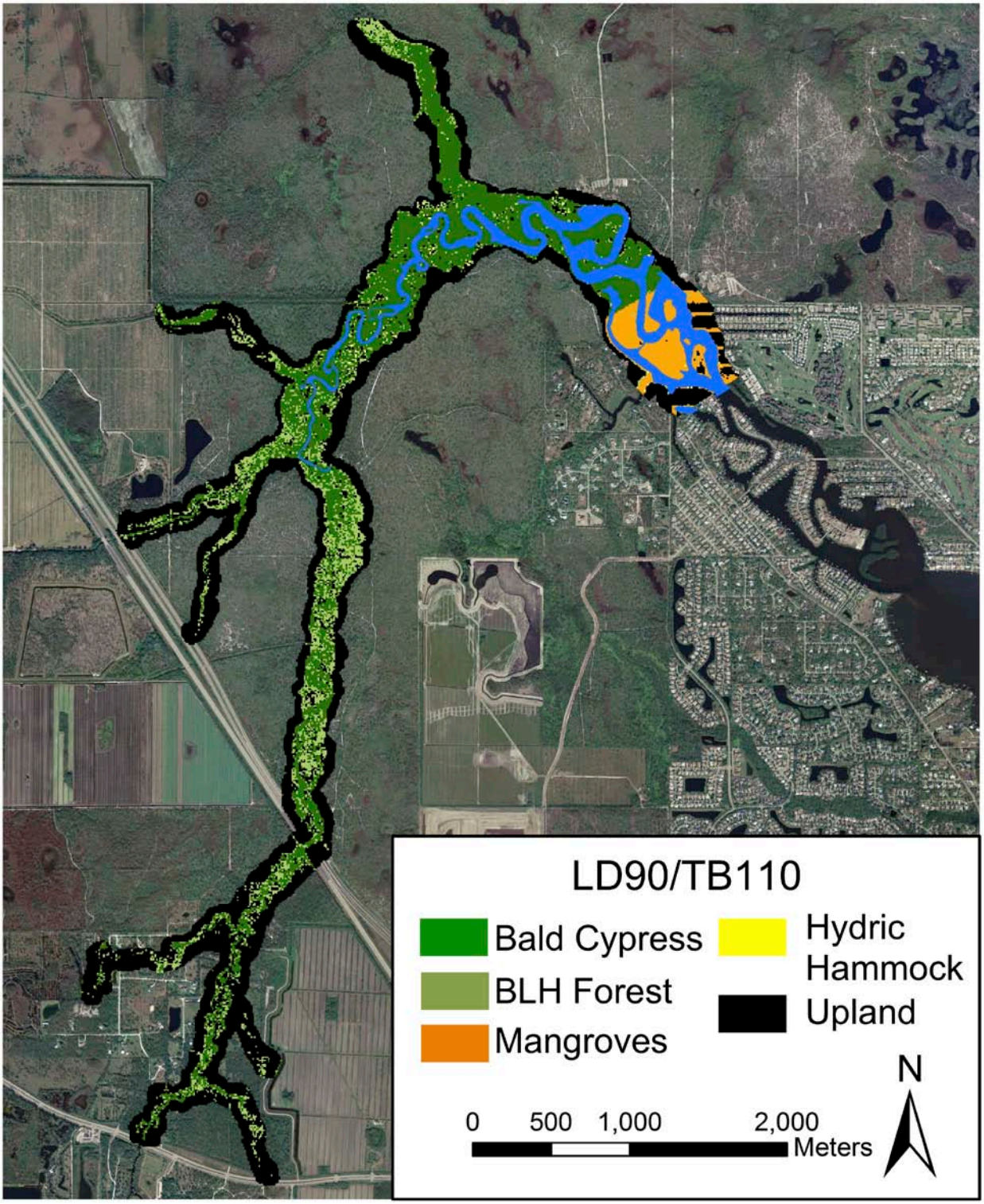

Figure 6-15. Modeled floodplain vegetation results from the EcoLox model under the LD90/TB110 restoration scenario.

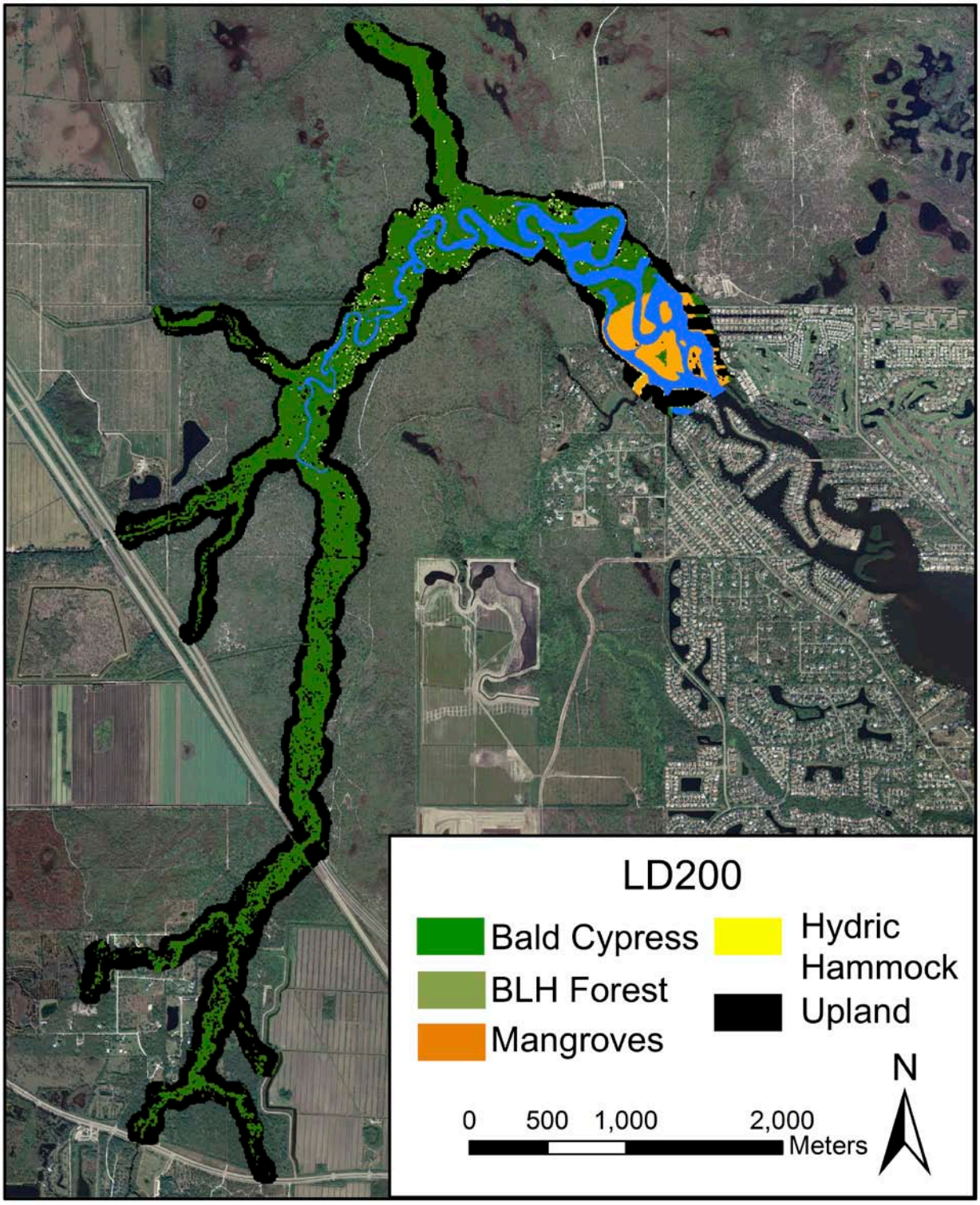

Figure 6-16. Modeled floodplain vegetation results from the EcoLox model using the LD200 restoration scenario.

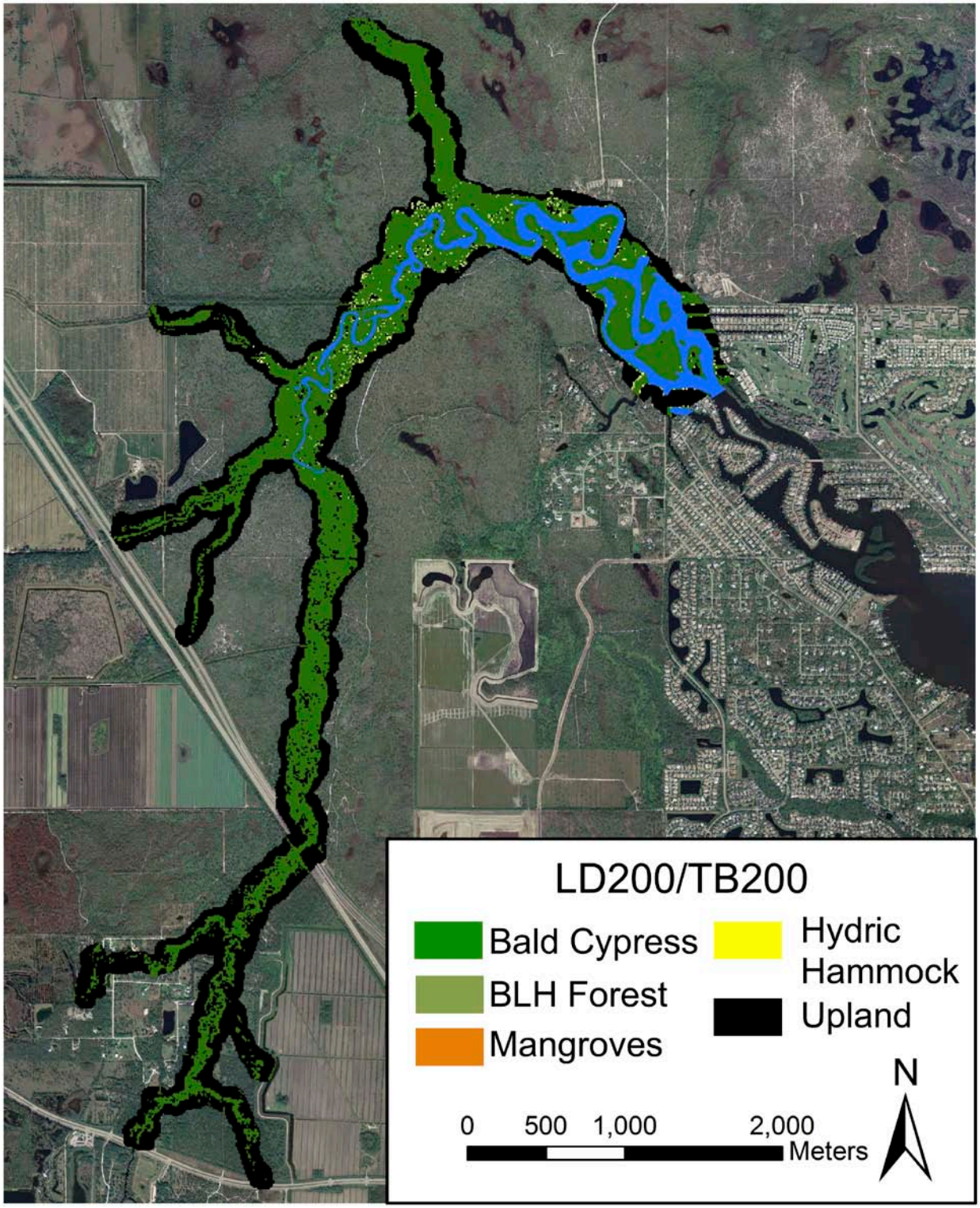

Figure 6-17. Modeled floodplain vegetation results from the EcoLox model under the LD200/TB200 restoration scenario.

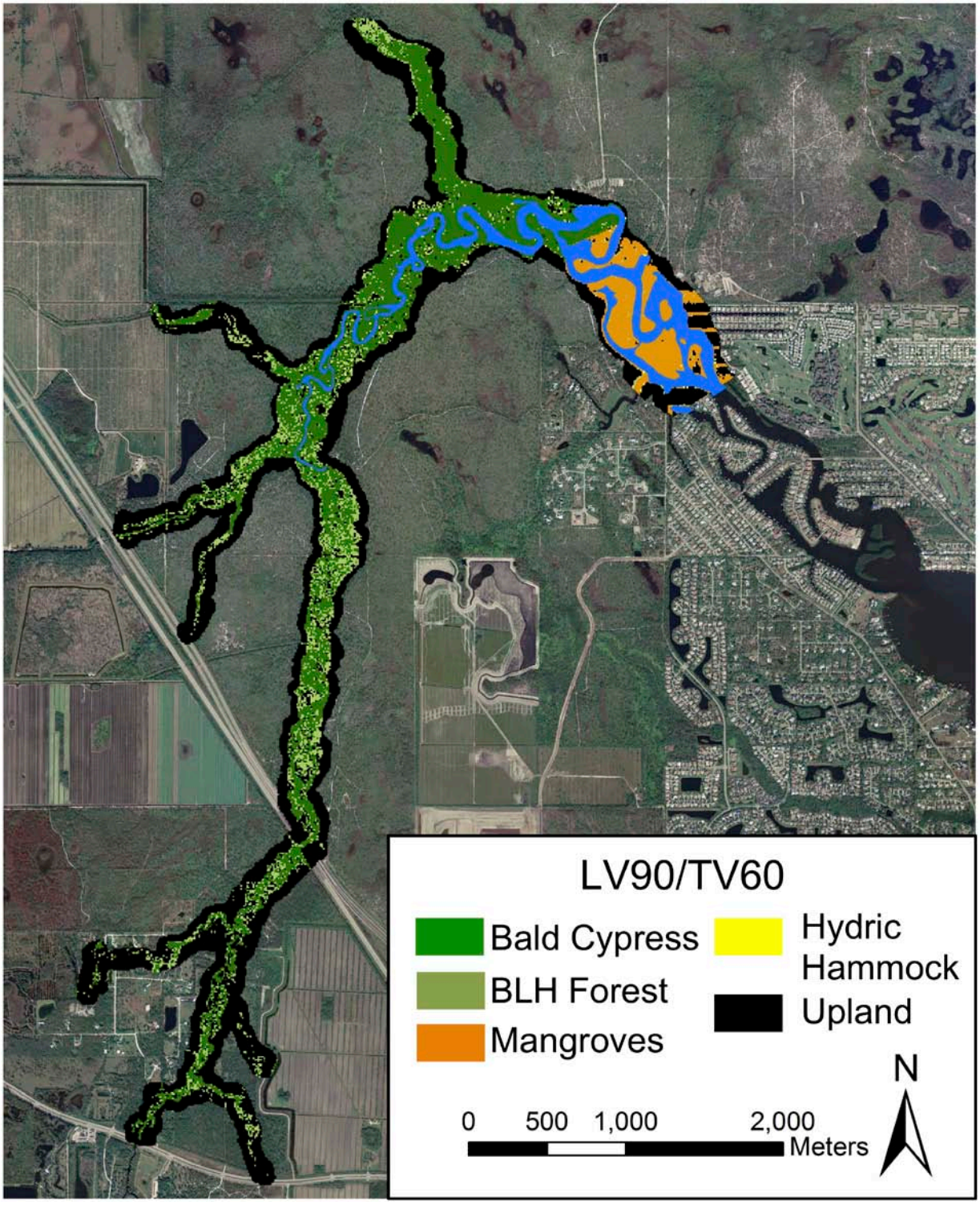

Figure 6-18. Modeled floodplain vegetation results from the EcoLox model under the LV90/TV60 restoration scenario.

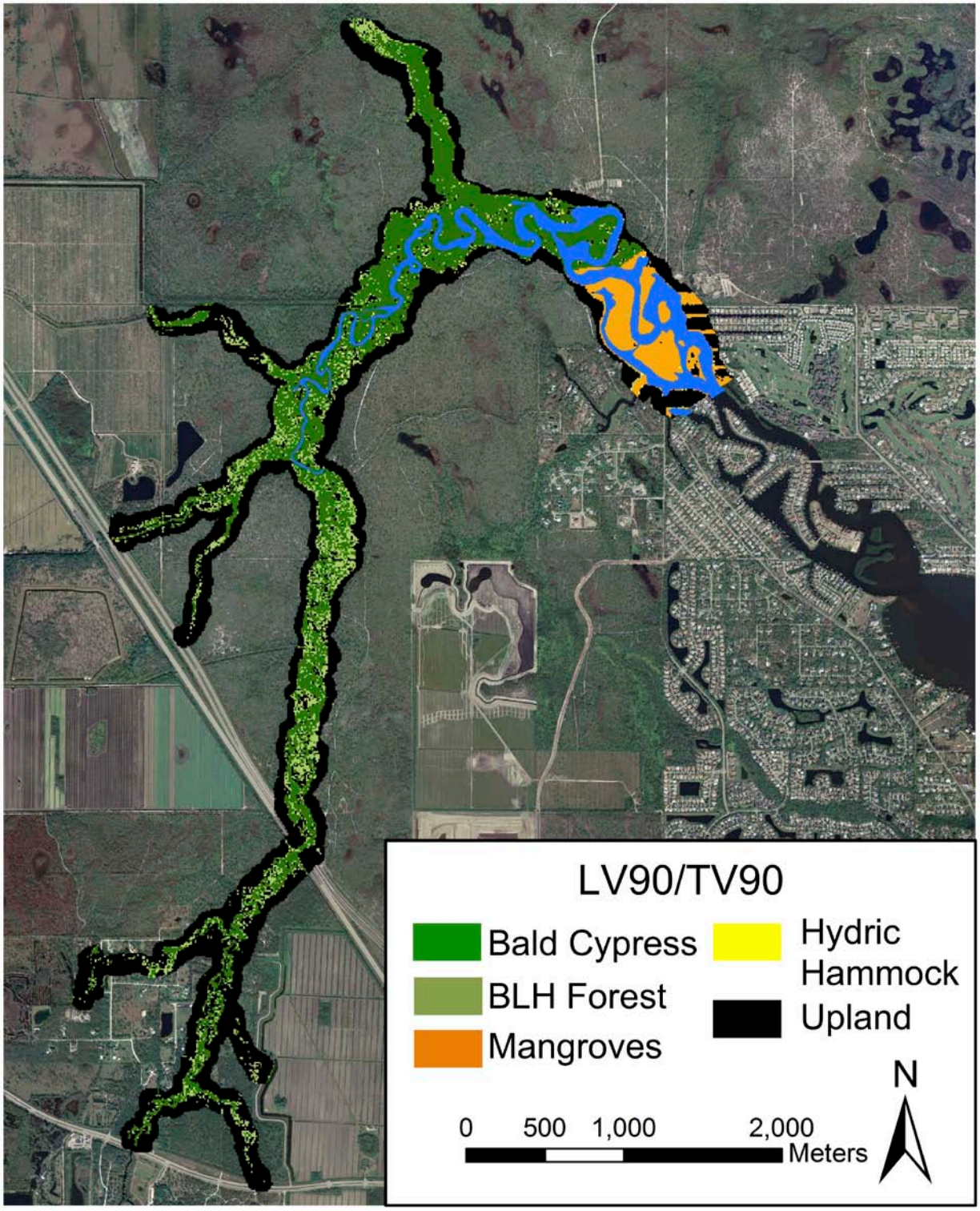

Figure 6-19. Modeled floodplain vegetation results from the EcoLox model under the LV90/TV90 restoration scenario.

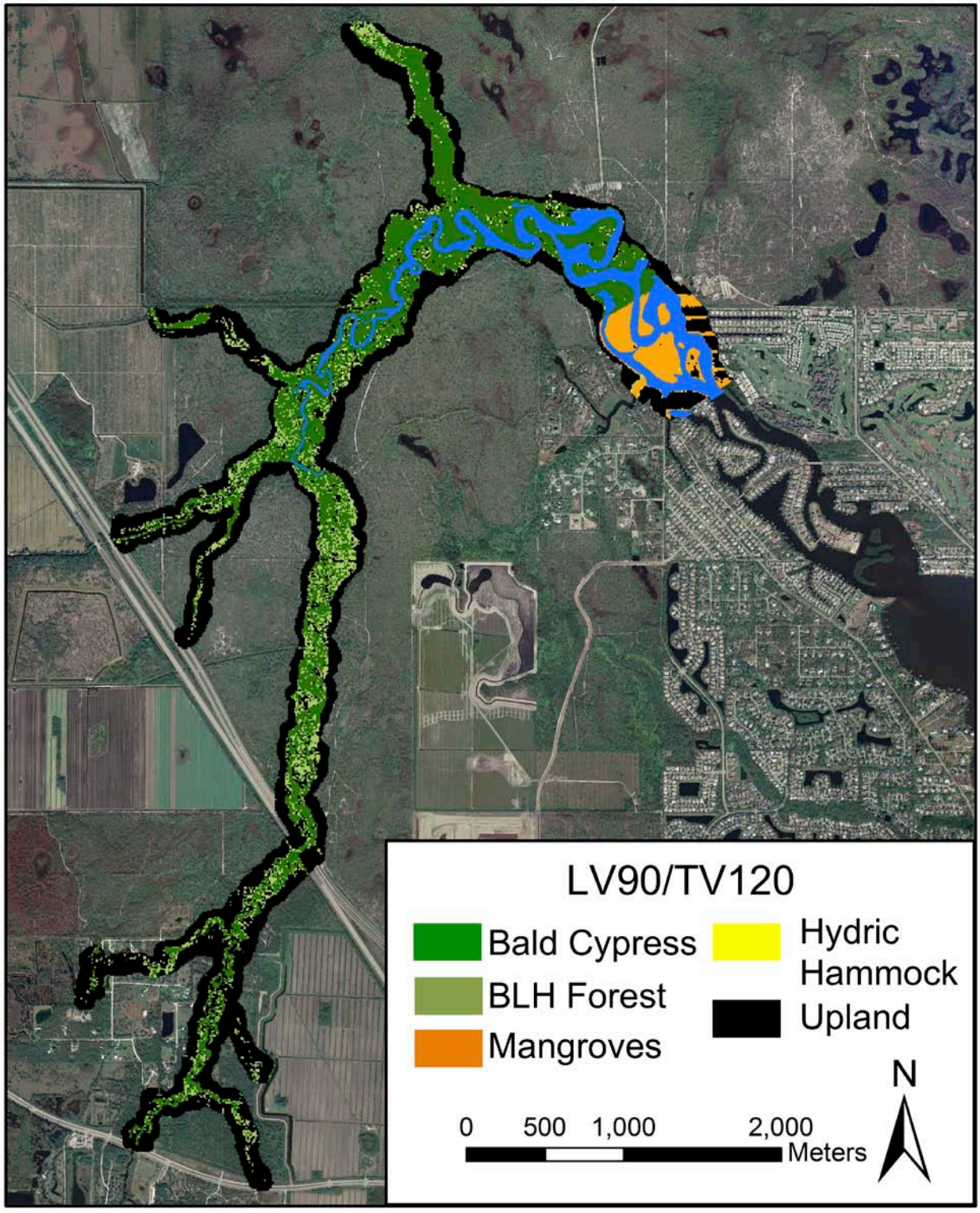

Figure 6-20. Modeled floodplain vegetation results from the EcoLox model under the LV90/TV120 restoration scenario.

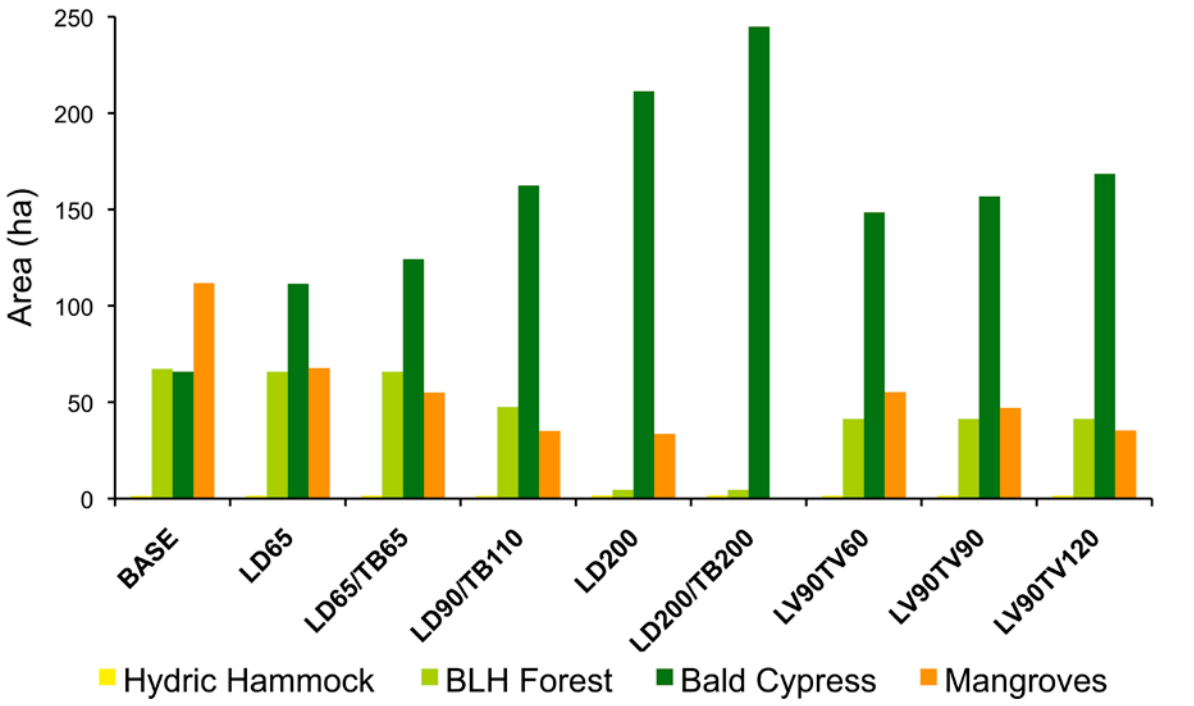

Figure 6-21. Distribution of habitat types under the BASE case and eight restoration scenarios.

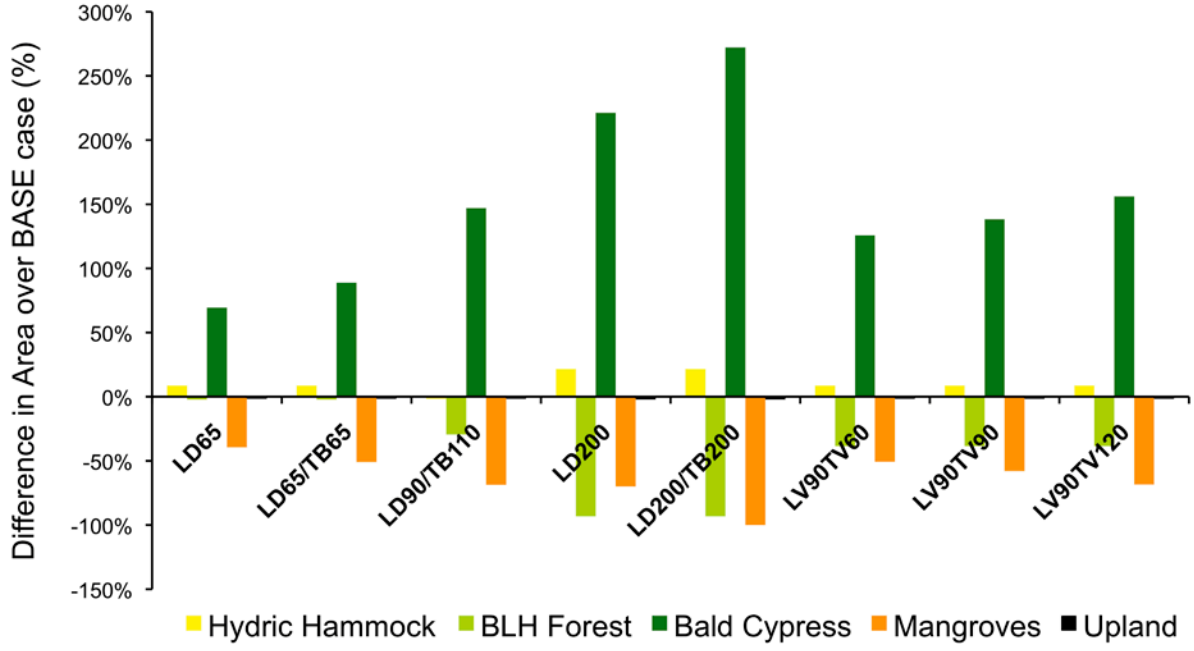

Figure 6-22. Percentage change in each category of floodplain vegetation from the BASE case for the eight restoration scenarios.

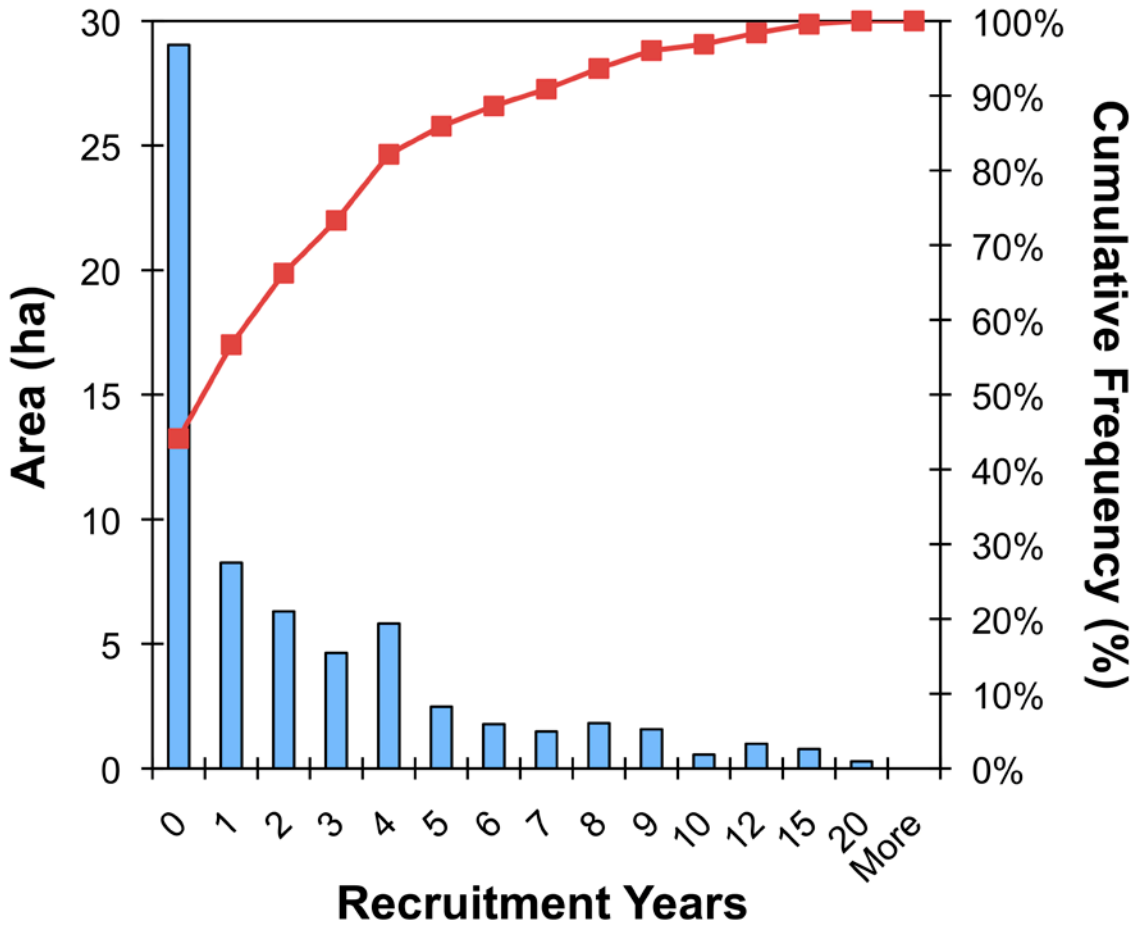

Figure 6-23. Distribution of recruitment years (i.e., number of years during the 40-year period of record with successful seedling recruitment) in areas with bald cypress habitat type under the BASE case.

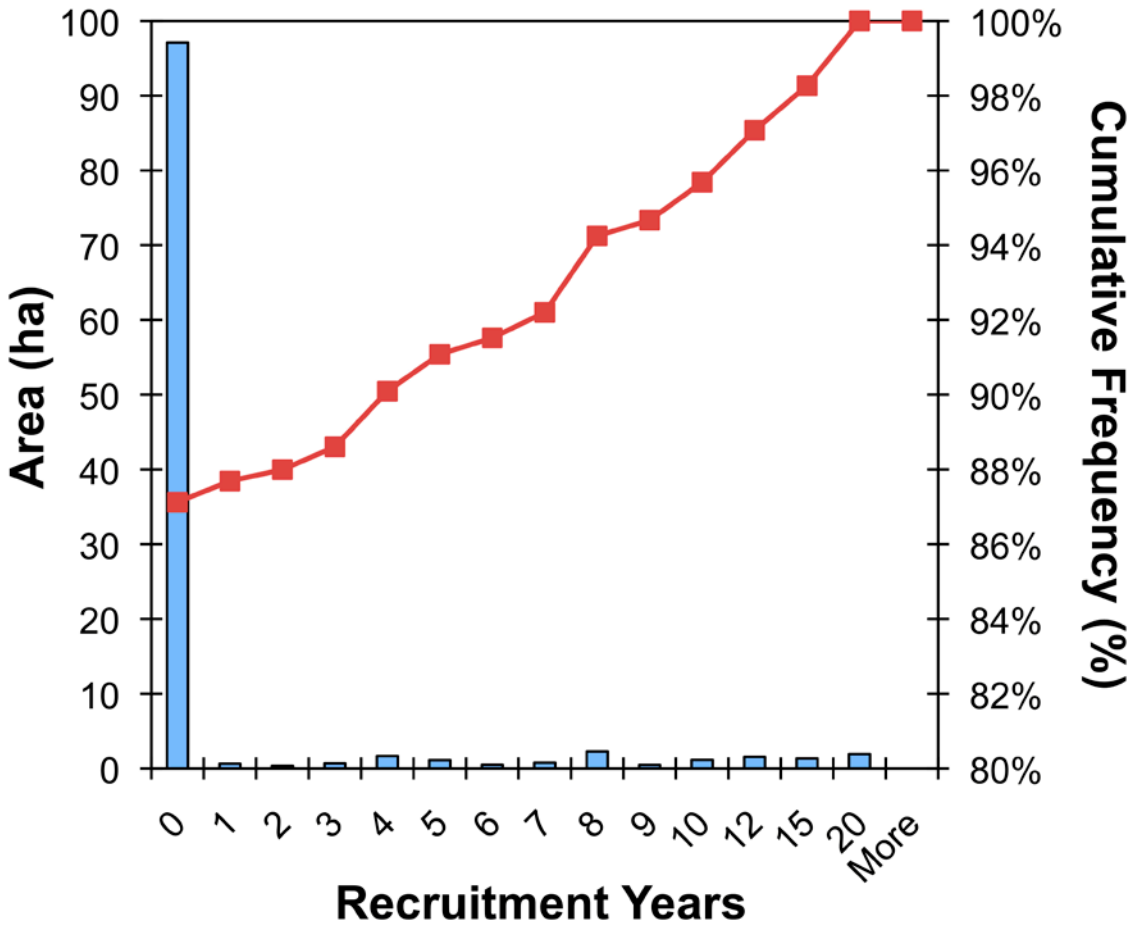

Figure 6-24. Distribution of recruitment years (i.e., number of years during the 40-year period of record with successful seedling recruitment) in areas with bald cypress habitat type under the LD65 restoration scenario case.

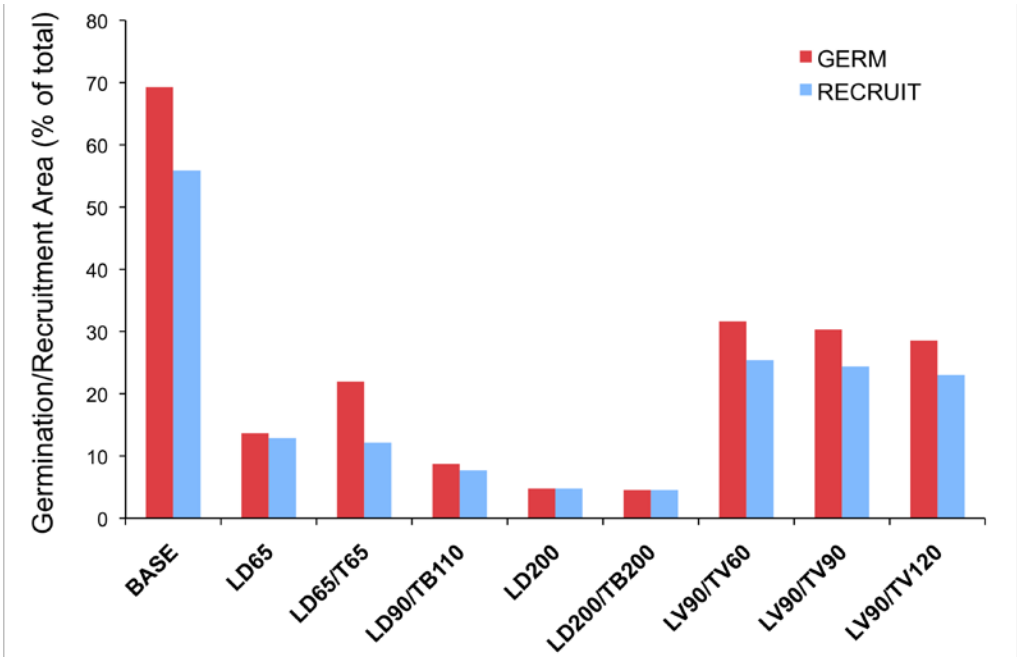

Figure 6-25. Area of bald cypress swamp with one or more germination years (red bars) and recruitment years (blue bars) over the 40-year period of record, expressed as a percentage of the total bald cypress habitat area for the BASE case and eight restoration scenarios.

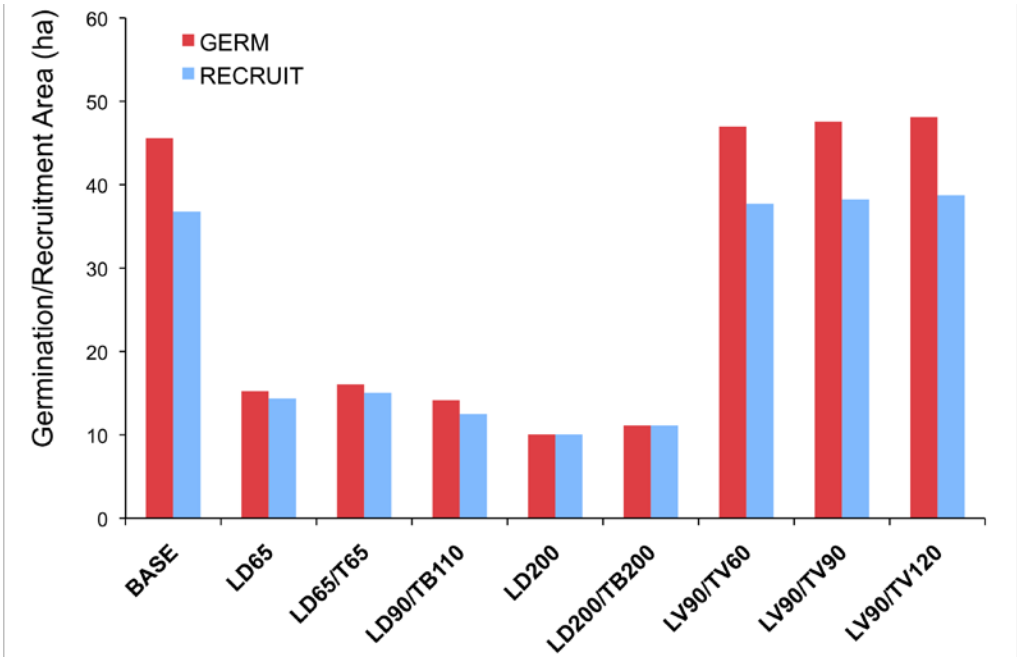

Figure 6-26. Total area of bald cypress swamp with one or more germination years (red bars) and recruitment years (blue bars) over the 40-year period of record for the BASE case and eight restoration scenarios.

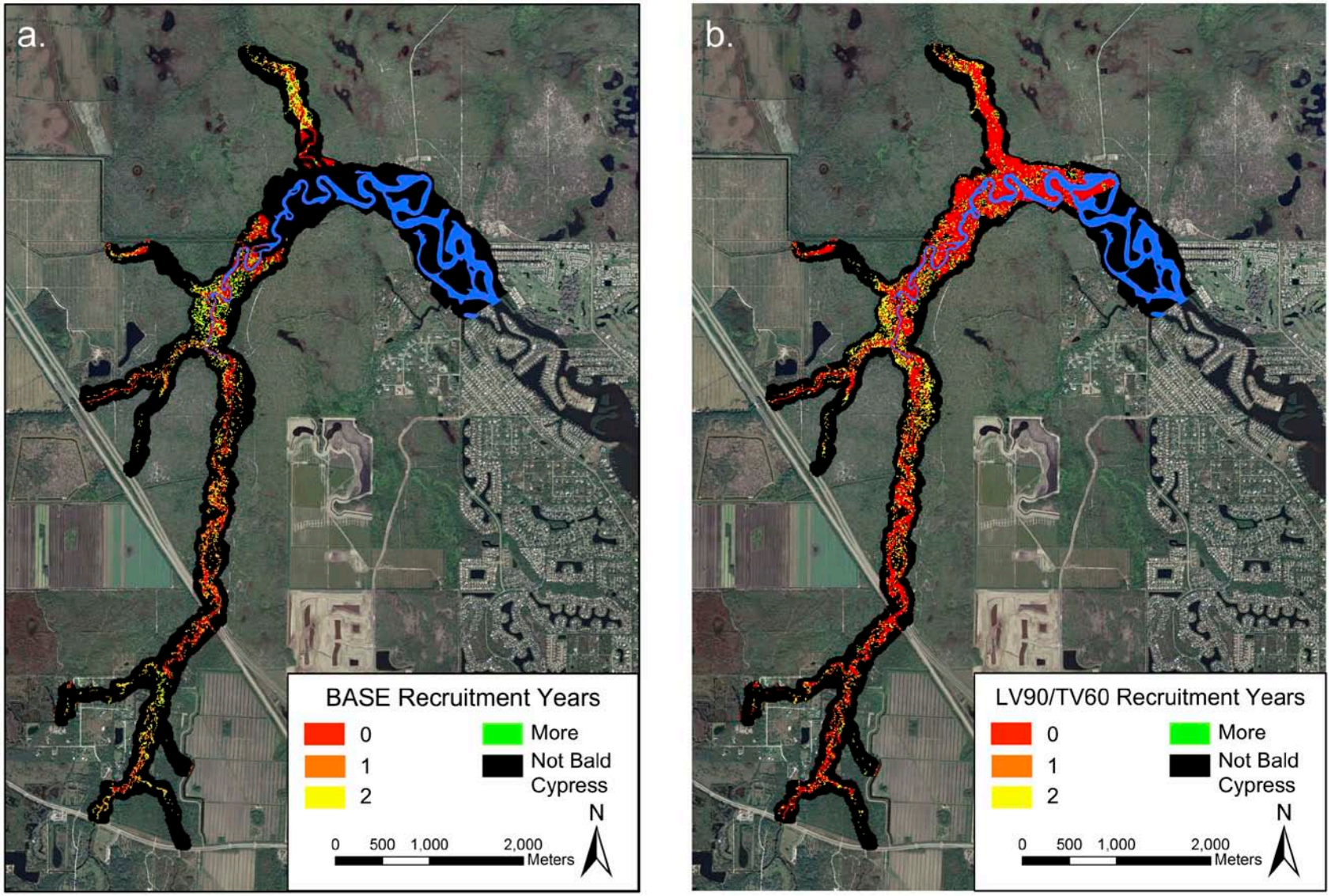

Figure 6-27. Spatial distribution of recruitment years for areas of bald cypress area under the (a) BASE case and (b) LV90/TV60 restoration scenario.

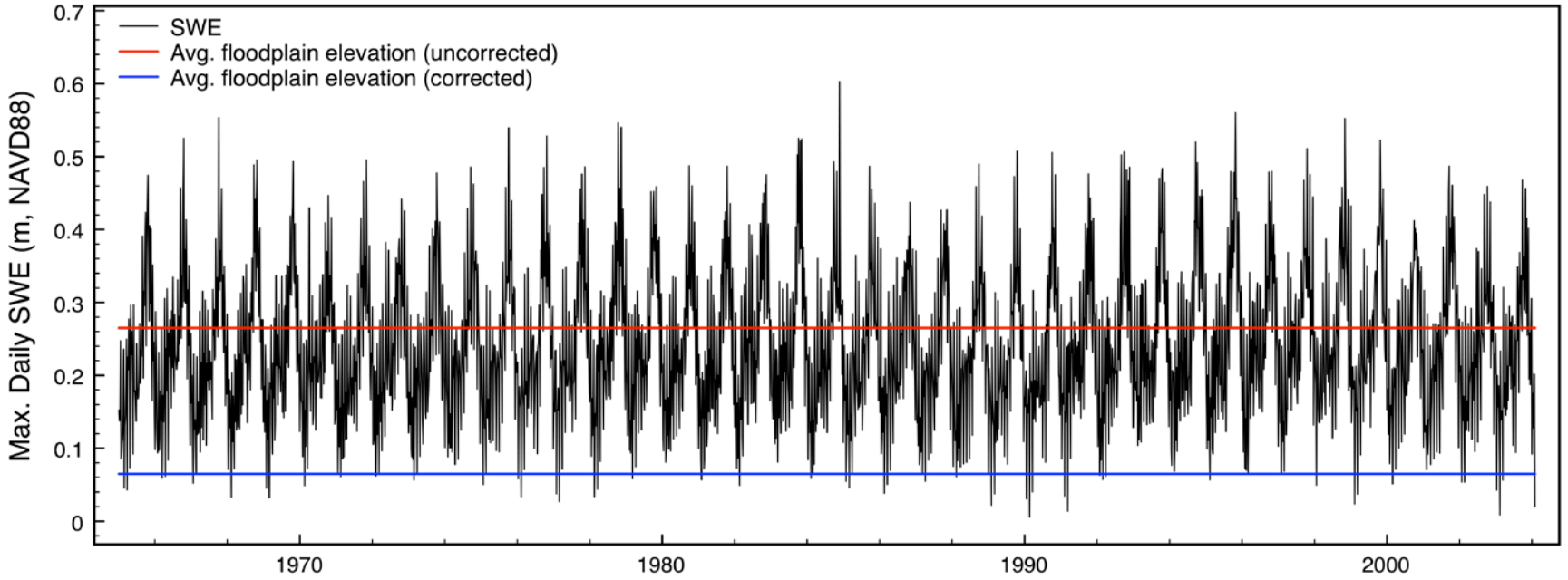

Figure 6-28. Surface water elevation (SWE) in Reach 20 over the 40-year period of record and the average corrected (blue line) and uncorrected (red line) floodplain elevation from LiDAR data.

CHAPTER 7
CONCLUSION

Bald cypress floodplain swamp and hydric hammock have been identified as valued ecosystem components (VECs) in the Northwest Fork of the Loxahatchee River (NW Fork), which has suffered from increased salinity and reduced hydroperiod due to hydrologic modifications in the watershed. The NW Fork has been the focus of intensive data collection and modeling efforts aimed at developing ecosystem restoration scenarios to benefit VECs, but previous studies had overlooked hydrological conditions in the floodplain vadose zone. To meet the goal of protecting and restoring bald cypress swamp, this four-year study investigated soil moisture (θ) and soil porewater electrical conductivity (σ_w) dynamics in the floodplain of the Loxahatchee River at two transects—an upstream, freshwater transect dominated by bald cypress (T1) and a downstream, transitionally-tidal transect with a mix of freshwater and salt-tolerant species (T7). These data were complemented by collocated surface water and groundwater stage and salinity and meteorological data.

The analysis in Chapter 2 showed that complex interactions of rainfall, surface water, and groundwater dominate the dynamics of θ and σ_w in coastal wetlands. In particular, upstream σ_w rarely exceeded tolerance thresholds for bald cypress, but did so more frequently (and for longer duration) in some downstream areas. These data provided a better explanation for the observed spatial patterns of floodplain vegetation than either surface water or groundwater data, reinforcing the importance of monitoring in the vadose zone. The θ and σ_w relationships drawn in the study allow us to assess the likely impacts of restoration and management scenarios on the ecological communities in the floodplain of the Loxahatchee River. For example, the proposed

restoration flow scenario (which was developed based on floodplain inundation and downstream surface water quality performance measures) will provide good θ conditions for bald cypress seed germination in the riverine floodplain at T1 during the dry season and maintain σ_w in the soil profile below the bald cypress tolerance threshold at T7.

Further analysis of detailed hydrological multivariate time series obtained in and around the Loxahatchee River was pursued in Chapters 3, 4, and 5 using dynamic factor analysis (DFA). The analysis was successfully applied to understand the hydrological processes in this area, which has been affected by reduced hydroperiod and increased saltwater intrusion. Applied to groundwater level data (Chapter 3), the technique proved to be a powerful tool for the study of interactions among 29 long-term, non-stationary hydrological time series (twelve water table elevation [WTE] series and seventeen candidate explanatory variables). Upstream and tidal surface water elevations (SWE), regional groundwater circulation (WTE_R), and cumulative net local recharge (R_{net}) were found to be the most important factors responsible for groundwater variation in the floodplain wetlands of the Loxahatchee River, and the analysis quantified the spatial distribution of the importance of each explanatory variable to WTE in the twelve monitoring wells.

The DFM resulting from the DFA (Model II) had good results (overall $C_{eff} = 0.91$, $0.78 \leq C_{eff} \leq 1.0$, visual inspection) and is useful for filling in data gaps during the study period and identifying the relative importance and relationships between hydrological variables of interest. The reduced model with no common trends (Model III) did a fair to excellent job (overall $C_{eff} = 0.81$, $0.59 \leq C_{eff} \leq 0.94$), and is likely adequate for describing

variations in WTE in the Loxahatchee River floodplain. This empirical model may be deemed useful for assessment of the effects of Loxahatchee River restoration and management scenarios on WTE dynamics.

The study also provides a quantitative validation of our qualitative expectations that tidal effects propagate some distance inland (along a river or estuary), river effects propagate some distance inland from the banks (here to swamps/floodplains), hydraulic structure effects propagate some distance from the structure, and net recharge effects are highly localized. Results of the analysis presented here have practical implications, in addition to guiding climate change mitigation planning and ecohydrologic analysis of salinity in coastal river wetlands. For example, mechanistic modeling efforts that consider spatial variability of land covers and soils would likely benefit from knowledge of where tidal effects end and the degree to which local rainfall variability is an important determining factor. Mechanistic frameworks using conditional modeling approaches can also benefit from knowing which explanatory variables are most important as a function of the relative location of a study area to the ocean, a tidal river, or hydraulic structures.

In Chapter 4, short-and long-term shallow groundwater electrical conductivity (GWEC) dynamics were observed in the floodplain wetlands along a gradient from the river's freshwater, riverine reach downstream through the upper and lower tidal reaches. Sharp GWEC gradients were observed on transects with multiple wells, with high GWEC closer to the river decreasing by several orders of magnitude with increasing distance from the river. Peaks in surface water electrical conductivity (SWEC) and GWEC were often poorly correlated, with GWEC series evolving in a delayed and

extended manner relative to SWEC. Thus, surface water reached higher maximum salinities than groundwater in the adjacent floodplain, but average groundwater salinities were often higher over seasonal and yearly time periods. On riverine transects T1 and T3, GWEC was always well below the 0.3125 S/m environmental threshold proposed for ecological restoration of the freshwater floodplain swamp. GWEC also generally remained below this value on upper tidal transects T7 and T8, with the exception of well T8-W1, which had high values of GWEC for much of 2006 and 2007. GWEC in the lower tidal floodplain was above the threshold (in wells T9-W1 and T9-W2) over the entire four-year study. High-resolution GWEC data revealed daily oscillations in GWEC in both tidal and riverine reaches and flushing of salts from the shallow groundwater was also observed in both reaches.

DFA was again used to study of interactions among these long-term, non-stationary hydrological time series, and a DFM consisting of three common trends and four explanatory variables (Model II) simulated observed GWEC data well ($C_{eff} = 0.85$; $0.52 \leq C_{eff} \leq 0.99$). The best DFM used cumulative net recharge from the S-46 weather station ($R_{net,S46}$), a single trend fit to nine regional USGS wells (WTE_R), cumulative flow deficit at Lainhart Dam calculated with a critical flow of 3.0 $m^3 s^{-1}$ ($CFD_{3.0}$), and cumulative salinity deviation calculated from surface water electrical conductivity (SWEC) measured at RK 9.5 in the NW Fork ($CSD_{RK9.5}$).

In Chapter 5, DFA was applied to improve the model of floodplain soil moisture developed in Chapter 2. The resulting identified the most useful explanatory variables for describing Θ_e variation: surface water elevations (SWE), capped water table elevation (WTE_{κ}), and cumulative net recharge (R_{net}). The analysis also quantified the

spatial distribution of the importance of explanatory variables to Θ_e in each location, highlighting the differential effects of surface water and groundwater on floodplain soil moisture. Variation in Θ_e series was adequately described using just these explanatory variables after removing the trends (overall $C_{eff} = 0.79$, $0.59 \leq C_{eff} \leq 0.93$). The complex variability observed in these multivariate hydrological datasets was simplified using DFA, and the resulting models are useful for assessing the effects of proposed ecological restoration and management scenarios on Θ_e dynamics in the floodplain.

Finally, an initial ecohydrological model (EcoLox) was developed to assess the likely impacts of restoration and management scenarios on the floodplain vegetation of the Loxahatchee River (Chapter 6). EcoLox was used to successfully simulate historic conditions and examine the likely results of proposed restoration. In general, the model predicts the possibility of restoring large areas of bald cypress habitat, but raises concerns about the natural regeneration potential of these areas. Additional work is required to improve the model structure (particularly the selection of the best porewater D_s:D_b ratio) and refine model inputs (above all, the LiDAR dataset needs to be thoroughly QA/QC'ed before making management decisions based on model results). The next step in the development of the EcoLox model will be to perform a global uncertainty and sensitivity analysis (UA/SA), which will help point out the most important model parameters and variables. With UA/SA results as guidance, future work may include more detailed simulations of surface water elevation and salinity, improved subroutines for seedling growth, and incorporation of the impacts of sea-level rise, fire, and frost.

The field and analytical methods used here can be successfully applied to other locations where restoration of floodplain ecosystems depends on hydrological conditions in the vadose zone. These efforts would be further improved by species-specific studies of moisture requirements for seed germination and studies on the effects of variable tidal inundation on the seeds and seedlings of important floodplain species. Continued monitoring of river and floodplain hydrology and vegetation in the Loxahatchee River will be important to determine whether the restoration flow scenario is achieving the goal of protecting and restoring VECs.

APPENDIX A
MEAN DAILY SOIL MOISTURE AND POREWATER SALINITY DATA

Table A-1. Mean daily soil moisture (θ) and porewater salinity (σ_w) for measurement locations on Transect 1.

	T1-60 (25 cm)		T1-60 (35 cm)		T1-60 (55 cm)		T1-50 (30 cm)		T1-50 (50 cm)		T1-50 (95 cm)		T1-30 (25 cm)		T1-30 (50 cm)		T1-30 (80 cm)		T1-1 (25 cm)		T1-1 (50 cm)		T1-1 (72 cm)	
Date	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w
9/17/2004	0.055	0.106	0.184	0.000	0.317	0.000	0.174	0.000	0.281	0.007	0.344	0.045												
9/18/2004	0.053	0.101	0.181	0.000	0.317	0.000	0.174	0.000	0.282	0.016	0.343	0.047												
9/19/2004	0.052	0.098	0.179	0.000	0.318	0.000	0.174	0.000	0.283	0.021	0.341	0.049												
9/20/2004	0.069	0.126	0.193	0.000	0.320	0.000	0.189	0.000	0.310	0.025	0.340	0.049												
9/21/2004	0.262	0.000	0.350	0.009	0.325	0.000	0.314	0.005	0.334	0.027	0.344	0.047												
9/22/2004	0.308	0.000	0.352	0.004	0.326	0.000	0.321	0.006	0.336	0.018	0.344	0.047												
9/23/2004	0.291	0.000	0.353	0.002	0.325	0.000	0.320	0.007	0.335	0.018	0.341	0.047												
9/24/2004	0.241	0.000	0.351	0.000	0.324	0.002	0.320	0.006	0.333	0.025	0.338	0.046												
9/25/2004	0.193	0.000	0.349	0.000	0.324	0.017	0.320	0.020	0.330	0.037	0.336	0.045												
9/26/2004	0.314	0.000	0.346	0.001	0.330	0.013	0.331	0.021	0.340	0.031	0.343	0.045												
9/27/2004	0.316	0.000	0.352	0.003	0.332	0.012	0.334	0.022	0.342	0.031	0.344	0.045												
9/28/2004	0.316	0.000	0.354	0.004	0.331	0.004	0.337	0.024	0.341	0.032	0.342	0.045												
9/29/2004	0.313	0.000	0.354	0.005	0.329	0.000	0.337	0.025	0.340	0.033	0.338	0.046												
9/30/2004	0.309	0.000	0.357	0.001	0.330	0.000	0.338	0.024	0.339	0.031	0.336	0.045												
10/1/2004	0.293	0.000	0.357	0.003	0.329	0.004	0.340	0.024	0.339	0.027	0.334	0.045												
10/2/2004	0.226	0.000	0.357	0.001	0.328	0.001	0.339	0.019	0.339	0.025	0.333	0.044												
10/3/2004	0.151	0.000	0.356	0.000	0.328	0.000	0.321	0.020	0.336	0.027	0.332	0.044												
10/4/2004	0.119	0.000	0.355	0.000	0.327	0.002	0.252	0.003	0.335	0.025	0.330	0.044												
10/5/2004	0.096	1.076	0.354	0.000	0.327	0.011	0.185	0.000	0.335	0.024	0.329	0.045												
10/6/2004	0.084	0.383	0.284	0.000	0.328	0.015	0.156	0.000	0.334	0.021	0.329	0.045												
10/7/2004	0.076	0.212	0.250	0.000	0.328	0.009	0.140	0.000	0.333	0.022	0.328	0.046												
10/8/2004	0.072	0.170	0.236	0.000	0.328	0.003	0.129	0.000	0.329	0.021	0.327	0.046												
10/9/2004	0.070	0.154	0.230	0.000	0.328	0.001	0.142	0.000	0.329	0.017	0.327	0.046												
10/10/2004	0.068	0.146	0.227	0.000	0.328	0.000	0.148	0.000	0.329	0.016	0.327	0.047												
10/11/2004	0.067	0.140	0.225	0.000	0.329	0.002	0.148	0.000	0.330	0.016	0.327	0.047												
10/12/2004	0.068	0.142	0.224	0.000	0.329	0.003	0.148	0.000	0.330	0.015	0.326	0.047												
10/13/2004	0.067	0.134	0.222	0.000	0.329	0.002	0.146	0.000	0.330	0.015	0.325	0.048												
10/14/2004	0.065	0.124	0.219	0.000	0.329	0.000	0.144	0.000	0.331	0.016	0.325	0.048												
10/15/2004	0.063	0.120	0.215	0.000	0.329	0.000	0.141	0.000	0.331	0.016	0.324	0.049												
10/16/2004	0.061	0.110	0.212	0.000	0.331	0.000	0.138	0.000	0.331	0.016	0.325	0.049												
10/17/2004	0.059	0.105	0.208	0.000	0.331	0.000	0.136	0.000	0.332	0.016	0.325	0.049												
10/18/2004	0.058	0.101	0.204	0.000	0.331	0.000	0.134	0.000	0.332	0.016	0.325	0.049												
10/19/2004	0.057	0.099	0.201	0.000	0.331	0.000	0.133	0.000	0.333	0.016	0.325	0.049												
10/20/2004	0.058	0.099	0.203	0.000	0.331	0.000	0.152	0.000	0.334	0.016	0.325	0.049												
10/21/2004	0.065	0.119	0.208	0.000	0.331	0.000	0.170	0.000	0.336	0.017	0.325	0.049												
10/22/2004	0.065	0.122	0.208	0.000	0.331	0.000	0.170	0.000	0.336	0.017	0.325	0.049												
10/23/2004	0.074	0.194	0.211	0.000	0.332	0.000	0.178	0.007	0.338	0.018	0.325	0.049												
10/24/2004	0.076	0.163	0.215	0.000	0.332	0.000	0.184	0.044	0.339	0.017	0.325	0.050												
10/25/2004	0.070	0.127	0.213	0.000	0.332	0.000	0.180	0.045	0.340	0.017	0.325	0.050												
10/26/2004	0.067	0.116	0.211	0.000	0.331	0.000	0.178	0.037	0.340	0.017	0.325	0.050												
10/27/2004	0.064	0.108	0.209	0.000	0.331	0.000	0.176	0.025	0.340	0.017	0.325	0.050												
10/28/2004	0.063	0.105	0.208	0.000	0.331	0.000	0.175	0.014	0.340	0.018	0.325	0.050												
10/29/2004	0.063	0.103	0.207	0.000	0.331	0.000	0.176	0.006	0.340	0.017	0.324	0.050												
10/30/2004	0.062	0.102	0.206	0.000	0.330	0.000	0.175	0.000	0.340	0.018	0.324	0.050												
10/31/2004	0.061	0.099	0.205	0.000	0.330	0.000	0.173	0.000	0.341	0.018	0.324	0.050												

Table A-1. Continued.

	T1-60 (25 cm)		T1-60 (35 cm)		T1-60 (55 cm)		T1-50 (30 cm)		T1-50 (50 cm)		T1-50 (95 cm)		T1-30 (25 cm)		T1-30 (50 cm)		T1-30 (80 cm)		T1-1 (25 cm)		T1-1 (50 cm)		T1-1 (72 cm)	
Date	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w
11/1/2004	0.061	0.099	0.204	0.000	0.330	0.000	0.172	0.000	0.340	0.018	0.323	0.051												
11/2/2004	0.060	0.098	0.203	0.000	0.329	0.000	0.170	0.000	0.340	0.018	0.323	0.051												
11/3/2004	0.060	0.097	0.202	0.000	0.329	0.000	0.168	0.000	0.340	0.019	0.323	0.051												
11/4/2004	0.058	0.093	0.201	0.000	0.328	0.000	0.163	0.000	0.339	0.018	0.322	0.051												
11/5/2004	0.057	0.092	0.197	0.000	0.328	0.000	0.142	0.012	0.338	0.018	0.321	0.051												
11/6/2004	0.055	0.088	0.191	0.000	0.328	0.000	0.126	0.095	0.336	0.018	0.320	0.050												
11/7/2004	0.052	0.085	0.184	0.000	0.328	0.000	0.120	0.155	0.335	0.015	0.319	0.051												
11/8/2004	0.051	0.084	0.175	0.000	0.328	0.000	0.115	0.195	0.335	0.013	0.319	0.051												
11/9/2004	0.050	0.082	0.165	0.000	0.328	0.000	0.110	0.226	0.335	0.010	0.320	0.051												
11/10/2004	0.048	0.079	0.154	0.000	0.328	0.000	0.105	0.276	0.334	0.008	0.320	0.051												
11/11/2004	0.047	0.078	0.145	0.000	0.327	0.000	0.096	0.723	0.331	0.006	0.319	0.051												
11/12/2004	0.046	0.077	0.136	0.000	0.327	0.000	0.088	0.000	0.326	0.004	0.318	0.051												
11/13/2004	0.044	0.075	0.129	0.000	0.327	0.000	0.082	0.000	0.317	0.002	0.318	0.052												
11/14/2004	0.049	0.081	0.127	0.000	0.328	0.000	0.081	0.000	0.304	0.001	0.319	0.052												
11/15/2004	0.060	0.096	0.129	0.000	0.328	0.000	0.082	0.010	0.302	0.001	0.319	0.052												
11/16/2004	0.055	0.085	0.125	0.000	0.328	0.000	0.076	0.060	0.288	0.001	0.319	0.052												
11/17/2004	0.051	0.080	0.122	0.000	0.327	0.000	0.073	0.066	0.264	0.000	0.318	0.052												
11/18/2004	0.050	0.077	0.122	0.000	0.327	0.000	0.072	0.066	0.257	0.000	0.318	0.052												
11/19/2004	0.049	0.076	0.119	0.000	0.327	0.000	0.072	0.064	0.252	0.000	0.318	0.054												
11/20/2004	0.047	0.075	0.115	0.000	0.327	0.000	0.070	0.063	0.246	0.000	0.317	0.055												
11/21/2004	0.045	0.072	0.111	0.000	0.327	0.000	0.067	0.064	0.236	0.000	0.317	0.056												
11/22/2004	0.045	0.073	0.110	0.000	0.327	0.000	0.066	0.064	0.228	0.000	0.317	0.056												
11/23/2004	0.044	0.070	0.107	0.000	0.326	0.000	0.064	0.063	0.221	0.000	0.316	0.057												
11/24/2004	0.043	0.069	0.103	0.000	0.326	0.000	0.063	0.063	0.212	0.000	0.316	0.057												
11/25/2004	0.042	0.070	0.101	0.000	0.325	0.000	0.062	0.063	0.205	0.000	0.315	0.058												
11/26/2004	0.041	0.068	0.097	2.518	0.325	0.000	0.060	0.064	0.196	0.000	0.316	0.057												
11/27/2004	0.040	0.068	0.094	4.550	0.325	0.000	0.058	0.062	0.189	0.000	0.315	0.057												
11/28/2004	0.041	0.068	0.092	1.686	0.325	0.000	0.059	0.064	0.184	0.000	0.315	0.057												
11/29/2004	0.043	0.069	0.089	0.526	0.325	0.000	0.057	0.063	0.178	0.000	0.316	0.056												
11/30/2004	0.043	0.068	0.085	0.339	0.325	0.000	0.055	0.061	0.173	0.000	0.316	0.056												
12/1/2004	0.042	0.066	0.080	0.217	0.326	0.000	0.056	0.062	0.171	0.000	0.316	0.057												
12/2/2004	0.041	0.064	0.076	0.177	0.326	0.000	0.053	0.062	0.161	0.000	0.315	0.056												
12/3/2004	0.040	0.063	0.072	0.155	0.326	0.000	0.051	0.061	0.152	0.000	0.315	0.055												
12/4/2004	0.039	0.063	0.068	0.135	0.326	0.000	0.049	0.059	0.145	0.000	0.315	0.055												
12/5/2004	0.039	0.062	0.065	0.122	0.327	0.000	0.048	0.058	0.139	0.000	0.315	0.054												
12/6/2004	0.038	0.061	0.063	0.113	0.328	0.000	0.047	0.058	0.135	0.000	0.315	0.055												
12/7/2004	0.037	0.061	0.062	0.112	0.328	0.000	0.046	0.058	0.133	0.000	0.316	0.056												
12/8/2004	0.036	0.060	0.060	0.105	0.328	0.000	0.045	0.057	0.128	0.000	0.316	0.056												
12/9/2004	0.036	0.060	0.058	0.104	0.328	0.000	0.044	0.057	0.124	0.000	0.316	0.056												
12/10/2004	0.035	0.058	0.057	0.098	0.328	0.000	0.044	0.057	0.121	0.000	0.315	0.057												
12/11/2004	0.034	0.057	0.055	0.096	0.319	0.000	0.043	0.056	0.118	0.000	0.316	0.057												
12/12/2004	0.033	0.056	0.054	0.093	0.269	0.000	0.041	0.056	0.112	0.000	0.317	0.057												
12/13/2004	0.032	0.056	0.052	0.089	0.250	0.000	0.040	0.055	0.107	0.000	0.318	0.057												
12/14/2004	0.031	0.055	0.051	0.086	0.233	0.000	0.040	0.055	0.103	0.000	0.319	0.058												
12/15/2004	0.031	0.054	0.050	0.084	0.214	0.000	0.039	0.055	0.099	0.000	0.321	0.058												
12/16/2004	0.030	0.054	0.049	0.084	0.195	0.000	0.038	0.054	0.095	3.904	0.322	0.058												
12/17/2004	0.030	0.053	0.048	0.082	0.183	0.000	0.037	0.053	0.094	3.993	0.323	0.058												
12/18/2004	0.031	0.053	0.048	0.082	0.178	0.000	0.037	0.054	0.094	5.094	0.324	0.060												
12/19/2004	0.036	0.055	0.047	0.081	0.173	0.000	0.037	0.053	0.091	0.995	0.325	0.061												
12/20/2004	0.039	0.056	0.047	0.080	0.166	0.000	0.036	0.053	0.085	0.356	0.325	0.061												

Table A-1. Continued.

	T1-60 (25 cm)		T1-60 (35 cm)		T1-60 (55 cm)		T1-50 (30 cm)		T1-50 (50 cm)		T1-50 (95 cm)		T1-30 (25 cm)		T1-30 (50 cm)		T1-30 (80 cm)		T1-1 (25 cm)		T1-1 (50 cm)		T1-1 (72 cm)	
Date	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w
12/21/2004	0.038	0.054	0.045	0.078	0.161	0.000	0.035	0.052	0.082	0.260	0.326	0.061												
12/22/2004	0.039	0.055	0.045	0.078	0.156	0.000	0.035	0.052	0.082	0.252	0.327	0.061												
12/23/2004	0.039	0.055	0.046	0.080	0.153	0.000	0.035	0.052	0.083	0.266	0.328	0.061												
12/24/2004	0.041	0.056	0.046	0.079	0.153	0.000	0.035	0.052	0.084	0.287	0.330	0.061												
12/25/2004	0.060	0.094	0.046	0.079	0.154	0.000	0.036	0.053	0.086	0.351	0.332	0.061												
12/26/2004	0.069	0.141	0.049	0.086	0.155	0.000	0.037	0.053	0.087	0.397	0.333	0.062												
12/27/2004	0.061	0.111	0.057	0.097	0.154	0.000	0.037	0.052	0.085	0.320	0.336	0.066												
12/28/2004	0.057	0.099	0.056	0.091	0.153	0.000	0.038	0.051	0.083	0.259	0.337	0.067												
12/29/2004	0.054	0.090	0.054	0.084	0.149	0.000	0.037	0.051	0.080	0.211	0.337	0.067												
12/30/2004	0.051	0.086	0.054	0.086	0.144	0.000	0.037	0.049	0.076	0.173	0.337	0.065												
12/31/2004	0.049	0.082	0.052	0.081	0.143	0.000	0.037	0.049	0.085	0.294	0.336	0.060												
1/1/2005	0.048	0.081	0.050	0.078	0.142	0.000	0.038	0.049	0.083	0.252	0.336	0.065												
1/2/2005	0.047	0.079	0.049	0.075	0.139	0.000	0.037	0.047	0.080	0.202	0.337	0.068												
1/3/2005	0.045	0.075	0.048	0.075	0.134	0.000	0.036	0.047	0.075	0.157	0.337	0.068												
1/4/2005	0.042	0.070	0.047	0.073	0.128	0.000	0.035	0.047	0.070	0.127	0.335	0.066												
1/5/2005	0.042	0.070	0.046	0.071	0.123	0.000	0.035	0.047	0.066	0.110	0.333	0.066												
1/6/2005	0.041	0.068	0.046	0.072	0.119	0.000	0.035	0.047	0.064	0.104	0.332	0.068												
1/7/2005	0.039	0.066	0.046	0.071	0.114	0.000	0.034	0.047	0.062	0.096	0.330	0.070												
1/8/2005	0.038	0.065	0.045	0.071	0.109	0.000	0.033	0.047	0.060	0.092	0.328	0.071												
1/9/2005	0.037	0.063	0.045	0.070	0.105	0.000	0.033	0.047	0.058	0.086	0.327	0.073												
1/10/2005	0.036	0.061	0.044	0.069	0.101	0.788	0.032	0.047	0.056	0.082	0.325	0.074												
1/11/2005	0.034	0.059	0.044	0.068	0.096	3.293	0.031	0.046	0.053	0.078	0.319	0.073												
1/12/2005	0.034	0.060	0.043	0.068	0.091	1.457	0.031	0.047	0.051	0.075	0.309	0.073												
1/13/2005	0.034	0.059	0.043	0.068	0.087	0.515	0.031	0.047	0.049	0.072	0.302	0.073												
1/14/2005	0.055	0.121	0.046	0.073	0.085	0.396	0.032	0.046	0.049	0.071	0.296	0.069	0.735	0.074	0.742	0.127	0.760	0.092	0.861	0.171	0.760	0.120	0.669	0.145
1/15/2005	0.079	0.236	0.079	0.208	0.093	1.379	0.065	0.023	0.057	0.080	0.302	0.066	0.741	0.079	0.742	0.130	0.764	0.091	0.865	0.170	0.758	0.123	0.669	0.149
1/16/2005	0.070	0.158	0.076	0.217	0.109	0.000	0.069	0.037	0.067	0.084	0.310	0.073	0.741	0.083	0.742	0.132	0.763	0.092	0.862	0.174	0.759	0.124	0.666	0.153
1/17/2005	0.058	0.105	0.067	0.152	0.117	0.000	0.060	0.053	0.068	0.075	0.314	0.074	0.741	0.084	0.742	0.132	0.763	0.092	0.860	0.177	0.761	0.122	0.668	0.154
1/18/2005	0.052	0.089	0.061	0.130	0.117	0.000	0.054	0.053	0.067	0.068	0.315	0.071	0.740	0.087	0.741	0.133	0.762	0.093	0.856	0.180	0.760	0.124	0.672	0.154
1/19/2005	0.048	0.083	0.058	0.118	0.115	0.000	0.050	0.053	0.065	0.060	0.314	0.071	0.741	0.088	0.740	0.133	0.762	0.093	0.855	0.181	0.759	0.126	0.671	0.154
1/20/2005	0.046	0.080	0.055	0.111	0.112	0.000	0.048	0.052	0.063	0.057	0.313	0.070	0.741	0.090	0.740	0.132	0.764	0.093	0.852	0.183	0.761	0.124	0.666	0.157
1/21/2005	0.044	0.076	0.053	0.105	0.109	0.000	0.045	0.050	0.060	0.054	0.312	0.070	0.742	0.091	0.740	0.132	0.763	0.093	0.852	0.179	0.759	0.127	0.672	0.155
1/22/2005	0.042	0.074	0.051	0.102	0.105	0.000	0.044	0.050	0.058	0.052	0.310	0.069	0.744	0.091	0.740	0.131	0.761	0.094	0.854	0.174	0.759	0.128	0.670	0.157
1/23/2005	0.041	0.073	0.050	0.098	0.102	0.000	0.042	0.049	0.057	0.052	0.308	0.069	0.744	0.094	0.741	0.130	0.763	0.093	0.851	0.178	0.758	0.129	0.673	0.156
1/24/2005	0.039	0.069	0.048	0.094	0.099	0.000	0.040	0.048	0.056	0.052	0.307	0.068	0.746	0.092	0.742	0.129	0.765	0.093	0.852	0.175	0.759	0.131	0.678	0.154
1/25/2005	0.037	0.067	0.047	0.091	0.097	0.805	0.038	0.048	0.054	0.052	0.305	0.068	0.746	0.091	0.741	0.130	0.764	0.093	0.849	0.175	0.760	0.129	0.676	0.155
1/26/2005	0.036	0.066	0.045	0.089	0.094	2.409	0.037	0.048	0.053	0.052	0.303	0.067	0.747	0.090	0.740	0.129	0.765	0.093	0.847	0.177	0.760	0.130	0.673	0.156
1/27/2005	0.035	0.065	0.045	0.088	0.091	0.966	0.036	0.047	0.051	0.051	0.300	0.068	0.745	0.090	0.740	0.128	0.763	0.094	0.830	0.173	0.759	0.131	0.670	0.157
1/28/2005							0.036	0.047	0.050	0.051	0.297	0.069	0.742	0.091	0.741	0.127	0.763	0.094	0.806	0.172	0.759	0.133	0.666	0.160
1/29/2005							0.034	0.047	0.049	0.051	0.293	0.069	0.743	0.090	0.741	0.126	0.763	0.094	0.802	0.169	0.760	0.132	0.665	0.161
1/30/2005							0.034	0.047	0.048	0.051	0.289	0.066	0.743	0.090	0.742	0.126	0.762	0.094	0.802	0.170	0.759	0.134	0.664	0.162
1/31/2005							0.033	0.046	0.047	0.051	0.287	0.064	0.744	0.090	0.742	0.126	0.761	0.095	0.804	0.171	0.759	0.136	0.664	0.162
2/1/2005							0.032	0.046	0.047	0.051	0.285	0.064	0.745	0.089	0.742	0.126	0.762	0.094	0.808	0.167	0.759	0.137	0.664	0.162
2/2/2005							0.031	0.046	0.046	0.051	0.281	0.064	0.744	0.090	0.741	0.126	0.763	0.094	0.801	0.170	0.759	0.138	0.666	0.161
2/3/2005							0.031	0.046	0.045	0.050	0.277	0.064	0.744	0.090	0.741	0.126	0.763	0.094	0.799	0.168	0.758	0.140	0.665	0.161
2/4/2005							0.031	0.047	0.044	0.050	0.272	0.063	0.745	0.089	0.740	0.128	0.766	0.094	0.796	0.170	0.759	0.140	0.668	0.161
2/5/2005							0.030	0.047	0.043	0.050	0.267	0.062	0.745	0.089	0.740	0.127	0.767	0.094	0.788	0.170	0.759	0.141	0.669	0.160
2/6/2005							0.029	0.046	0.042	0.049	0.262	0.061	0.745	0.088	0.740	0.126	0.764	0.095	0.781	0.169	0.758	0.142	0.667	0.161
2/7/2005							0.029	0.046	0.041	0.049	0.254	0.060	0.741	0.088	0.741	0.124	0.762	0.096	0.774	0.172	0.759	0.141	0.664	0.163
2/8/2005							0.028	0.046	0.040	0.050	0.249	0.058	0.737	0.088	0.740	0.125	0.763	0.097	0.773	0.172	0.759	0.141	0.664	0.163

Table A-1. Continued.

	T1-60 (25 cm)		T1-60 (35 cm)		T1-60 (55 cm)		T1-50 (30 cm)		T1-50 (50 cm)		T1-50 (95 cm)		T1-30 (25 cm)		T1-30 (50 cm)		T1-30 (80 cm)		T1-1 (25 cm)		T1-1 (50 cm)		T1-1 (72 cm)	
Date	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w
2/9/2005							0.028	0.046	0.039	0.048	0.244	0.057	0.736	0.088	0.740	0.125	0.763	0.097	0.772	0.173	0.759	0.142	0.663	0.164
2/10/2005							0.028	0.046	0.038	0.048	0.240	0.056	0.735	0.087	0.740	0.124	0.762	0.098	0.770	0.174	0.759	0.143	0.662	0.164
2/11/2005							0.027	0.046	0.037	0.047	0.234	0.056	0.733	0.088	0.742	0.122	0.763	0.098	0.766	0.172	0.760	0.141	0.663	0.164
2/12/2005							0.026	0.046	0.036	0.047	0.228	0.055	0.733	0.085	0.741	0.122	0.762	0.099	0.757	0.170	0.760	0.141	0.669	0.162
2/13/2005							0.026	0.045	0.035	0.047	0.223	0.055	0.732	0.085	0.741	0.121	0.762	0.099	0.748	0.174	0.759	0.139	0.669	0.163
2/14/2005							0.026	0.045	0.034	0.046	0.218	0.053	0.731	0.083	0.740	0.121	0.762	0.100	0.745	0.172	0.759	0.137	0.670	0.163
2/15/2005							0.025	0.045	0.033	0.046	0.213	0.051	0.730	0.083	0.741	0.121	0.764	0.100	0.741	0.173	0.760	0.133	0.676	0.161
2/16/2005							0.025	0.046	0.032	0.046	0.208	0.049	0.729	0.083	0.741	0.120	0.763	0.101	0.738	0.175	0.759	0.132	0.675	0.161
2/17/2005							0.025	0.045	0.032	0.045	0.205	0.048	0.729	0.083	0.741	0.120	0.764	0.101	0.736	0.174	0.759	0.130	0.675	0.162
2/18/2005							0.025	0.045	0.031	0.045	0.201	0.047	0.728	0.084	0.742	0.119	0.761	0.102	0.732	0.177	0.760	0.126	0.675	0.162
2/19/2005							0.024	0.045	0.030	0.045	0.196	0.046	0.725	0.085	0.742	0.118	0.760	0.102	0.726	0.177	0.761	0.123	0.676	0.161
2/20/2005							0.024	0.045	0.030	0.045	0.192	0.046	0.724	0.083	0.742	0.118	0.759	0.103	0.724	0.173	0.760	0.122	0.675	0.161
2/21/2005							0.024	0.045	0.029	0.044	0.188	0.047	0.723	0.082	0.742	0.118	0.758	0.104	0.718	0.176	0.759	0.122	0.667	0.164
2/22/2005							0.023	0.044	0.029	0.045	0.184	0.046	0.721	0.082	0.742	0.117	0.758	0.104	0.714	0.179	0.759	0.119	0.668	0.163
2/23/2005							0.023	0.044	0.028	0.044	0.183	0.046	0.722	0.081	0.743	0.117	0.759	0.104	0.715	0.180	0.759	0.118	0.668	0.163
2/24/2005							0.023	0.044	0.027	0.044	0.183	0.046	0.720	0.084	0.743	0.116	0.760	0.103	0.716	0.179	0.760	0.117	0.669	0.163
2/25/2005							0.023	0.044	0.027	0.044	0.184	0.045	0.731	0.086	0.744	0.115	0.761	0.103	0.729	0.180	0.760	0.117	0.665	0.165
2/26/2005							0.024	0.044	0.027	0.043	0.189	0.045	0.734	0.090	0.744	0.115	0.760	0.104	0.727	0.184	0.760	0.116	0.661	0.166
2/27/2005							0.033	0.043	0.029	0.044	0.192	0.046	0.738	0.093	0.744	0.115	0.759	0.105	0.731	0.185	0.761	0.115	0.662	0.165
2/28/2005							0.059	0.036	0.034	0.046	0.197	0.047	0.737	0.099	0.744	0.115	0.756	0.107	0.735	0.185	0.761	0.117	0.664	0.163
3/1/2005	0.055	0.098	0.064	0.140	0.058	0.107	0.055	0.041	0.040	0.048	0.198	0.048	0.736	0.101	0.745	0.114	0.756	0.108	0.734	0.187	0.761	0.117	0.670	0.161
3/2/2005	0.052	0.091	0.062	0.134	0.060	0.113	0.051	0.045	0.041	0.047	0.198	0.048	0.732	0.102	0.744	0.115	0.756	0.108	0.733	0.184	0.761	0.119	0.671	0.161
3/3/2005	0.049	0.087	0.059	0.123	0.061	0.113	0.048	0.047	0.040	0.045	0.198	0.048	0.730	0.102	0.743	0.116	0.757	0.108	0.735	0.182	0.760	0.122	0.671	0.160
3/4/2005	0.091	0.547	0.075	0.314	0.085	0.116	0.080	0.196	0.063	0.078	0.223	0.051	0.745	0.104	0.744	0.115	0.759	0.107	0.832	0.184	0.759	0.124	0.672	0.159
3/5/2005	0.063	0.135	0.060	0.134	0.099	0.000	0.063	0.105	0.070	0.111	0.266	0.057	0.748	0.103	0.743	0.114	0.759	0.107	0.839	0.187	0.759	0.123	0.671	0.159
3/6/2005	0.055	0.108	0.055	0.118	0.099	0.000	0.054	0.087	0.066	0.108	0.269	0.058	0.746	0.104	0.743	0.115	0.757	0.108	0.837	0.188	0.759	0.124	0.670	0.159
3/7/2005	0.050	0.095	0.052	0.110	0.095	1.179	0.048	0.078	0.061	0.096	0.267	0.058	0.744	0.105	0.743	0.115	0.756	0.108	0.823	0.190	0.759	0.124	0.669	0.159
3/8/2005	0.048	0.090	0.050	0.105	0.092	1.698	0.045	0.074	0.058	0.090	0.265	0.058	0.745	0.104	0.743	0.114	0.756	0.109	0.817	0.190	0.759	0.123	0.666	0.161
3/9/2005	0.079	0.165	0.063	1.561	0.101	0.913	0.063	0.067	0.067	0.152	0.270	0.059	0.750	0.104	0.743	0.115	0.756	0.109	0.831	0.190	0.760	0.124	0.671	0.158
3/10/2005	0.080	0.419	0.075	0.254	0.203	0.000	0.087	0.840	0.181	0.000	0.308	0.063	0.755	0.100	0.743	0.115	0.756	0.108	0.841	0.194	0.760	0.124	0.673	0.157
3/11/2005	0.062	0.131	0.073	0.220	0.221	0.000	0.074	0.211	0.177	0.000	0.309	0.061	0.754	0.098	0.743	0.115	0.759	0.105	0.839	0.201	0.760	0.125	0.671	0.158
3/12/2005	0.056	0.109	0.070	0.198	0.222	0.000	0.064	0.144	0.164	0.000	0.311	0.058	0.755	0.097	0.743	0.114	0.759	0.103	0.837	0.204	0.760	0.125	0.670	0.158
3/13/2005	0.052	0.100	0.068	0.180	0.220	0.000	0.058	0.119	0.155	0.000	0.311	0.055	0.755	0.097	0.743	0.115	0.761	0.100	0.836	0.206	0.760	0.126	0.668	0.159
3/14/2005	0.049	0.092	0.066	0.169	0.217	0.000	0.054	0.106	0.148	0.000	0.312	0.053	0.754	0.099	0.743	0.115	0.762	0.099	0.833	0.212	0.759	0.127	0.668	0.159
3/15/2005	0.046	0.088	0.065	0.164	0.215	0.000	0.051	0.099	0.143	0.000	0.314	0.052	0.755	0.099	0.743	0.115	0.763	0.097	0.832	0.215	0.760	0.127	0.667	0.160
3/16/2005	0.045	0.085	0.064	0.157	0.213	0.000	0.050	0.095	0.139	0.000	0.312	0.051	0.754	0.101	0.743	0.116	0.761	0.097	0.831	0.215	0.759	0.130	0.666	0.160
3/17/2005	0.062	0.065	0.067	0.190	0.215	0.000	0.055	0.304	0.145	0.000	0.310	0.052	0.756	0.099	0.745	0.115	0.760	0.097	0.832	0.214	0.758	0.133	0.669	0.159
3/18/2005	0.078	0.488	0.084	0.432	0.263	0.000	0.083	0.397	0.205	0.000	0.315	0.048	0.756	0.099	0.745	0.115	0.764	0.094	0.832	0.215	0.759	0.133	0.671	0.159
3/19/2005	0.063	0.135	0.082	0.380	0.264	0.000	0.073	0.201	0.197	0.000	0.317	0.045	0.757	0.097	0.744	0.116	0.764	0.094	0.832	0.216	0.760	0.133	0.671	0.159
3/20/2005	0.057	0.112	0.079	0.300	0.264	0.000	0.066	0.153	0.185	0.000	0.319	0.043	0.756	0.098	0.744	0.116	0.761	0.093	0.830	0.219	0.759	0.134	0.671	0.159
3/21/2005	0.066	0.196	0.078	0.391	0.263	0.000	0.067	0.281	0.182	0.000	0.320	0.044	0.756	0.099	0.744	0.116	0.762	0.092	0.829	0.220	0.759	0.135	0.672	0.158
3/22/2005	0.079	0.524	0.096	2.243	0.265	0.000	0.118	0.379	0.257	0.000	0.323	0.052	0.756	0.099	0.744	0.117	0.759	0.092	0.830	0.223	0.758	0.137	0.671	0.159
3/23/2005	0.068	0.160	0.099	0.000	0.265	0.000	0.156	0.000	0.279	0.000	0.325	0.054	0.757	0.098	0.744	0.118	0.758	0.093	0.835	0.214	0.758	0.137	0.672	0.158
3/24/2005	0.063	0.136	0.099	0.000	0.265	0.000	0.157	0.000	0.279	0.000	0.325	0.054	0.757	0.099	0.744	0.119	0.761	0.092	0.837	0.206	0.759	0.136	0.672	0.158
3/25/2005	0.060	0.123	0.098	0.000	0.265	0.000	0.144	0.000	0.278	0.000	0.325	0.053	0.758	0.099	0.744	0.119	0.759	0.092	0.835	0.203	0.760	0.137	0.667	0.160
3/26/2005	0.062	0.132	0.098	0.000	0.265	0.000	0.150	0.000	0.278	0.000	0.325	0.053	0.757	0.101	0.744	0.119	0.757	0.093	0.836	0.199	0.758	0.139	0.665	0.161
3/27/2005	0.061	0.128	0.098	0.000	0.264	0.000	0.150	0.000	0.278	0.000	0.324	0.055	0.756	0.103	0.744	0.121	0.758	0.093	0.840	0.190	0.760	0.138	0.666	0.161
3/28/2005	0.059	0.118	0.097	1.213	0.264	0.000	0.147	0.000	0.278	0.000	0.323	0.056	0.757	0.102	0.744	0.121	0.759	0.093	0.837	0.189	0.758	0.141	0.668	0.161
3/29/2005	0.056	0.108	0.095	3.663	0.264	0.000	0.143	0.000	0.279	0.000	0.323	0.057	0.757	0.103	0.744	0.122	0.756	0.093	0.840	0.184	0.759	0.140	0.672	0.159
3/30/2005	0.053	0.102	0.093	6.462	0.264	0.000	0.137	0.000	0.279	0.000	0.323	0.058	0.757	0.103	0.744	0.123	0.758	0.093	0.846	0.175	0.760	0.138	0.669	0.160

Table A-1. Continued.

	T1-60 (25 cm)		T1-60 (35 cm)		T1-60 (55 cm)		T1-50 (30 cm)		T1-50 (50 cm)		T1-50 (95 cm)		T1-30 (25 cm)		T1-30 (50 cm)		T1-30 (80 cm)		T1-1 (25 cm)		T1-1 (50 cm)		T1-1 (72 cm)	
Date	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w
3/31/2005	0.051	0.097	0.091	1.577	0.264	0.000	0.130	0.000	0.280	0.000	0.322	0.060	0.757	0.105	0.744	0.124	0.756	0.093	0.847	0.171	0.760	0.138	0.668	0.162
4/1/2005	0.049	0.093	0.089	0.812	0.264	0.000	0.114	0.000	0.280	0.000	0.321	0.060	0.757	0.105	0.745	0.123	0.756	0.093	0.844	0.173	0.760	0.137	0.668	0.162
4/2/2005	0.050	0.094	0.087	0.654	0.264	0.000	0.096	1.339	0.279	0.000	0.320	0.059	0.757	0.104	0.744	0.124	0.755	0.094	0.840	0.178	0.761	0.136	0.665	0.163
4/3/2005	0.058	0.114	0.089	0.810	0.265	0.000	0.094	2.462	0.282	0.000	0.321	0.059	0.757	0.104	0.744	0.125	0.755	0.094	0.844	0.178	0.760	0.137	0.664	0.164
4/4/2005	0.054	0.103	0.085	0.496	0.266	0.000	0.088	0.732	0.282	0.000	0.320	0.061	0.757	0.104	0.744	0.126	0.757	0.093	0.842	0.181	0.760	0.137	0.661	0.165
4/5/2005	0.051	0.096	0.082	0.374	0.267	0.000	0.083	0.366	0.281	0.000	0.319	0.062	0.758	0.103	0.743	0.126	0.756	0.093	0.841	0.183	0.760	0.136	0.663	0.165
4/6/2005	0.048	0.090	0.080	0.310	0.267	0.000	0.078	0.253	0.279	0.000	0.318	0.062	0.757	0.103	0.743	0.126	0.757	0.093	0.842	0.181	0.760	0.134	0.664	0.164
4/7/2005	0.046	0.086	0.077	0.271	0.267	0.000	0.075	0.210	0.277	0.000	0.316	0.063	0.756	0.105	0.743	0.127	0.758	0.092	0.843	0.177	0.760	0.135	0.662	0.166
4/8/2005	0.073	0.227	0.091	1.963	0.268	0.000	0.093	0.279	0.280	0.000	0.317	0.060	0.756	0.105	0.744	0.127	0.759	0.092	0.844	0.177	0.759	0.136	0.661	0.166
4/9/2005	0.064	0.137	0.094	2.461	0.269	0.000	0.092	4.390	0.281	0.000	0.317	0.055	0.757	0.105	0.743	0.127	0.758	0.092	0.842	0.180	0.759	0.136	0.662	0.166
4/10/2005	0.057	0.111	0.089	0.948	0.270	0.000	0.086	0.468	0.281	0.000	0.316	0.056	0.757	0.104	0.743	0.128	0.757	0.093	0.841	0.182	0.759	0.136	0.662	0.166
4/11/2005	0.053	0.100	0.085	0.483	0.270	0.000	0.081	0.308	0.281	0.000	0.314	0.058	0.757	0.105	0.743	0.128	0.758	0.092	0.842	0.182	0.759	0.136	0.661	0.166
4/12/2005	0.049	0.093	0.082	0.360	0.270	0.000	0.078	0.244	0.280	0.000	0.313	0.060	0.757	0.105	0.744	0.128	0.758	0.092	0.840	0.183	0.758	0.138	0.661	0.167
4/13/2005	0.047	0.088	0.080	0.301	0.270	0.000	0.075	0.212	0.278	0.000	0.312	0.061	0.756	0.106	0.744	0.128	0.758	0.092	0.838	0.184	0.757	0.139	0.661	0.167
4/14/2005	0.044	0.083	0.077	0.256	0.270	0.000	0.072	0.181	0.271	0.000	0.312	0.062	0.756	0.107	0.743	0.130	0.758	0.093	0.839	0.183	0.758	0.139	0.661	0.167
4/15/2005	0.042	0.079	0.075	0.230	0.271	0.000	0.068	0.155	0.245	0.000	0.312	0.060	0.756	0.107	0.743	0.130	0.757	0.093	0.840	0.179	0.759	0.138	0.662	0.166
4/16/2005	0.040	0.076	0.073	0.212	0.273	0.000	0.064	0.139	0.231	0.000	0.312	0.059	0.756	0.106	0.742	0.131	0.757	0.093	0.842	0.178	0.759	0.138	0.662	0.167
4/17/2005	0.038	0.072	0.072	0.200	0.273	0.000	0.060	0.121	0.210	0.000	0.312	0.054	0.757	0.105	0.743	0.131	0.758	0.093	0.841	0.180	0.760	0.137	0.661	0.167
4/18/2005	0.036	0.071	0.070	0.186	0.274	0.000	0.055	0.107	0.186	0.000	0.311	0.050	0.756	0.105	0.742	0.131	0.759	0.093	0.841	0.180	0.761	0.135	0.661	0.167
4/19/2005	0.035	0.069	0.068	0.173	0.273	0.000	0.051	0.097	0.165	0.000	0.310	0.047	0.756	0.105	0.742	0.132	0.759	0.093	0.842	0.181	0.760	0.135	0.660	0.167
4/20/2005	0.034	0.067	0.066	0.160	0.273	0.000	0.048	0.090	0.151	0.000	0.309	0.046	0.757	0.105	0.742	0.132	0.759	0.093	0.842	0.181	0.760	0.136	0.660	0.167
4/21/2005	0.033	0.064	0.064	0.152	0.273	0.000	0.045	0.085	0.141	0.000	0.308	0.045	0.756	0.106	0.742	0.132	0.758	0.093	0.841	0.181	0.759	0.136	0.659	0.167
4/22/2005	0.033	0.063	0.062	0.140	0.273	0.000	0.043	0.082	0.132	0.000	0.308	0.045	0.755	0.108	0.742	0.133	0.758	0.093	0.842	0.181	0.758	0.136	0.661	0.166
4/23/2005	0.032	0.062	0.059	0.130	0.272	0.000	0.042	0.079	0.123	0.000	0.307	0.044	0.754	0.109	0.742	0.133	0.759	0.093	0.839	0.186	0.760	0.135	0.660	0.166
4/24/2005	0.030	0.060	0.057	0.123	0.273	0.000	0.040	0.077	0.114	0.000	0.307	0.044	0.754	0.109	0.743	0.133	0.754	0.094	0.837	0.190	0.762	0.133	0.661	0.165
4/25/2005	0.029	0.059	0.054	0.114	0.273	0.000	0.038	0.074	0.105	0.000	0.307	0.044	0.755	0.106	0.742	0.134	0.756	0.094	0.838	0.193	0.761	0.135	0.662	0.165
4/26/2005	0.028	0.058	0.053	0.111	0.262	0.000	0.037	0.073	0.098	2.471	0.307	0.044	0.754	0.104	0.742	0.135	0.755	0.094	0.837	0.196	0.760	0.136	0.663	0.164
4/27/2005	0.028	0.058	0.051	0.104	0.232	0.000	0.036	0.070	0.093	3.413	0.307	0.045	0.754	0.102	0.741	0.135	0.754	0.094	0.834	0.202	0.761	0.136	0.662	0.164
4/28/2005	0.027	0.057	0.049	0.099	0.216	0.000	0.035	0.070	0.092	1.708	0.307	0.047	0.756	0.102	0.741	0.136	0.754	0.094	0.836	0.197	0.761	0.137	0.663	0.163
4/29/2005	0.026	0.057	0.048	0.098	0.195	0.000	0.034	0.069	0.089	0.779	0.307	0.048	0.756	0.101	0.741	0.137	0.755	0.094	0.834	0.192	0.761	0.138	0.663	0.163
4/30/2005	0.026	0.057	0.047	0.095	0.173	0.000	0.034	0.068	0.082	0.313	0.306	0.047	0.751	0.100	0.741	0.138	0.756	0.094	0.786	0.193	0.761	0.139	0.663	0.164
5/1/2005	0.026	0.056	0.045	0.092	0.160	0.000	0.033	0.067	0.074	0.187	0.305	0.046	0.746	0.098	0.741	0.138	0.756	0.094	0.773	0.191	0.760	0.140	0.662	0.164
5/2/2005	0.026	0.057	0.045	0.093	0.151	0.000	0.032	0.066	0.068	0.146	0.303	0.045	0.746	0.095	0.741	0.139	0.757	0.094	0.775	0.188	0.760	0.141	0.656	0.166
5/3/2005	0.025	0.054	0.045	0.092	0.143	0.000	0.031	0.064	0.064	0.131	0.299	0.044	0.750	0.093	0.740	0.140	0.754	0.095	0.795	0.185	0.760	0.143	0.655	0.166
5/4/2005	0.046	0.333	0.057	0.132	0.143	0.000	0.031	0.065	0.067	0.145	0.299	0.045	0.756	0.091	0.741	0.140	0.752	0.095	0.827	0.180	0.760	0.144	0.655	0.166
5/5/2005	0.077	0.240	0.071	0.197	0.188	0.000	0.047	0.086	0.104	1.269	0.309	0.047	0.759	0.090	0.741	0.139	0.752	0.095	0.849	0.172	0.759	0.146	0.653	0.168
5/6/2005	0.065	0.135	0.065	0.153	0.214	0.000	0.050	0.092	0.138	0.000	0.317	0.049	0.758	0.091	0.741	0.139	0.753	0.095	0.851	0.170	0.758	0.147	0.655	0.168
5/7/2005	0.059	0.111	0.065	0.154	0.226	0.000	0.069	0.198	0.237	0.000	0.321	0.052							0.852	0.169	0.758	0.147	0.661	0.167
5/8/2005	0.054	0.097	0.066	0.159	0.235	0.000	0.087	0.764	0.251	0.000	0.325	0.054							0.853	0.164	0.759	0.145	0.660	0.168
5/9/2005	0.050	0.087	0.066	0.160	0.237	0.000	0.068	0.154	0.226	0.000	0.326	0.049							0.851	0.169	0.759	0.143	0.660	0.168
5/10/2005	0.047	0.083	0.064	0.148	0.236	0.000	0.058	0.112	0.198	0.000	0.328	0.047							0.849	0.172	0.759	0.142	0.659	0.168
5/11/2005	0.044	0.078	0.061	0.139	0.233	0.000	0.054	0.101	0.179	0.000	0.330	0.047							0.852	0.164	0.759	0.141	0.659	0.169
5/12/2005	0.041	0.073	0.059	0.130	0.229	0.000	0.052	0.095	0.170	0.000	0.331	0.049							0.855	0.158	0.760	0.140	0.657	0.170
5/13/2005	0.039	0.070	0.058	0.127	0.225	0.000	0.050	0.092	0.163	0.000	0.331	0.049							0.858	0.151	0.760	0.139	0.656	0.171
5/14/2005	0.037	0.068	0.056	0.120	0.220	0.000	0.049	0.090	0.158	0.000	0.330	0.049							0.862	0.145	0.759	0.138	0.657	0.171
5/15/2005	0.035	0.066	0.055	0.116	0.215	0.000	0.049	0.089	0.157	0.000	0.330	0.051							0.863	0.143	0.759	0.137	0.658	0.170
5/16/2005	0.034	0.064	0.054	0.112	0.213	0.000	0.049	0.090	0.156	0.000	0.331	0.052							0.863	0.143	0.759	0.137	0.659	0.170
5/17/2005	0.033	0.064	0.052	0.107	0.208	0.000	0.047	0.087	0.152	0.000	0.331	0.053							0.865	0.141	0.759	0.134	0.660	0.169
5/18/2005	0.031	0.061	0.051	0.105	0.202	0.000	0.046	0.084	0.142	0.000	0.331	0.052							0.866	0.141	0.761	0.131	0.659	0.169
5/19/2005	0.031	0.061	0.050	0.101	0.195	0.000	0.043	0.080	0.130	0.000	0.326	0.049	0.756	0.109	0.741	0.148	0.746	0.099	0.864	0.145	0.761	0.130	0.651	0.173

Table A-1. Continued.

	T1-60 (25 cm)		T1-60 (35 cm)		T1-60 (55 cm)		T1-50 (30 cm)		T1-50 (50 cm)		T1-50 (95 cm)		T1-30 (25 cm)		T1-30 (50 cm)		T1-30 (80 cm)		T1-1 (25 cm)		T1-1 (50 cm)		T1-1 (72 cm)	
Date	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w
5/20/2005	0.030	0.061	0.050	0.098	0.185	0.000	0.041	0.077	0.118	0.000	0.322	0.048	0.755	0.111	0.740	0.148	0.749	0.099	0.849	0.150	0.759	0.131	0.655	0.172
5/21/2005	0.028	0.059	0.048	0.092	0.173	0.000	0.039	0.073	0.100	1.300	0.320	0.045	0.751	0.113	0.740	0.149	0.751	0.098	0.822	0.154	0.759	0.128	0.658	0.170
5/22/2005	0.028	0.058	0.047	0.090	0.163	0.000	0.036	0.070	0.088	0.568	0.319	0.045	0.751	0.112	0.740	0.150	0.751	0.098	0.854	0.157	0.759	0.128	0.652	0.172
5/23/2005	0.027	0.057	0.046	0.089	0.156	0.000	0.035	0.069	0.084	0.348	0.318	0.047	0.754	0.111	0.739	0.151	0.751	0.098	0.855	0.158	0.759	0.127	0.649	0.171
5/24/2005	0.026	0.057	0.045	0.088	0.148	0.000	0.034	0.068	0.081	0.271	0.318	0.049	0.752	0.112	0.740	0.150	0.748	0.098	0.855	0.158	0.759	0.126	0.655	0.168
5/25/2005	0.028	0.059	0.044	0.085	0.137	0.000	0.033	0.067	0.075	0.190	0.317	0.050	0.752	0.110	0.740	0.151	0.747	0.099	0.857	0.157	0.759	0.126	0.655	0.168
5/26/2005	0.074	0.166	0.044	0.085	0.133	0.000	0.032	0.065	0.076	0.192	0.319	0.052	0.755	0.107	0.740	0.151	0.745	0.099	0.856	0.159	0.759	0.126	0.653	0.170
5/27/2005	0.080	0.469	0.056	0.113	0.143	0.000	0.032	0.065	0.082	0.295	0.322	0.053	0.756	0.105	0.740	0.152	0.747	0.099	0.854	0.161	0.760	0.125	0.654	0.171
5/28/2005	0.067	0.142	0.059	0.118	0.149	0.000	0.035	0.069	0.082	0.282	0.323	0.052	0.754	0.106	0.740	0.151	0.745	0.100	0.855	0.160	0.760	0.123	0.654	0.170
5/29/2005	0.060	0.114	0.056	0.112	0.144	0.000	0.036	0.070	0.078	0.213	0.322	0.050	0.753	0.106	0.741	0.151	0.746	0.100	0.857	0.162	0.760	0.124	0.654	0.169
5/30/2005	0.055	0.099	0.053	0.106	0.138	0.000	0.036	0.069	0.075	0.185	0.321	0.051	0.753	0.107	0.741	0.151	0.747	0.099	0.852	0.171	0.760	0.125	0.655	0.168
5/31/2005	0.071	0.226	0.057	0.123	0.138	0.000	0.034	0.068	0.079	0.325	0.323	0.051	0.755	0.107	0.741	0.151	0.747	0.099	0.854	0.167	0.760	0.125	0.656	0.168
6/1/2005	0.089	1.182	0.072	0.208	0.172	0.000	0.038	0.072	0.117	0.363	0.339	0.053	0.757	0.103	0.741	0.151	0.747	0.100	0.859	0.158	0.760	0.124	0.654	0.169
6/2/2005	0.099	0.458	0.084	0.203	0.229	0.000	0.090	0.072	0.225	0.000	0.364	0.052	0.757	0.105	0.741	0.151	0.743	0.101	0.860	0.158	0.760	0.124	0.658	0.167
6/3/2005	0.088	0.360	0.102	0.000	0.264	0.000	0.179	0.001	0.276	0.000	0.370	0.055	0.757	0.104	0.740	0.152	0.743	0.101	0.861	0.158	0.758	0.127	0.660	0.166
6/4/2005	0.093	4.443	0.128	0.000	0.265	0.000	0.206	0.007	0.278	0.000	0.373	0.055	0.758	0.104	0.740	0.152	0.743	0.102	0.860	0.157	0.758	0.127	0.656	0.168
6/5/2005	0.081	0.306	0.131	0.000	0.264	0.000	0.192	0.000	0.277	0.000	0.374	0.053	0.758	0.105	0.741	0.151	0.743	0.102	0.860	0.157	0.758	0.127	0.657	0.167
6/6/2005	0.094	0.155	0.163	0.000	0.264	0.000	0.201	0.001	0.278	0.000	0.374	0.052	0.757	0.107	0.742	0.151	0.742	0.102	0.861	0.156	0.759	0.126	0.658	0.166
6/7/2005	0.155	0.000	0.369	0.000	0.267	0.000	0.326	0.000	0.282	0.000	0.376	0.046	0.756	0.110	0.742	0.151	0.744	0.102	0.862	0.155	0.759	0.126	0.658	0.167
6/8/2005	0.110	1.109	0.367	0.000	0.265	0.000	0.322	0.000	0.282	0.000	0.375	0.051	0.754	0.113	0.742	0.152	0.745	0.102	0.864	0.153	0.759	0.126	0.660	0.165
6/9/2005	0.088	2.071	0.366	0.000	0.264	0.000	0.308	0.000	0.283	0.000	0.375	0.052	0.755	0.114	0.741	0.155	0.745	0.102	0.866	0.151	0.760	0.126	0.652	0.169
6/10/2005	0.078	0.257	0.360	0.000	0.264	0.000	0.300	0.000	0.285	0.000	0.374	0.053	0.755	0.114	0.741	0.156	0.743	0.102	0.868	0.149	0.760	0.125	0.656	0.166
6/11/2005	0.123	0.095	0.359	0.000	0.266	0.000	0.267	0.000	0.290	0.006	0.375	0.050	0.754	0.117	0.742	0.155	0.740	0.103	0.865	0.152	0.761	0.124	0.653	0.168
6/12/2005	0.117	0.000	0.361	0.000	0.266	0.000	0.277	0.000	0.293	0.008	0.375	0.048	0.753	0.119	0.741	0.156	0.742	0.102	0.865	0.154	0.761	0.124	0.653	0.168
6/13/2005	0.091	1.907	0.359	0.000	0.265	0.000	0.248	0.000	0.294	0.000	0.373	0.051	0.752	0.121	0.741	0.157	0.740	0.102	0.865	0.152	0.761	0.125	0.660	0.164
6/14/2005	0.074	0.201	0.344	0.000	0.263	0.000	0.163	0.000	0.296	0.000	0.371	0.047	0.751	0.123	0.740	0.158	0.741	0.101	0.864	0.159	0.760	0.126	0.655	0.167
6/15/2005	0.067	0.147	0.266	0.000	0.263	0.000	0.140	0.000	0.297	0.000	0.369	0.050	0.750	0.124	0.739	0.159	0.742	0.100	0.859	0.165	0.760	0.127	0.657	0.166
6/16/2005	0.062	0.124	0.238	0.000	0.262	0.000	0.125	0.000	0.296	0.000	0.367	0.052	0.750	0.124	0.739	0.160	0.743	0.099	0.862	0.163	0.760	0.128	0.659	0.165
6/17/2005	0.059	0.112	0.224	0.000	0.262	0.000	0.133	0.000	0.299	0.000	0.365	0.052	0.751	0.123	0.739	0.161	0.745	0.098	0.862	0.165	0.759	0.131	0.658	0.165
6/18/2005	0.060	0.117	0.224	0.000	0.263	0.000	0.182	0.000	0.304	0.000	0.365	0.051	0.750	0.126	0.739	0.162	0.741	0.099	0.862	0.166	0.760	0.131	0.657	0.166
6/19/2005	0.061	0.120	0.224	0.000	0.263	0.000	0.189	0.000	0.307	0.000	0.364	0.055	0.749	0.129	0.739	0.163	0.740	0.099	0.861	0.167	0.761	0.130	0.659	0.166
6/20/2005	0.060	0.117	0.224	0.000	0.264	0.000	0.189	0.000	0.310	0.000	0.364	0.055	0.750	0.129	0.739	0.165	0.742	0.099	0.862	0.166	0.762	0.129	0.661	0.165
6/21/2005	0.062	0.124	0.226	0.000	0.265	0.000	0.193	0.000	0.312	0.000	0.364	0.054	0.750	0.129	0.740	0.164	0.737	0.100	0.862	0.166	0.761	0.131	0.653	0.169
6/22/2005	0.065	0.176	0.226	0.000	0.265	0.000	0.198	0.000	0.313	0.000	0.363	0.053			0.740	0.164	0.739	0.099	0.863	0.164	0.760	0.133	0.654	0.169
6/23/2005	0.082	0.373	0.242	0.000	0.267	0.000	0.217	0.000	0.315	0.000	0.362	0.053			0.740	0.164	0.740	0.099	0.866	0.161	0.758	0.134	0.655	0.168
6/24/2005	0.100	1.460	0.274	0.000	0.268	0.000	0.247	0.000	0.315	0.000	0.362	0.050			0.741	0.163	0.741	0.099	0.863	0.164	0.758	0.134	0.659	0.167
6/25/2005	0.088	0.745	0.281	0.000	0.267	0.000	0.250	0.000	0.315	0.000	0.361	0.050			0.741	0.163	0.741	0.099	0.863	0.166	0.758	0.134	0.661	0.166
6/26/2005	0.080	0.270	0.280	0.000	0.268	0.000	0.242	0.000	0.316	0.000	0.361	0.051			0.740	0.165	0.739	0.100	0.861	0.168	0.758	0.134	0.661	0.166
6/27/2005	0.092	1.619	0.283	0.000	0.269	0.000	0.252	0.000	0.318	0.000	0.361	0.050			0.741	0.164	0.739	0.100	0.861	0.169	0.758	0.133	0.661	0.166
6/28/2005	0.088	0.804	0.283	0.000	0.269	0.000	0.247	0.000	0.318	0.000	0.361	0.049			0.741	0.164	0.740	0.100	0.863	0.168	0.758	0.133	0.651	0.170
6/29/2005	0.206	0.145	0.287	0.000	0.271	0.000	0.271	0.000	0.319	0.000	0.363	0.048			0.741	0.164	0.737	0.101	0.865	0.167	0.758	0.132	0.654	0.169
6/30/2005	0.405	0.000	0.294	0.000	0.274	0.000	0.306	0.000	0.322	0.000	0.364	0.048			0.740	0.165	0.735	0.102	0.866	0.166	0.759	0.131	0.652	0.169
7/1/2005	0.405	0.000	0.293	0.000	0.273	0.000	0.306	0.000	0.321	0.000	0.363	0.049			0.741	0.165	0.735	0.102	0.864	0.170	0.758	0.131	0.651	0.170
7/2/2005	0.378	0.000	0.292	0.000	0.272	0.000	0.305	0.000	0.318	0.000	0.363	0.049			0.739	0.167	0.739	0.101	0.865	0.169	0.758	0.132	0.655	0.168
7/3/2005	0.243	0.000	0.289	0.000	0.270	0.000	0.303	0.000	0.315	0.000	0.361	0.047			0.740	0.166	0.738	0.101	0.868	0.167	0.758	0.132	0.652	0.169
7/4/2005	0.164	0.000	0.288	0.000	0.269	0.000	0.304	0.000	0.312	0.000	0.361	0.048			0.739	0.168	0.736	0.102	0.870	0.165	0.758	0.132	0.651	0.170
7/5/2005	0.135	0.000	0.288	0.000	0.268	0.000	0.305	0.000	0.310	0.000	0.361	0.049			0.738	0.169	0.736	0.102	0.871	0.164	0.759	0.132	0.651	0.170
7/6/2005	0.113	0.000	0.287	0.000	0.267	0.000	0.297	0.000	0.308	0.000	0.359	0.049			0.739	0.169	0.736	0.102	0.873	0.161	0.760	0.131	0.653	0.169
7/7/2005	0.098	0.554	0.287	0.000	0.266	0.000	0.284	0.000	0.307	0.000	0.356	0.049			0.739	0.169	0.738	0.101	0.875	0.158	0.761	0.130	0.656	0.169
7/8/2005	0.087	0.662	0.288	0.000	0.266	0.000	0.219	0.000	0.305	0.000	0.349	0.048			0.741	0.168	0.738	0.101	0.877	0.156	0.759	0.132	0.651	0.171

Table A-1. Continued.

	T1-60 (25 cm)		T1-60 (35 cm)		T1-60 (55 cm)		T1-50 (30 cm)		T1-50 (50 cm)		T1-50 (95 cm)		T1-30 (25 cm)		T1-30 (50 cm)		T1-30 (80 cm)		T1-1 (25 cm)		T1-1 (50 cm)		T1-1 (72 cm)	
Date	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w
7/9/2005	0.078	0.258	0.263	0.000	0.265	0.000	0.153	0.000	0.304	0.000	0.348	0.046			0.741	0.169	0.737	0.101	0.875	0.159	0.757	0.134	0.650	0.172
7/10/2005	0.094	0.917	0.253	0.000	0.267	0.000	0.193	0.000	0.304	0.000	0.350	0.045			0.741	0.169	0.740	0.101	0.871	0.167	0.759	0.131	0.651	0.171
7/11/2005	0.095	5.635	0.259	0.000	0.268	0.000	0.252	0.000	0.307	0.000	0.351	0.048			0.742	0.168	0.738	0.101	0.872	0.166	0.760	0.130	0.650	0.172
7/12/2005	0.085	0.585	0.253	0.000	0.268	0.000	0.217	0.000	0.310	0.000	0.350	0.048			0.739	0.171	0.737	0.101	0.873	0.165	0.759	0.129	0.652	0.171
7/13/2005	0.075	0.222	0.242	0.000	0.267	0.000	0.187	0.000	0.308	0.000	0.349	0.048			0.741	0.169	0.738	0.101	0.875	0.162	0.759	0.129	0.649	0.172
7/14/2005	0.080	0.373	0.236	0.000	0.268	0.000	0.170	0.000	0.309	0.000	0.349	0.048			0.742	0.168	0.740	0.100	0.877	0.159	0.759	0.128	0.649	0.172
7/15/2005	0.087	1.798	0.243	0.000	0.269	0.000	0.191	0.000	0.309	0.000	0.350	0.048			0.741	0.169	0.738	0.101	0.877	0.158	0.760	0.127	0.652	0.171
7/16/2005	0.076	0.222	0.235	0.000	0.269	0.000	0.180	0.000	0.309	0.000	0.349	0.049			0.741	0.169	0.740	0.100	0.878	0.157	0.760	0.127	0.652	0.171
7/17/2005	0.070	0.164	0.229	0.000	0.269	0.000	0.181	0.000	0.309	0.000	0.349	0.049			0.740	0.171	0.740	0.100	0.878	0.156	0.761	0.125	0.649	0.173
7/18/2005	0.066	0.145	0.225	0.000	0.269	0.000	0.183	0.000	0.309	0.000	0.349	0.050			0.739	0.173	0.741	0.100	0.879	0.155	0.762	0.124	0.651	0.172
7/19/2005	0.064	0.135	0.221	0.000	0.269	0.000	0.179	0.000	0.309	0.000	0.348	0.050			0.738	0.175	0.741	0.100	0.880	0.155	0.762	0.122	0.652	0.172
7/20/2005	0.062	0.126	0.217	0.000	0.269	0.000	0.178	0.000	0.309	0.000	0.348	0.051			0.738	0.176	0.738	0.101	0.881	0.154	0.763	0.121	0.654	0.172
7/21/2005	0.060	0.122	0.214	0.000	0.269	0.000	0.181	0.000	0.309	0.000	0.348	0.051			0.738	0.176	0.736	0.102	0.882	0.153	0.760	0.124	0.650	0.174
7/22/2005	0.059	0.117	0.211	0.000	0.270	0.000	0.177	0.000	0.309	0.000	0.348	0.051			0.738	0.177	0.736	0.102	0.882	0.152	0.759	0.124	0.655	0.173
7/23/2005	0.057	0.109	0.207	0.000	0.270	0.000	0.177	0.000	0.309	0.000	0.348	0.051			0.740	0.175	0.735	0.102	0.883	0.152	0.760	0.123	0.652	0.175
7/24/2005	0.077	0.070	0.212	0.000	0.271	0.000	0.194	0.000	0.309	0.000	0.349	0.051			0.742	0.173	0.737	0.102	0.884	0.152	0.761	0.121	0.653	0.175
7/25/2005	0.099	1.637	0.232	0.000	0.273	0.000	0.213	0.000	0.309	0.000	0.349	0.051			0.742	0.173	0.738	0.101	0.882	0.156	0.761	0.119	0.655	0.173
7/26/2005	0.081	0.351	0.224	0.000	0.272	0.000	0.196	0.000	0.308	0.000	0.349	0.051	0.720	0.171	0.740	0.176	0.739	0.101	0.884	0.155	0.760	0.120	0.654	0.173
7/27/2005	0.070	0.175	0.215	0.000	0.272	0.000	0.181	0.000	0.309	0.000	0.348	0.052	0.719	0.175	0.741	0.176	0.737	0.102	0.888	0.152	0.759	0.119	0.655	0.173
7/28/2005	0.064	0.138	0.208	0.000	0.271	0.000	0.169	0.000	0.310	0.000	0.348	0.053	0.716	0.178	0.741	0.175	0.732	0.104	0.889	0.150	0.758	0.119	0.653	0.174
7/29/2005	0.059	0.117	0.203	0.000	0.272	0.000	0.168	0.000	0.312	0.000	0.348	0.053	0.715	0.178	0.741	0.175	0.738	0.102	0.889	0.150	0.757	0.119	0.654	0.174
7/30/2005	0.056	0.110	0.200	0.000	0.272	0.000	0.173	0.000	0.313	0.000	0.347	0.053	0.714	0.178	0.740	0.177	0.738	0.103	0.888	0.151	0.757	0.117	0.653	0.175
7/31/2005	0.064	1.552	0.203	0.000	0.273	0.000	0.185	0.000	0.315	0.000	0.348	0.053	0.712	0.180	0.741	0.176	0.739	0.103	0.888	0.151	0.757	0.115	0.646	0.178
8/1/2005	0.081	0.368	0.216	0.000	0.274	0.000	0.201	0.000	0.316	0.000	0.348	0.054	0.708	0.184	0.740	0.177	0.738	0.103	0.887	0.152	0.756	0.116	0.652	0.175
8/2/2005	0.074	0.202	0.215	0.000	0.274	0.000	0.207	0.000	0.318	0.000	0.348	0.054	0.708	0.183	0.741	0.176	0.737	0.103	0.886	0.155	0.753	0.116	0.644	0.179
8/3/2005	0.087	0.164	0.222	0.000	0.274	0.000	0.216	0.000	0.318	0.000	0.348	0.054	0.706	0.184	0.740	0.177	0.738	0.103	0.884	0.157	0.752	0.115	0.650	0.176
8/4/2005	0.134	0.000	0.272	0.000	0.277	0.000	0.281	0.000	0.321	0.000	0.350	0.054	0.704	0.184	0.740	0.178	0.736	0.104	0.883	0.159	0.752	0.113	0.647	0.177
8/5/2005	0.146	0.000	0.285	0.000	0.278	0.000	0.327	0.004	0.323	0.000	0.350	0.053	0.703	0.185	0.741	0.176	0.736	0.104	0.881	0.161	0.751	0.113	0.645	0.178
8/6/2005	0.110	0.975	0.282	0.000	0.276	0.000	0.327	0.006	0.321	0.000	0.348	0.056	0.704	0.182	0.740	0.177	0.735	0.105	0.879	0.166	0.749	0.113	0.649	0.175
8/7/2005	0.090	1.672	0.281	0.000	0.276	0.000	0.244	0.001	0.320	0.000	0.347	0.057	0.702	0.183	0.740	0.176	0.735	0.105	0.877	0.168	0.747	0.113	0.651	0.174
8/8/2005	0.082	0.341	0.280	0.000	0.275	0.000	0.186	0.000	0.320	0.000	0.346	0.057	0.700	0.184	0.740	0.177	0.734	0.105	0.877	0.169	0.747	0.112	0.652	0.173
8/9/2005	0.074	0.209	0.262	0.000	0.275	0.000	0.169	0.000	0.319	0.000	0.346	0.057	0.700	0.184	0.740	0.177	0.736	0.104	0.878	0.170	0.747	0.111	0.654	0.172
8/10/2005	0.071	0.181	0.230	0.000	0.275	0.000	0.179	0.000	0.320	0.000	0.347	0.057	0.699	0.185	0.740	0.177	0.736	0.104	0.879	0.170	0.746	0.113	0.645	0.176
8/11/2005	0.069	0.168	0.224	0.000	0.274	0.000	0.183	0.000	0.319	0.000	0.347	0.058	0.698	0.187	0.740	0.177	0.735	0.104	0.877	0.172	0.745	0.114	0.648	0.173
8/12/2005	0.068	0.161	0.221	0.000	0.274	0.000	0.186	0.000	0.319	0.000	0.347	0.058	0.698	0.186	0.740	0.178	0.736	0.104	0.876	0.173	0.744	0.115	0.646	0.173
8/13/2005	0.068	0.157	0.219	0.000	0.274	0.000	0.199	0.000	0.319	0.000	0.347	0.057	0.699	0.185	0.738	0.181	0.735	0.104	0.877	0.172	0.746	0.113	0.643	0.175
8/14/2005	0.067	0.156	0.217	0.000	0.274	0.000	0.194	0.000	0.329	0.000	0.347	0.058	0.699	0.185	0.739	0.181	0.736	0.104	0.875	0.175	0.746	0.113	0.642	0.175
8/15/2005	0.065	0.142	0.213	0.000	0.274	0.000	0.183	0.000	0.331	0.000	0.346	0.058	0.694	0.191	0.737	0.183	0.737	0.103	0.872	0.178	0.746	0.115	0.641	0.176
8/16/2005	0.062	0.130	0.208	0.000	0.274	0.000	0.182	0.000	0.333	0.001	0.346	0.058	0.695	0.190	0.737	0.184	0.736	0.104	0.872	0.178	0.747	0.115	0.640	0.177
8/17/2005	0.060	0.124	0.204	0.000	0.273	0.000	0.184	0.000	0.335	0.001	0.346	0.058	0.695	0.188	0.737	0.184	0.736	0.104	0.873	0.178	0.750	0.115	0.639	0.177
8/18/2005	0.059	0.120	0.202	0.000	0.273	0.000	0.187	0.000	0.334	0.001	0.346	0.059	0.693	0.193	0.738	0.183	0.736	0.104	0.868	0.180	0.750	0.116	0.638	0.178
8/19/2005	0.058	0.116	0.199	0.000	0.273	0.000	0.184	0.000	0.338	0.001	0.346	0.059	0.693	0.191	0.738	0.185	0.736	0.104	0.864	0.182	0.754	0.115	0.640	0.178
8/20/2005	0.056	0.112	0.195	0.000	0.272	0.000	0.181	0.000	0.339	0.001	0.346	0.060	0.694	0.190	0.739	0.183	0.733	0.105	0.854	0.188	0.751	0.115	0.643	0.177
8/21/2005	0.055	0.108	0.192	0.000	0.272	0.000	0.179	0.000	0.339	0.001	0.346	0.059	0.691	0.193	0.739	0.184	0.732	0.105	0.856	0.187	0.752	0.116	0.642	0.178
8/22/2005	0.054	0.107	0.190	0.000	0.272	0.000	0.177	0.000	0.338	0.001	0.345	0.060	0.691	0.193	0.739	0.184	0.734	0.105	0.855	0.190	0.752	0.116	0.641	0.179
8/23/2005	0.053	0.106	0.187	0.000	0.271	0.000	0.173	0.000	0.339	0.001	0.346	0.060	0.691	0.192	0.738	0.186	0.734	0.105	0.858	0.190	0.752	0.114	0.641	0.179
8/24/2005	0.052	0.102	0.183	0.000	0.270	0.000	0.174	0.000	0.339	0.001	0.346	0.060	0.691	0.195	0.737	0.188	0.735	0.105	0.853	0.193	0.752	0.117	0.640	0.180
8/25/2005	0.052	0.099	0.184	0.000	0.270	0.000	0.180	0.000	0.339	0.001	0.346	0.060	0.692	0.193	0.739	0.185	0.736	0.104	0.848	0.199	0.751	0.116	0.642	0.179
8/26/2005	0.090	0.181	0.216	0.000	0.273	0.000	0.227	0.000	0.340	0.001	0.347	0.058	0.691	0.194	0.740	0.184	0.736	0.105	0.848	0.200	0.753	0.115	0.641	0.178
8/27/2005	0.090	1.911	0.233	0.000	0.273	0.000	0.211	0.000	0.338	0.001	0.347	0.055	0.691	0.193	0.739	0.185	0.735	0.105	0.852	0.195	0.752	0.114	0.639	0.179

Table A-1. Continued.

	T1-60 (25 cm)		T1-60 (35 cm)		T1-60 (55 cm)		T1-50 (30 cm)		T1-50 (50 cm)		T1-50 (95 cm)		T1-30 (25 cm)		T1-30 (50 cm)		T1-30 (80 cm)		T1-1 (25 cm)		T1-1 (50 cm)		T1-1 (72 cm)	
Date	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w
8/28/2005	0.081	0.312	0.224	0.000	0.273	0.000	0.205	0.000	0.338	0.001	0.346	0.059	0.690	0.196	0.739	0.184	0.734	0.106	0.852	0.195	0.752	0.116	0.641	0.178
8/29/2005	0.081	0.294	0.226	0.000	0.273	0.000	0.229	0.000	0.338	0.001	0.347	0.060	0.690	0.196	0.739	0.184	0.731	0.107	0.850	0.198	0.752	0.115	0.641	0.177
8/30/2005	0.074	0.201	0.220	0.000	0.273	0.000	0.202	0.000	0.337	0.001	0.346	0.061	0.690	0.196	0.738	0.185	0.732	0.107	0.848	0.202	0.751	0.116	0.644	0.175
8/31/2005	0.075	0.123	0.215	0.000	0.273	0.000	0.183	0.001	0.339	0.001	0.346	0.061	0.691	0.193	0.739	0.185	0.731	0.107	0.848	0.202	0.751	0.115	0.641	0.176
9/1/2005	0.111	0.000	0.274	0.000	0.276	0.000	0.254	0.007	0.340	0.001	0.348	0.060	0.690	0.195	0.739	0.185	0.734	0.107	0.846	0.206	0.751	0.118	0.639	0.176
9/2/2005	0.098	1.166	0.272	0.000	0.276	0.000	0.233	0.001	0.339	0.001	0.347	0.060	0.690	0.196	0.738	0.186	0.732	0.107	0.846	0.206	0.752	0.116	0.643	0.174
9/3/2005	0.122	0.000	0.274	0.000	0.278	0.000	0.299	0.014	0.342	0.002	0.349	0.061	0.688	0.201	0.738	0.186	0.738	0.105	0.845	0.210	0.754	0.116	0.647	0.173
9/4/2005	0.271	0.000	0.279	0.000	0.281	0.000	0.310	0.020	0.345	0.002	0.351	0.062	0.688	0.201	0.736	0.189	0.740	0.105	0.840	0.212	0.752	0.117	0.647	0.173
9/5/2005	0.375	0.000	0.282	0.000	0.282	0.000	0.313	0.020	0.344	0.002	0.351	0.062	0.688	0.201	0.735	0.189	0.740	0.105	0.841	0.213	0.752	0.115	0.641	0.175
9/6/2005	0.376	0.000	0.281	0.000	0.281	0.000	0.314	0.022	0.338	0.001	0.349	0.062	0.688	0.199	0.736	0.187	0.740	0.104	0.837	0.217	0.752	0.114	0.641	0.174
9/7/2005	0.360	0.000	0.278	0.000	0.279	0.000	0.314	0.018	0.337	0.001	0.348	0.063	0.688	0.197	0.737	0.185	0.738	0.104						
9/8/2005	0.243	0.000	0.275	0.000	0.277	0.000	0.314	0.007	0.338	0.001	0.346	0.064	0.689	0.195	0.738	0.183	0.739	0.104						
9/9/2005	0.162	0.000	0.273	0.000	0.276	0.000	0.311	0.001	0.337	0.001	0.346	0.062	0.689	0.195	0.737	0.184	0.739	0.103						
9/10/2005	0.126	0.000	0.272	0.000	0.276	0.000	0.307	0.000	0.337	0.001	0.346	0.062	0.688	0.197	0.737	0.184	0.739	0.103						
9/11/2005	0.111	0.000	0.273	0.000	0.276	0.000	0.306	0.000	0.339	0.001	0.347	0.062	0.688	0.198	0.737	0.184	0.739	0.102						
9/12/2005	0.100	0.662	0.273	0.000	0.276	0.000	0.292	0.000	0.339	0.001	0.347	0.062	0.688	0.198	0.737	0.185	0.740	0.101						
9/13/2005	0.090	1.353	0.274	0.000	0.275	0.000	0.242	0.000	0.338	0.001	0.346	0.061	0.689	0.196	0.736	0.186	0.741	0.101						
9/14/2005	0.082	0.366	0.275	0.000	0.275	0.000	0.236	0.000	0.337	0.001	0.346	0.061	0.687	0.200	0.736	0.188	0.741	0.101						
9/15/2005	0.077	0.245	0.272	0.000	0.274	0.000	0.229	0.000	0.336	0.001	0.346	0.061	0.688	0.199	0.735	0.189	0.739	0.101	0.832	0.227	0.753	0.120	0.640	0.170
9/16/2005	0.073	0.194	0.249	0.000	0.275	0.000	0.219	0.000	0.322	0.000	0.346	0.062	0.688	0.199	0.736	0.189	0.737	0.102	0.832	0.229	0.752	0.122	0.639	0.171
9/17/2005	0.070	0.176	0.238	0.000	0.275	0.000	0.208	0.000	0.317	0.000	0.346	0.061	0.688	0.199	0.737	0.187	0.735	0.102	0.827	0.233	0.751	0.123	0.638	0.172
9/18/2005	0.067	0.157	0.223	0.000	0.274	0.000	0.200	0.000	0.320	0.000	0.345	0.061	0.688	0.200	0.736	0.188	0.735	0.102	0.828	0.234	0.752	0.122	0.637	0.172
9/19/2005	0.064	0.137	0.213	0.000	0.274	0.000	0.198	0.000	0.320	0.000	0.345	0.062	0.687	0.201	0.737	0.188	0.735	0.102	0.825	0.237	0.753	0.121	0.639	0.172
9/20/2005	0.063	0.135	0.208	0.000	0.273	0.000	0.175	0.000	0.320	0.000	0.344	0.063	0.687	0.201	0.738	0.187	0.736	0.102	0.827	0.239	0.752	0.120	0.647	0.169
9/21/2005	0.062	0.132	0.206	0.000	0.274	0.000	0.173	0.000	0.320	0.000	0.344	0.063	0.688	0.199	0.737	0.187	0.735	0.102	0.830	0.236	0.753	0.120	0.645	0.169
9/22/2005	0.116	0.050	0.238	0.000	0.277	0.000	0.246	0.000	0.322	0.000	0.347	0.062	0.686	0.202	0.736	0.188	0.735	0.102	0.832	0.236	0.751	0.121	0.642	0.170
9/23/2005	0.140	0.000	0.257	0.000	0.279	0.000	0.289	0.000	0.324	0.000	0.347	0.057	0.686	0.202	0.736	0.188	0.735	0.102	0.826	0.239	0.752	0.120	0.637	0.171
9/24/2005	0.108	0.000	0.255	0.000	0.277	0.000	0.273	0.000	0.322	0.000	0.346	0.061	0.688	0.199	0.735	0.189	0.736	0.102	0.827	0.240	0.753	0.121	0.638	0.169
9/25/2005	0.093	3.765	0.254	0.000	0.277	0.000	0.252	0.000	0.321	0.000	0.346	0.061	0.686	0.203	0.736	0.188	0.737	0.101	0.827	0.241	0.753	0.120	0.641	0.168
9/26/2005	0.087	0.650	0.253	0.000	0.276	0.000	0.247	0.000	0.319	0.000	0.345	0.061	0.686	0.202	0.736	0.188	0.738	0.101	0.827	0.241	0.753	0.122	0.641	0.168
9/27/2005	0.083	0.371	0.254	0.000	0.275	0.000	0.237	0.000	0.318	0.000	0.345	0.061	0.686	0.202	0.735	0.189	0.737	0.101	0.828	0.243	0.751	0.123	0.639	0.169
9/28/2005	0.080	0.291	0.255	0.000	0.275	0.000	0.217	0.000	0.319	0.000	0.345	0.062	0.689	0.198	0.735	0.189	0.738	0.100	0.824	0.248	0.751	0.124	0.641	0.167
9/29/2005	0.079	0.271	0.256	0.000	0.276	0.000	0.203	0.000	0.320	0.000	0.345	0.061	0.688	0.200	0.736	0.188	0.736	0.101						
9/30/2005	0.077	0.240	0.256	0.000	0.275	0.000	0.196	0.000	0.319	0.000	0.345	0.062	0.689	0.198	0.735	0.188	0.737	0.100						
10/1/2005	0.106	0.030	0.260	0.000	0.277	0.000	0.233	0.000	0.320	0.000	0.347	0.062	0.686	0.202	0.736	0.187	0.742	0.099						
10/2/2005	0.093	0.634	0.258	0.000	0.276	0.000	0.218	0.000	0.317	0.000	0.347	0.061	0.685	0.204	0.736	0.186	0.740	0.099						
10/3/2005	0.083	0.370	0.258	0.000	0.275	0.000	0.207	0.000	0.318	0.000	0.346	0.061	0.687	0.201	0.736	0.187	0.741	0.099						
10/4/2005	0.090	0.475	0.260	0.000	0.276	0.000	0.214	0.000	0.317	0.000	0.346	0.061	0.687	0.202	0.737	0.186	0.737	0.100						
10/5/2005	0.103	0.000	0.261	0.000	0.276	0.000	0.236	0.000	0.316	0.000	0.346	0.061	0.685	0.203	0.742	0.179	0.742	0.098						
10/6/2005	0.142	0.000	0.265	0.000	0.278	0.000	0.295	0.000	0.316	0.000	0.348	0.060	0.685	0.205	0.745	0.174	0.743	0.098						
10/7/2005	0.150	0.000	0.265	0.000	0.278	0.000	0.298	0.005	0.319	0.000	0.348	0.057	0.688	0.198	0.743	0.177	0.743	0.098						
10/8/2005	0.124	0.000	0.263	0.000	0.276	0.000	0.298	0.002	0.317	0.000	0.347	0.060	0.685	0.204	0.743	0.175	0.743	0.098						
10/9/2005	0.101	0.466	0.262	0.000	0.275	0.000	0.293	0.000	0.319	0.000	0.346	0.060	0.685	0.204	0.739	0.181	0.743	0.097						
10/10/2005	0.091	2.076	0.262	0.000	0.274	0.000	0.283	0.000	0.321	0.000	0.346	0.059	0.685	0.203	0.737	0.183	0.743	0.097						
10/11/2005	0.086	0.515	0.264	0.000	0.274	0.000	0.275	0.000	0.321	0.000	0.346	0.059	0.685	0.203	0.741	0.179	0.743	0.097						
10/12/2005	0.081	0.313	0.264	0.000	0.274	0.000	0.246	0.000	0.317	0.000	0.346	0.059	0.685	0.204	0.742	0.178	0.741	0.097						
10/13/2005	0.078	0.256	0.265	0.000	0.274	0.000	0.236	0.000	0.317	0.000	0.346	0.059	0.686	0.202	0.741	0.180	0.741	0.097						
10/14/2005	0.075	0.216	0.266	0.000	0.274	0.000	0.230	0.000	0.317	0.000	0.346	0.058	0.687	0.201	0.741	0.180	0.741	0.098	0.814	0.273	0.749	0.136	0.641	0.165
10/15/2005	0.074	0.205	0.266	0.000	0.273	0.000	0.227	0.000	0.317	0.000	0.346	0.058	0.686	0.201	0.738	0.182	0.739	0.098	0.815	0.269	0.749	0.136	0.640	0.166
10/16/2005	0.071	0.180	0.257	0.000	0.274	0.000	0.223	0.000	0.318	0.000	0.346	0.058	0.687	0.201	0.738	0.183	0.740	0.098	0.817	0.267	0.749	0.136	0.640	0.167

Table A-1. Continued.

	T1-60 (25 cm)		T1-60 (35 cm)		T1-60 (55 cm)		T1-50 (30 cm)		T1-50 (50 cm)		T1-50 (95 cm)		T1-30 (25 cm)		T1-30 (50 cm)		T1-30 (80 cm)		T1-1 (25 cm)		T1-1 (50 cm)		T1-1 (72 cm)	
Date	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w
10/17/2005	0.068	0.157	0.227	0.000	0.274	0.000	0.215	0.000	0.322	0.000	0.346	0.058	0.685	0.203	0.737	0.184	0.741	0.097	0.814	0.272	0.750	0.135	0.642	0.167
10/18/2005	0.065	0.144	0.219	0.000	0.274	0.000	0.207	0.000	0.321	0.000	0.346	0.059	0.686	0.203	0.737	0.184	0.741	0.097	0.811	0.277	0.751	0.134	0.641	0.167
10/19/2005	0.083	0.127	0.222	0.000	0.274	0.000	0.215	0.000	0.321	0.000	0.347	0.059	0.686	0.202	0.737	0.183	0.741	0.098	0.809	0.278	0.749	0.136	0.639	0.168
10/20/2005	0.229	0.000	0.275	0.000	0.280	0.000	0.284	0.000	0.322	0.000	0.349	0.059	0.685	0.204	0.737	0.183	0.742	0.098	0.812	0.276	0.748	0.135	0.643	0.166
10/21/2005	0.187	0.000	0.274	0.000	0.279	0.000	0.284	0.000	0.317	0.000	0.349	0.059	0.685	0.203	0.737	0.183	0.741	0.098	0.811	0.278	0.749	0.134	0.647	0.164
10/22/2005	0.172	0.000	0.272	0.000	0.278	0.000	0.283	0.000	0.313	0.000	0.347	0.058	0.686	0.201	0.738	0.181	0.743	0.097	0.814	0.274	0.749	0.133	0.647	0.164
10/23/2005	0.136	0.000	0.269	0.000	0.276	0.000	0.282	0.000	0.311	0.000	0.347	0.057	0.686	0.201	0.738	0.181	0.742	0.097	0.815	0.274	0.748	0.134	0.644	0.165
10/24/2005	0.252	0.000	0.272	0.000	0.278	0.000	0.284	0.001	0.314	0.000	0.349	0.054	0.688	0.201	0.738	0.181	0.741	0.097	0.816	0.279	0.749	0.135	0.645	0.165
10/25/2005	0.336	0.001	0.279	0.000	0.282	0.000	0.293	0.003	0.320	0.000	0.353	0.053	0.691	0.201	0.738	0.181	0.741	0.097	0.813	0.292	0.751	0.136	0.642	0.167
10/26/2005	0.337	0.001	0.279	0.000	0.280	0.000	0.294	0.002	0.319	0.000	0.352	0.053	0.689	0.202	0.738	0.181	0.741	0.097	0.817	0.286	0.751	0.137	0.643	0.166
10/27/2005	0.337	0.000	0.280	0.000	0.280	0.000	0.295	0.001	0.318	0.000	0.351	0.054	0.688	0.201	0.738	0.179	0.740	0.097	0.820	0.279	0.751	0.135	0.644	0.166
10/28/2005	0.301	0.000	0.279	0.000	0.280	0.000	0.294	0.001	0.318	0.000	0.350	0.055	0.688	0.199	0.737	0.180	0.741	0.097	0.814	0.280	0.750	0.137	0.641	0.167
10/29/2005	0.198	0.000	0.278	0.000	0.279	0.000	0.294	0.006	0.317	0.000	0.349	0.055	0.686	0.200	0.738	0.177	0.742	0.096	0.817	0.276	0.750	0.135	0.641	0.167
10/30/2005	0.133	0.000	0.277	0.000	0.279	0.000	0.281	0.007	0.319	0.000	0.349	0.053	0.688	0.197	0.739	0.174	0.742	0.096	0.817	0.277	0.750	0.135	0.642	0.167
10/31/2005	0.109	0.000	0.276	0.000	0.278	0.000	0.223	0.000	0.318	0.000	0.348	0.054	0.688	0.196	0.739	0.175	0.743	0.096	0.813	0.279	0.749	0.135	0.639	0.168
11/1/2005	0.103	0.000	0.277	0.000	0.277	0.000	0.233	0.000	0.317	0.000	0.348	0.054	0.689	0.194	0.738	0.175	0.744	0.095	0.813	0.277	0.751	0.136	0.635	0.170
11/2/2005	0.110	0.000	0.278	0.000	0.278	0.000	0.243	0.000	0.318	0.000	0.349	0.054	0.687	0.197	0.738	0.176	0.746	0.095	0.811	0.283	0.751	0.136	0.638	0.169
11/3/2005	0.102	0.000	0.279	0.000	0.278	0.000	0.242	0.000	0.319	0.000	0.349	0.054	0.687	0.195	0.738	0.176	0.745	0.095	0.810	0.284	0.749	0.138	0.639	0.169
11/4/2005	0.100	0.122	0.281	0.000	0.278	0.000	0.240	0.000	0.319	0.000	0.349	0.054	0.688	0.191	0.739	0.173	0.744	0.095	0.815	0.278	0.749	0.139	0.638	0.169
11/5/2005	0.095	2.176	0.282	0.000	0.278	0.000	0.237	0.000	0.318	0.000	0.349	0.054	0.688	0.191	0.740	0.172	0.744	0.095	0.812	0.285	0.751	0.138	0.640	0.169
11/6/2005	0.091	1.115	0.281	0.000	0.277	0.000	0.234	0.000	0.318	0.000	0.349	0.054	0.687	0.193	0.740	0.171	0.744	0.095	0.814	0.284	0.750	0.137	0.642	0.168
11/7/2005	0.088	0.568	0.282	0.000	0.277	0.000	0.230	0.000	0.319	0.000	0.349	0.054	0.687	0.192	0.740	0.171	0.744	0.095	0.819	0.285	0.750	0.138	0.644	0.168
11/8/2005	0.085	0.400	0.283	0.000	0.277	0.000	0.233	0.000	0.320	0.000	0.349	0.054	0.689	0.189	0.740	0.170	0.744	0.095	0.816	0.284	0.749	0.138	0.646	0.167
11/9/2005	0.083	0.334	0.282	0.000	0.276	0.000	0.229	0.000	0.320	0.000	0.348	0.054	0.687	0.192	0.740	0.170	0.745	0.095	0.812	0.288	0.749	0.139	0.645	0.168
11/10/2005	0.081	0.270	0.283	0.000	0.276	0.000	0.227	0.000	0.321	0.000	0.348	0.054	0.688	0.189	0.741	0.169	0.745	0.095	0.813	0.289	0.749	0.138	0.644	0.168
11/11/2005	0.079	0.242	0.283	0.000	0.276	0.000	0.230	0.000	0.321	0.000	0.348	0.054	0.689	0.189	0.740	0.170	0.746	0.095	0.813	0.291	0.747	0.140	0.643	0.169
11/12/2005	0.078	0.234	0.280	0.000	0.276	0.000	0.230	0.000	0.321	0.000	0.349	0.054	0.688	0.189	0.741	0.170	0.745	0.095	0.811	0.292	0.749	0.139	0.643	0.169
11/13/2005	0.077	0.211	0.266	0.000	0.276	0.000	0.230	0.000	0.322	0.000	0.349	0.055	0.688	0.188	0.741	0.170	0.745	0.095	0.817	0.287	0.751	0.138	0.642	0.170
11/14/2005	0.077	0.212	0.246	0.000	0.276	0.000	0.228	0.000	0.322	0.000	0.348	0.055	0.688	0.189	0.742	0.167	0.744	0.095	0.813	0.291	0.749	0.139	0.638	0.172
11/15/2005	0.076	0.206	0.240	0.000	0.276	0.000	0.227	0.000	0.322	0.001	0.348	0.055	0.688	0.187	0.742	0.166	0.743	0.095	0.811	0.292	0.748	0.137	0.640	0.171
11/16/2005	0.075	0.196	0.236	0.000	0.276	0.000	0.226	0.000	0.322	0.000	0.348	0.055	0.687	0.189	0.742	0.166	0.744	0.095	0.812	0.290	0.749	0.138	0.646	0.168
11/17/2005	0.074	0.196	0.232	0.000	0.276	0.000	0.224	0.000	0.322	0.000	0.348	0.055	0.688	0.188	0.742	0.166	0.744	0.095	0.811	0.293	0.752	0.136	0.645	0.169
11/18/2005	0.074	0.188	0.230	0.000	0.276	0.000	0.223	0.000	0.322	0.000	0.349	0.055	0.688	0.187	0.742	0.166	0.745	0.095	0.808	0.297	0.749	0.137	0.646	0.168
11/19/2005	0.080	0.166	0.231	0.000	0.276	0.000	0.230	0.000	0.323	0.000	0.349	0.055	0.689	0.186	0.742	0.166	0.743	0.095	0.810	0.295	0.747	0.138	0.647	0.168
11/20/2005	0.146	0.000	0.270	0.000	0.280	0.000	0.284	0.005	0.324	0.001	0.351	0.053	0.689	0.186	0.742	0.165	0.743	0.096	0.816	0.290	0.746	0.139	0.646	0.169
11/21/2005	0.121	0.000	0.267	0.000	0.278	0.000	0.283	0.018	0.322	0.000	0.349	0.052	0.689	0.185	0.744	0.163	0.744	0.095	0.813	0.293	0.746	0.137	0.648	0.168
11/22/2005	0.108	0.000	0.268	0.000	0.278	0.000	0.285	0.007	0.319	0.000	0.349	0.052	0.688	0.185	0.742	0.165	0.745	0.095	0.808	0.301	0.751	0.138	0.645	0.169
11/23/2005	0.098	3.037	0.269	0.000	0.278	0.000	0.288	0.004	0.318	0.000	0.349	0.052	0.690	0.183	0.743	0.163	0.747	0.094	0.808	0.299	0.751	0.138	0.645	0.169
11/24/2005	0.093	2.607	0.270	0.000	0.278	0.000	0.290	0.005	0.319	0.001	0.348	0.052	0.689	0.184	0.744	0.162	0.747	0.094	0.806	0.301	0.752	0.137	0.644	0.169
11/25/2005	0.089	0.721	0.271	0.000	0.278	0.000	0.291	0.005	0.318	0.001	0.349	0.052	0.688	0.184	0.743	0.163	0.745	0.094	0.810	0.294	0.750	0.140	0.644	0.168
11/26/2005	0.087	0.517	0.272	0.000	0.278	0.000	0.291	0.006	0.317	0.000	0.349	0.052	0.687	0.185	0.743	0.161	0.745	0.094	0.807	0.300	0.751	0.139	0.644	0.168
11/27/2005	0.084	0.361	0.272	0.000	0.278	0.000	0.291	0.006	0.316	0.000	0.349	0.052	0.687	0.185	0.743	0.161	0.747	0.094	0.807	0.300	0.749	0.141	0.642	0.169
11/28/2005	0.083	0.318	0.273	0.000	0.278	0.000	0.291	0.005	0.315	0.000	0.349	0.052	0.687	0.184	0.744	0.159	0.747	0.094	0.811	0.294	0.749	0.140	0.640	0.170
11/29/2005	0.089	0.213	0.274	0.000	0.278	0.000	0.292	0.007	0.319	0.001	0.349	0.052	0.688	0.182	0.743	0.159	0.749	0.093	0.808	0.300	0.749	0.140	0.640	0.169
11/30/2005	0.098	2.119	0.275	0.000	0.279	0.000	0.293	0.013	0.322	0.001	0.349	0.052	0.688	0.182	0.743	0.159	0.747	0.093	0.811	0.296	0.748	0.141	0.641	0.169
12/1/2005	0.090	3.186	0.275	0.000	0.278	0.000	0.294	0.014	0.314	0.000	0.349	0.051	0.690	0.179	0.743	0.159	0.747	0.093	0.807	0.302	0.748	0.141	0.644	0.167
12/2/2005	0.084	0.346	0.275	0.000	0.278	0.000	0.295	0.015	0.315	0.000	0.349	0.051	0.688	0.181	0.743	0.159	0.747	0.093	0.810	0.299	0.748	0.140	0.647	0.166
12/3/2005	0.080	0.262	0.276	0.000	0.278	0.000	0.297	0.014	0.316	0.001	0.350	0.051	0.689	0.179	0.743	0.159	0.748	0.093	0.809	0.299	0.747	0.141	0.646	0.166
12/4/2005	0.078	0.232	0.274	0.000	0.279	0.000	0.297	0.013	0.316	0.001	0.349	0.051	0.689	0.179	0.743	0.159	0.747	0.093	0.809	0.299	0.750	0.139	0.648	0.165
12/5/2005	0.078	0.233	0.265	0.000	0.278	0.000	0.297	0.011	0.316	0.001	0.349	0.051	0.689	0.178	0.744	0.156	0.748	0.093	0.811	0.294	0.750	0.140	0.645	0.166

Table A-1. Continued.

	T1-60 (25 cm)		T1-60 (35 cm)		T1-60 (55 cm)		T1-50 (30 cm)		T1-50 (50 cm)		T1-50 (95 cm)		T1-30 (25 cm)		T1-30 (50 cm)		T1-30 (80 cm)		T1-1 (25 cm)		T1-1 (50 cm)		T1-1 (72 cm)	
Date	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w
12/6/2005	0.079	0.248	0.261	0.000	0.279	0.000	0.297	0.011	0.317	0.001	0.349	0.052	0.689	0.177	0.743	0.157	0.749	0.093	0.808	0.301	0.750	0.139	0.647	0.165
12/7/2005	0.078	0.236	0.259	0.000	0.279	0.000	0.297	0.010	0.317	0.001	0.350	0.052	0.688	0.179	0.743	0.157	0.749	0.093	0.807	0.298	0.747	0.141	0.642	0.167
12/8/2005	0.085	1.421	0.256	0.000	0.280	0.000	0.299	0.014	0.324	0.002	0.350	0.053	0.688	0.178	0.744	0.155	0.751	0.092	0.808	0.298	0.748	0.139	0.645	0.166
12/9/2005	0.095	1.853	0.263	0.000	0.280	0.000	0.299	0.018	0.325	0.002	0.350	0.052	0.690	0.176	0.744	0.154	0.750	0.092	0.812	0.292	0.748	0.138	0.648	0.164
12/10/2005	0.089	0.747	0.259	0.000	0.279	0.000	0.298	0.017	0.325	0.002	0.350	0.051	0.689	0.176	0.745	0.153	0.748	0.093	0.808	0.297	0.750	0.140	0.645	0.165
12/11/2005	0.084	0.376	0.256	0.000	0.279	0.000	0.298	0.017	0.325	0.002	0.349	0.051	0.689	0.177	0.745	0.153	0.748	0.093	0.804	0.304	0.750	0.139	0.644	0.165
12/12/2005	0.080	0.267	0.253	0.000	0.278	0.000	0.295	0.016	0.326	0.002	0.349	0.051	0.690	0.175	0.745	0.153	0.749	0.092	0.808	0.304	0.748	0.141	0.644	0.165
12/13/2005	0.077	0.221	0.249	0.000	0.279	0.000	0.289	0.015	0.327	0.003	0.350	0.050	0.689	0.177	0.745	0.153	0.750	0.092	0.809	0.305	0.748	0.142	0.643	0.165
12/14/2005	0.074	0.192	0.243	0.000	0.279	0.000	0.285	0.014	0.328	0.003	0.350	0.051	0.689	0.176	0.745	0.152	0.751	0.092	0.808	0.302	0.748	0.140	0.644	0.164
12/15/2005	0.074	0.188	0.240	0.000	0.279	0.000	0.280	0.013	0.329	0.004	0.349	0.051	0.689	0.177	0.745	0.152	0.750	0.092	0.806	0.303	0.748	0.143	0.641	0.165
12/16/2005	0.074	0.185	0.238	0.000	0.279	0.000	0.277	0.013	0.330	0.004	0.349	0.051	0.691	0.173	0.745	0.151	0.749	0.092	0.806	0.303	0.750	0.141	0.641	0.165
12/17/2005	0.073	0.182	0.236	0.000	0.279	0.000	0.276	0.012	0.331	0.004	0.350	0.052	0.691	0.173	0.744	0.152	0.749	0.092	0.811	0.295	0.749	0.141	0.640	0.166
12/18/2005	0.072	0.172	0.233	0.000	0.279	0.000	0.243	0.005	0.330	0.003	0.349	0.052	0.689	0.176	0.744	0.152	0.749	0.092	0.809	0.297	0.749	0.141	0.642	0.165
12/19/2005	0.071	0.168	0.230	0.000	0.279	0.000	0.214	0.000	0.334	0.004	0.349	0.052	0.689	0.176	0.744	0.153	0.748	0.093	0.804	0.306	0.750	0.140	0.648	0.162
12/20/2005	0.072	0.171	0.229	0.000	0.279	0.000	0.189	0.000	0.334	0.004	0.348	0.052	0.690	0.174	0.744	0.153	0.750	0.092	0.806	0.303	0.748	0.141	0.645	0.163
12/21/2005	0.069	0.155	0.224	0.000	0.278	0.000	0.179	0.000	0.334	0.004	0.349	0.051	0.689	0.175	0.743	0.153	0.748	0.092	0.804	0.307	0.746	0.142	0.646	0.162
12/22/2005	0.066	0.138	0.220	0.000	0.279	0.000	0.179	0.000	0.335	0.004	0.349	0.051	0.689	0.176	0.744	0.153	0.748	0.092	0.807	0.304	0.747	0.144	0.645	0.162
12/23/2005	0.064	0.130	0.216	0.000	0.279	0.000	0.177	0.000	0.335	0.005	0.349	0.051	0.689	0.176	0.743	0.152	0.748	0.092	0.807	0.302	0.748	0.144	0.647	0.162
12/24/2005	0.063	0.126	0.213	0.000	0.278	0.000	0.181	0.000	0.334	0.005	0.349	0.051	0.689	0.176	0.749	0.145	0.749	0.092	0.808	0.301	0.748	0.143	0.645	0.162
12/25/2005	0.062	0.121	0.209	0.000	0.278	0.000	0.172	0.000	0.335	0.005	0.348	0.051	0.690	0.174	0.755	0.137	0.749	0.092	0.808	0.300	0.748	0.143	0.647	0.161
12/26/2005	0.060	0.112	0.204	0.000	0.278	0.000	0.159	0.000	0.336	0.005	0.349	0.051	0.690	0.175	0.756	0.136	0.750	0.091	0.809	0.301	0.748	0.142	0.647	0.161
12/27/2005	0.058	0.107	0.198	0.000	0.279	0.000	0.151	0.000	0.337	0.005	0.349	0.052	0.690	0.175	0.759	0.132	0.746	0.092	0.806	0.305	0.748	0.142	0.648	0.161
12/28/2005	0.056	0.101	0.192	0.000	0.278	0.000	0.146	0.000	0.337	0.006	0.348	0.051	0.691	0.172	0.760	0.130	0.747	0.092	0.807	0.303	0.746	0.143	0.647	0.161
12/29/2005	0.055	0.097	0.187	0.000	0.278	0.000	0.144	0.000	0.338	0.006	0.348	0.051	0.691	0.172	0.761	0.128	0.748	0.092	0.809	0.299	0.748	0.142	0.647	0.160
12/30/2005	0.054	0.095	0.182	0.000	0.278	0.000	0.139	0.000	0.339	0.006	0.348	0.051	0.691	0.170	0.761	0.128	0.749	0.091	0.810	0.300	0.749	0.144	0.648	0.160
12/31/2005	0.052	0.091	0.176	0.000	0.279	0.000	0.133	0.000	0.340	0.006	0.348	0.051	0.691	0.170	0.760	0.127	0.750	0.091	0.810	0.297	0.748	0.145	0.648	0.159
1/1/2006	0.051	0.090	0.170	0.000	0.279	0.000	0.128	0.000	0.340	0.006	0.348	0.052	0.692	0.169	0.761	0.126	0.747	0.092	0.811	0.296	0.747	0.143	0.645	0.161
1/2/2006	0.050	0.087	0.165	0.000	0.279	0.000	0.122	0.000	0.339	0.006	0.348	0.052	0.691	0.169	0.760	0.127	0.751	0.091	0.813	0.294	0.747	0.143	0.645	0.160
1/3/2006	0.048	0.084	0.159	0.000	0.278	0.000	0.107	0.000	0.336	0.005	0.348	0.052	0.690	0.169	0.760	0.126	0.750	0.091	0.807	0.300	0.747	0.143	0.645	0.160
1/4/2006	0.046	0.080	0.151	0.000	0.279	0.000	0.096	1.277	0.344	0.006	0.348	0.049	0.690	0.169	0.761	0.125	0.749	0.091	0.807	0.302	0.749	0.145	0.646	0.160
1/5/2006	0.045	0.078	0.143	0.000	0.278	0.000	0.089	0.563	0.343	0.006	0.348	0.048	0.690	0.168	0.762	0.125	0.750	0.091	0.809	0.300	0.748	0.143	0.646	0.160
1/6/2006	0.041	0.073	0.135	0.000	0.278	0.000	0.083	0.289	0.320	0.002	0.348	0.053	0.690	0.169	0.758	0.130	0.750	0.091	0.809	0.300	0.746	0.144	0.644	0.161
1/7/2006	0.039	0.070	0.126	0.000	0.279	0.000	0.078	0.205	0.297	0.000	0.349	0.058	0.691	0.168	0.756	0.130	0.750	0.091	0.813	0.293	0.747	0.143	0.648	0.159
1/8/2006	0.036	0.066	0.119	0.000	0.279	0.000	0.075	0.171	0.278	0.000	0.350	0.061	0.692	0.167	0.756	0.130	0.750	0.091	0.815	0.289	0.747	0.141	0.647	0.160
1/9/2006	0.035	0.064	0.112	0.000	0.280	0.000	0.073	0.155	0.267	0.000	0.350	0.062	0.692	0.166	0.754	0.131	0.751	0.091	0.816	0.286	0.747	0.140	0.647	0.160
1/10/2006	0.034	0.064	0.106	0.000	0.280	0.000	0.071	0.146	0.255	0.000	0.349	0.063	0.693	0.164	0.754	0.130	0.749	0.091	0.817	0.285	0.748	0.137	0.646	0.161
1/11/2006	0.032	0.063	0.099	0.827	0.280	0.000	0.069	0.136	0.249	0.000	0.348	0.063	0.693	0.163	0.754	0.130	0.751	0.090	0.818	0.284	0.747	0.137	0.649	0.160
1/12/2006	0.031	0.062	0.094	2.987	0.280	0.000	0.067	0.127	0.244	0.000	0.348	0.062	0.694	0.161	0.756	0.128	0.750	0.091	0.818	0.284	0.746	0.136	0.647	0.161
1/13/2006	0.029	0.059	0.089	0.723	0.280	0.000	0.066	0.121	0.238	0.000	0.346	0.062	0.692	0.164	0.756	0.128			0.817	0.284	0.746	0.135	0.648	0.161
1/14/2006	0.028	0.059	0.086	0.439	0.280	0.000	0.065	0.117	0.235	0.000	0.345	0.062	0.693	0.161	0.756	0.129			0.814	0.288	0.749	0.135	0.647	0.163
1/15/2006	0.026	0.057	0.081	0.276	0.281	0.000	0.062	0.110	0.228	0.000	0.344	0.061	0.695	0.160	0.756	0.128			0.814	0.287	0.750	0.133	0.649	0.162
1/16/2006	0.025	0.056	0.077	0.215	0.282	0.000	0.061	0.104	0.224	0.000	0.342	0.060	0.694	0.161	0.755	0.127			0.817	0.281	0.750	0.131	0.649	0.163
1/17/2006	0.025	0.056	0.074	0.175	0.282	0.000	0.059	0.099	0.220	0.000	0.341	0.059	0.694	0.161	0.755	0.127			0.817	0.279	0.749	0.130	0.650	0.163
1/18/2006	0.023	0.055	0.070	0.149	0.284	0.000	0.058	0.096	0.210	0.000	0.340	0.055	0.695	0.160	0.755	0.127			0.810	0.282	0.749	0.128	0.650	0.164
1/19/2006	0.022	0.053	0.068	0.136	0.285	0.000	0.055	0.090	0.199	0.000	0.339	0.048	0.696	0.159	0.755	0.127			0.806	0.281	0.749	0.127	0.651	0.164
1/20/2006	0.022	0.054	0.065	0.122	0.286	0.000	0.053	0.085	0.189	0.000	0.338	0.044	0.695	0.159	0.756	0.126			0.805	0.277	0.747	0.128	0.648	0.165
1/21/2006	0.022	0.054	0.063	0.113	0.287	0.000	0.051	0.081	0.187	0.000	0.337	0.043	0.695	0.160	0.757	0.125			0.805	0.280	0.748	0.128	0.645	0.166
1/22/2006	0.021	0.053	0.062	0.107	0.288	0.000	0.050	0.080	0.190	0.000	0.337	0.045	0.695	0.160	0.757	0.126			0.802	0.286	0.747	0.128	0.647	0.165
1/23/2006	0.021	0.054	0.059	0.088	0.288	0.000	0.050	0.080	0.190	0.000	0.336	0.048	0.695	0.161	0.757	0.125			0.801	0.288	0.748	0.127	0.647	0.165
1/24/2006	0.020	0.052	0.058	0.083	0.288	0.000	0.050	0.079	0.189	0.000	0.336	0.050	0.694	0.162	0.758	0.125			0.800	0.288	0.748	0.127	0.646	0.165

Table A-1. Continued.

	T1-60 (25 cm)		T1-60 (35 cm)		T1-60 (55 cm)		T1-50 (30 cm)		T1-50 (50 cm)		T1-50 (95 cm)		T1-30 (25 cm)		T1-30 (50 cm)		T1-30 (80 cm)		T1-1 (25 cm)		T1-1 (50 cm)		T1-1 (72 cm)	
Date	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w
1/25/2006	0.019	0.052	0.056	0.074	0.282	0.000	0.049	0.078	0.183	0.000	0.337	0.050	0.695	0.161	0.757	0.125			0.801	0.287	0.746	0.128	0.646	0.164
1/26/2006	0.018	0.050	0.054	0.065	0.239	0.000	0.046	0.074	0.178	0.000	0.337	0.048	0.695	0.162	0.758	0.124			0.801	0.287	0.747	0.127	0.647	0.163
1/27/2006	0.017	0.050	0.052	0.057	0.218	0.000	0.045	0.072	0.178	0.000	0.337	0.049	0.696	0.160	0.757	0.123			0.801	0.286	0.746	0.127	0.650	0.161
1/28/2006	0.017	0.050	0.049	0.054	0.198	0.000	0.044	0.070	0.178	0.000	0.338	0.050	0.695	0.161	0.757	0.123			0.800	0.287	0.746	0.127	0.649	0.161
1/29/2006	0.015	0.048	0.048	0.052	0.188	0.000	0.043	0.070	0.178	0.000	0.338	0.050	0.695	0.161	0.757	0.123			0.802	0.284	0.746	0.127	0.648	0.161
1/30/2006							0.042	0.068	0.179	0.000	0.338	0.050	0.695	0.160	0.758	0.123			0.803	0.282	0.746	0.127	0.645	0.162
1/31/2006							0.042	0.068	0.179	0.000	0.339	0.050	0.696	0.160	0.757	0.124			0.802	0.284	0.746	0.128	0.645	0.161
2/1/2006							0.042	0.067	0.176	0.000	0.339	0.051	0.696	0.161	0.756	0.124			0.799	0.286	0.746	0.128	0.645	0.161
2/2/2006							0.041	0.066	0.172	0.000	0.339	0.051	0.695	0.162	0.754	0.126			0.802	0.281	0.746	0.127	0.647	0.159
2/3/2006							0.041	0.067	0.173	0.000	0.339	0.051	0.695	0.161	0.751	0.131			0.806	0.278	0.746	0.127	0.645	0.160
2/4/2006							0.098	0.020	0.220	0.000	0.359	0.050	0.698	0.159	0.751	0.131			0.809	0.277	0.749	0.125	0.647	0.154
2/5/2006							0.091	1.053	0.264	0.000	0.377	0.044	0.698	0.160	0.751	0.130			0.809	0.278	0.749	0.127	0.647	0.154
2/6/2006							0.081	0.223	0.257	0.000	0.379	0.042	0.698	0.161	0.752	0.128			0.812	0.274	0.748	0.128	0.647	0.153
2/7/2006							0.075	0.163	0.251	0.000	0.379	0.044	0.698	0.160	0.752	0.128			0.814	0.270	0.748	0.127	0.648	0.153
2/8/2006							0.072	0.142	0.245	0.000	0.379	0.046	0.699	0.158	0.752	0.128			0.814	0.272	0.747	0.129	0.646	0.154
2/9/2006							0.069	0.128	0.241	0.000	0.378	0.047	0.699	0.157	0.752	0.127			0.817	0.268	0.748	0.126	0.649	0.153
2/10/2006							0.066	0.119	0.238	0.000	0.378	0.048	0.699	0.157	0.752	0.126			0.816	0.268	0.748	0.126	0.649	0.153
2/11/2006							0.065	0.113	0.235	0.000	0.377	0.048	0.699	0.155	0.752	0.126			0.816	0.268	0.750	0.126	0.649	0.152
2/12/2006							0.063	0.109	0.234	0.000	0.376	0.048	0.700	0.155	0.752	0.126			0.817	0.267	0.751	0.125	0.650	0.152
2/13/2006							0.061	0.104	0.231	0.000	0.364	0.045	0.700	0.154	0.751	0.126			0.819	0.263	0.750	0.126	0.650	0.152
2/14/2006							0.060	0.101	0.228	0.000	0.361	0.044	0.701	0.153	0.751	0.124			0.821	0.259	0.750	0.126	0.652	0.151
2/15/2006	0.031	0.062	0.073	0.054	0.250	0.009	0.058	0.097	0.227	0.000	0.357	0.044	0.701	0.152	0.751	0.124			0.820	0.259	0.749	0.126	0.649	0.152
2/16/2006	0.030	0.060	0.072	0.036	0.250	0.011	0.057	0.095	0.226	0.000	0.355	0.045	0.702	0.150	0.751	0.123			0.819	0.260	0.750	0.123	0.650	0.152
2/17/2006	0.028	0.058	0.072	0.023	0.251	0.010	0.056	0.093	0.223	0.000	0.353	0.045	0.701	0.152	0.752	0.123			0.816	0.262	0.750	0.124	0.652	0.151
2/18/2006	0.028	0.059	0.071	0.011	0.251	0.009	0.055	0.090	0.221	0.000	0.352	0.045	0.702	0.150	0.752	0.124			0.816	0.262	0.750	0.123	0.652	0.151
2/19/2006	0.026	0.057	0.069	0.006	0.252	0.007	0.054	0.088	0.218	0.000	0.352	0.045	0.701	0.152	0.752	0.124			0.814	0.265	0.750	0.122	0.651	0.152
2/20/2006	0.026	0.058	0.067	0.003	0.252	0.006	0.053	0.086	0.216	0.000	0.351	0.045	0.702	0.151					0.812	0.266	0.750	0.120	0.651	0.152
2/21/2006					0.248	0.002	0.051	0.083	0.213	0.000	0.351	0.046	0.701	0.152					0.813	0.263	0.750	0.121	0.650	0.153
2/22/2006					0.247	0.001	0.050	0.081	0.209	0.000	0.350	0.046	0.702	0.151					0.816	0.258	0.750	0.120	0.653	0.152
2/23/2006	0.024	0.057	0.060	0.020	0.240	0.000	0.049	0.080	0.207	0.000	0.349	0.046	0.701	0.151					0.813	0.259	0.749	0.121	0.653	0.152
2/24/2006	0.022	0.053	0.059	0.023	0.222	0.000	0.048	0.077	0.203	0.000	0.348	0.046	0.701	0.151					0.812	0.262	0.749	0.122	0.654	0.153
2/25/2006	0.022	0.054	0.058	0.033	0.211	0.000	0.047	0.077	0.203	0.000	0.348	0.045	0.701	0.151					0.812	0.260	0.749	0.122	0.652	0.153
2/26/2006	0.021	0.054	0.057	0.035	0.203	0.000	0.047	0.077	0.204	0.000	0.347	0.046	0.702	0.150					0.810	0.263	0.749	0.120	0.651	0.154
2/27/2006	0.020	0.053	0.056	0.041	0.196	0.000	0.046	0.075	0.202	0.000	0.348	0.046	0.701	0.151					0.814	0.257	0.748	0.121	0.652	0.154
2/28/2006	0.019	0.052	0.052	0.041	0.188	0.000	0.045	0.072	0.200	0.000	0.348	0.046	0.702	0.149					0.813	0.258	0.749	0.120	0.653	0.154
3/1/2006	0.018	0.051	0.050	0.041	0.181	0.000	0.043	0.070	0.199	0.000	0.348	0.046	0.701	0.149					0.814	0.253	0.748	0.119	0.651	0.154
3/2/2006	0.018	0.051	0.048	0.044	0.173	0.000	0.042	0.068	0.197	0.000	0.347	0.046	0.702	0.148					0.817	0.247	0.748	0.121	0.652	0.153
3/3/2006	0.017	0.051	0.046	0.045	0.166	0.000	0.041	0.067	0.194	0.000	0.347	0.046	0.701	0.148					0.817	0.248	0.748	0.120	0.656	0.151
3/4/2006	0.017	0.050	0.044	0.044	0.159	0.000	0.040	0.066	0.192	0.000	0.347	0.046	0.701	0.148					0.816	0.251	0.749	0.119	0.656	0.152
3/5/2006	0.016	0.050	0.042	0.043	0.153	0.000	0.039	0.065	0.191	0.000	0.348	0.046	0.701	0.148					0.815	0.253	0.748	0.119	0.654	0.153
3/6/2006	0.016	0.050	0.041	0.043	0.147	0.000	0.039	0.065	0.190	0.000	0.348	0.046	0.701	0.147					0.817	0.247	0.747	0.120	0.654	0.154
3/7/2006	0.015	0.049	0.039	0.041	0.141	0.000	0.038	0.063	0.189	0.000	0.347	0.047	0.701	0.147					0.815	0.250	0.747	0.120	0.654	0.154
3/8/2006	0.014	0.049	0.037	0.040	0.134	0.000	0.037	0.063	0.187	0.000	0.346	0.048	0.701	0.147					0.812	0.250	0.746	0.121	0.651	0.155
3/9/2006	0.013	0.048	0.036	0.039	0.126	0.000	0.036	0.061	0.189	0.000	0.344	0.047	0.701	0.146					0.763	0.254	0.745	0.120	0.651	0.155
3/10/2006	0.013	0.048	0.035	0.038	0.118	0.000	0.035	0.061		0.000	0.333	0.045	0.701	0.144					0.753	0.251	0.743	0.120	0.644	0.157
3/11/2006	0.013	0.048	0.034	0.036	0.110	0.000	0.034	0.060		0.000	0.314	0.045	0.702	0.141					0.745	0.259	0.743	0.121	0.642	0.159
3/12/2006	0.013	0.048	0.033	0.036	0.102	0.000	0.034	0.060		0.000	0.292	0.041	0.702	0.137					0.740	0.262	0.742	0.122	0.644	0.159
3/13/2006	0.013	0.048	0.032	0.035	0.096	1.152	0.033	0.058		0.000	0.275	0.038	0.700	0.134	0.760	0.116			0.738	0.263	0.742	0.122	0.644	0.159
3/14/2006	0.012	0.047	0.031	0.034	0.092	1.045	0.032	0.059		0.000	0.268	0.038	0.702	0.129	0.760	0.116			0.749	0.266	0.742	0.124	0.646	0.159
3/15/2006							0.032	0.058		0.000	0.267	0.037	0.705	0.124	0.760	0.117			0.753	0.272	0.743	0.125	0.648	0.160

Table A-1. Continued.

	T1-60 (25 cm)		T1-60 (35 cm)		T1-60 (55 cm)		T1-50 (30 cm)		T1-50 (50 cm)		T1-50 (95 cm)		T1-30 (25 cm)		T1-30 (50 cm)		T1-30 (80 cm)		T1-1 (25 cm)		T1-1 (50 cm)		T1-1 (72 cm)	
Date	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w
3/16/2006							0.030	0.056		0.000	0.265	0.038	0.706	0.119	0.760	0.116			0.755	0.268	0.743	0.124	0.648	0.160
3/17/2006							0.029	0.056		0.000	0.262	0.039	0.707	0.115	0.760	0.115			0.754	0.265	0.743	0.124	0.647	0.161
3/18/2006							0.029	0.055		0.000	0.259	0.039	0.708	0.112	0.760	0.114			0.755	0.261	0.742	0.125	0.647	0.160
3/19/2006	0.010	0.046	0.027	0.033	0.073	0.133	0.028	0.055		0.000	0.254	0.039	0.710	0.110	0.760	0.114			0.753	0.259	0.741	0.126	0.647	0.160
3/20/2006	0.010	0.046	0.028	0.034	0.072	0.128	0.027	0.054		0.000	0.249	0.039	0.711	0.108	0.761	0.113			0.754	0.247	0.740	0.126	0.647	0.160
3/21/2006	0.010	0.046	0.026	0.032	0.069	0.113	0.027	0.054		0.000	0.237	0.040	0.711	0.106	0.761	0.112			0.750	0.236	0.740	0.125	0.645	0.161
3/22/2006	0.010	0.046	0.027	0.034	0.065	0.101	0.026	0.053		0.000	0.224	0.038	0.712	0.102	0.762	0.111			0.753	0.214	0.739	0.124	0.647	0.161
3/23/2006	0.009	0.046	0.026	0.033	0.063	0.095	0.026	0.053		0.000	0.215	0.036	0.712	0.100	0.762	0.111			0.758	0.185	0.740	0.122	0.643	0.163
3/24/2006	0.009	0.046	0.026	0.034	0.062	0.091	0.025	0.052		0.000	0.213	0.034	0.715	0.097	0.764	0.109			0.763	0.173	0.740	0.122	0.643	0.163
3/25/2006	0.008	0.045	0.025	0.033	0.060	0.086	0.024	0.051		0.000	0.208	0.035	0.716	0.095	0.763	0.108			0.765	0.162	0.740	0.120	0.646	0.163
3/26/2006	0.007	0.044	0.024	0.032	0.057	0.081	0.022	0.049		0.000	0.202	0.036	0.717	0.092	0.763	0.107			0.763	0.159	0.742	0.115	0.647	0.165
3/27/2006	0.007	0.045	0.024	0.033	0.056	0.080	0.022	0.049		0.000	0.197	0.035	0.716	0.091	0.762	0.105			0.765	0.151	0.743	0.111	0.647	0.165
3/28/2006							0.021	0.049		0.000	0.192	0.034	0.715	0.089	0.762	0.104			0.765	0.148	0.743	0.109	0.648	0.165
3/29/2006							0.021	0.049		0.000	0.188	0.033	0.716	0.087	0.763	0.103			0.766	0.145	0.744	0.106	0.648	0.165
3/30/2006							0.020	0.049		0.000	0.184	0.032	0.714	0.088	0.764	0.100			0.768	0.142	0.744	0.105	0.649	0.165
3/31/2006							0.020	0.049		0.000	0.180	0.028	0.714	0.087	0.766	0.098			0.767	0.141	0.745	0.103	0.647	0.165
4/1/2006							0.020	0.049		0.000	0.176	0.026	0.713	0.085	0.767	0.095			0.767	0.141	0.745	0.101	0.646	0.166
4/2/2006							0.020	0.049		0.000	0.172	0.026	0.712	0.083	0.768	0.093			0.767	0.139	0.745	0.100	0.644	0.167
4/3/2006							0.019	0.048		0.000	0.168	0.025	0.712	0.080	0.770	0.091			0.768	0.137	0.745	0.099	0.644	0.166
4/4/2006							0.019	0.048		0.000	0.164	0.023	0.703	0.076	0.772	0.088			0.768	0.136	0.745	0.098	0.642	0.166
4/5/2006							0.019	0.048		0.000	0.160	0.021	0.688	0.065	0.774	0.085			0.770	0.133	0.746	0.098	0.646	0.164
4/6/2006							0.018	0.048		0.000	0.156	0.019	0.681	0.062					0.770	0.132	0.747	0.096	0.645	0.163
4/7/2006							0.018	0.048		0.000	0.151	0.018	0.672	0.056					0.769	0.131	0.748	0.095	0.645	0.161
4/8/2006							0.018	0.047		0.000	0.144	0.014	0.666	0.052					0.768	0.131	0.748	0.094	0.646	0.159
4/9/2006							0.018	0.047		0.000	0.140	0.009	0.688	0.062					0.775	0.135	0.749	0.094	0.647	0.158
4/10/2006							0.018	0.047		0.000	0.139	0.009	0.691	0.068					0.774	0.140	0.752	0.093	0.650	0.159
4/11/2006							0.018	0.047		0.000	0.138	0.008	0.687	0.069					0.773	0.145	0.752	0.093	0.648	0.161
4/12/2006							0.019	0.048		0.000	0.136	0.006	0.673	0.064					0.768	0.144	0.752	0.092	0.647	0.161
4/13/2006							0.024	0.051		0.000	0.134	0.003	0.665	0.063					0.766	0.144	0.753	0.092	0.648	0.159
4/14/2006							0.029	0.055		0.000	0.131	0.001	0.660	0.062					0.763	0.144	0.753	0.091	0.648	0.157
4/15/2006							0.031	0.056		0.000	0.128	0.001	0.656	0.061					0.764	0.142	0.752	0.092	0.647	0.156
4/16/2006							0.032	0.057		0.000	0.125	0.000	0.652	0.059					0.761	0.143	0.752	0.092	0.646	0.154
4/17/2006							0.033	0.057		0.000	0.121	0.000	0.647	0.057					0.759	0.144	0.752	0.092	0.646	0.151
4/18/2006							0.033	0.058		0.000	0.117	0.000	0.645	0.055					0.758	0.143	0.753	0.093	0.647	0.146
4/19/2006							0.033	0.057		0.000	0.114	0.000	0.643	0.055					0.758	0.144	0.753	0.093	0.647	0.144
4/20/2006							0.033	0.057		0.000	0.111	0.000	0.640	0.054					0.752	0.145	0.753	0.094	0.648	0.141
4/21/2006							0.033	0.057		0.000	0.108	0.000	0.636	0.052					0.740	0.143	0.752	0.095	0.645	0.140
4/22/2006							0.032	0.057		0.000	0.105	0.000	0.632	0.050					0.729	0.143	0.753	0.095	0.647	0.138
4/23/2006							0.032	0.057		0.000	0.102		0.629	0.048					0.717	0.144	0.752	0.096	0.643	0.139
4/24/2006							0.031	0.056		0.000	0.099		0.625	0.045					0.705	0.145	0.752	0.096	0.645	0.136
4/25/2006							0.031	0.056		0.000	0.096		0.619	0.043					0.695	0.142	0.752	0.096	0.647	0.134
4/26/2006							0.031	0.056		0.000	0.093		0.630	0.047					0.701	0.148	0.752	0.097	0.646	0.134
4/27/2006	0.021	0.053	0.024	0.033	0.020	0.038	0.045	0.073		0.000	0.092		0.637	0.054					0.711	0.161	0.752	0.096	0.647	0.136
4/28/2006	0.020	0.053	0.023	0.033	0.020	0.038	0.059	0.095		0.000	0.091		0.620	0.046					0.685	0.154	0.753	0.095	0.646	0.136
4/29/2006	0.019	0.052	0.023	0.033	0.020	0.038	0.057	0.091		0.000	0.090		0.613	0.040					0.670	0.152	0.750	0.094	0.645	0.136
4/30/2006	0.019	0.051	0.023	0.033	0.020	0.039	0.054	0.086		0.000	0.088		0.609	0.036					0.655	0.150	0.738	0.092	0.644	0.135
5/1/2006	0.018	0.051	0.023	0.034	0.019	0.038	0.052	0.082		0.000	0.087		0.605	0.034					0.645	0.150	0.736	0.091	0.644	0.134
5/2/2006	0.018	0.050	0.022	0.034	0.018	0.038	0.049	0.078		0.000	0.085		0.602	0.031					0.637	0.149	0.736	0.090	0.643	0.134
5/3/2006	0.017	0.050	0.022	0.034	0.018	0.038	0.047	0.074		0.000	0.084		0.599	0.027					0.631	0.148	0.735	0.090	0.644	0.132
5/4/2006	0.017	0.050	0.022	0.033	0.016	0.036	0.045	0.072		0.000	0.082		0.594	0.023					0.625	0.147	0.734	0.091	0.643	0.131

Table A-1. Continued.

	T1-60 (25 cm)		T1-60 (35 cm)		T1-60 (55 cm)		T1-50 (30 cm)		T1-50 (50 cm)		T1-50 (95 cm)		T1-30 (25 cm)		T1-30 (50 cm)		T1-30 (80 cm)		T1-1 (25 cm)		T1-1 (50 cm)		T1-1 (72 cm)	
Date	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w
5/5/2006	0.017	0.050	0.022	0.034	0.016	0.037	0.043	0.070		0.000	0.080		0.589	0.015					0.618	0.147	0.734	0.092	0.645	0.129
5/6/2006	0.016	0.049	0.022	0.034	0.016	0.037	0.042	0.068		0.000	0.078		0.585	0.009					0.613	0.145	0.733	0.093	0.644	0.129
5/7/2006	0.016	0.049	0.022	0.034	0.016	0.037	0.040	0.066		0.000	0.076		0.582	0.004					0.608	0.144	0.733	0.095	0.644	0.129
5/8/2006	0.016	0.049	0.022	0.034	0.016	0.037	0.039	0.065		0.000	0.075		0.579	0.001					0.603	0.142	0.733	0.094	0.644	0.129
5/9/2006	0.015	0.048	0.021	0.034	0.015	0.035	0.038	0.064		0.000	0.074		0.578	0.000					0.599	0.141	0.733	0.095	0.645	0.129
5/10/2006	0.014	0.047	0.021	0.034	0.014	0.035	0.036	0.062		0.000	0.073		0.577	0.000					0.597	0.141	0.733	0.095	0.645	0.129
5/11/2006	0.014	0.047	0.022	0.035	0.014	0.036	0.036	0.062		0.000	0.072		0.575	0.000					0.593	0.140	0.732	0.095	0.645	0.129
5/12/2006	0.014	0.047	0.021	0.034	0.015	0.037	0.035	0.061		0.000	0.071		0.575	0.000					0.588	0.136	0.731	0.097	0.642	0.131
5/13/2006	0.013	0.047	0.021	0.034	0.015	0.038	0.033	0.059		0.000	0.071		0.573	0.000					0.584	0.134	0.731	0.095	0.644	0.130
5/14/2006	0.012	0.047	0.020	0.034	0.015	0.038	0.032	0.058		0.000	0.070		0.571	0.000					0.581	0.132	0.731	0.094	0.644	0.130
5/15/2006	0.012	0.046	0.021	0.035	0.015	0.038	0.031	0.057		0.000	0.069		0.569	0.000					0.578	0.130	0.731	0.093	0.643	0.130
5/16/2006	0.011	0.045	0.021	0.035	0.014	0.037	0.031	0.057		0.000	0.069	0.037	0.594	0.027					0.609	0.201	0.732	0.093	0.648	0.129
5/17/2006	0.010	0.045	0.020	0.035	0.013	0.036	0.032	0.058		0.000	0.071	0.036	0.590	0.021					0.599	0.194	0.732	0.091	0.648	0.130
5/18/2006	0.011	0.046	0.020	0.035	0.016	0.040	0.044	0.072		0.000	0.070	0.037	0.580	0.007					0.585	0.168	0.731	0.093	0.643	0.132
5/19/2006	0.011	0.046	0.021	0.036	0.016	0.041	0.049	0.078		0.000	0.069	0.036	0.574	0.001					0.579	0.155	0.731	0.092	0.642	0.132
5/20/2006	0.011	0.046	0.021	0.036	0.015	0.041	0.049	0.078		0.000	0.069	0.036	0.571	0.000					0.575	0.152	0.730	0.094	0.642	0.131
5/21/2006	0.011	0.046	0.020	0.036	0.015	0.041	0.048	0.077		0.000	0.069	0.036	0.569	0.000					0.572	0.150	0.729	0.096	0.642	0.131
5/22/2006	0.012	0.047	0.021	0.037	0.015	0.040	0.046	0.074		0.000	0.068	0.035	0.567	0.000					0.570	0.148	0.728	0.099	0.644	0.129
5/23/2006	0.012	0.047	0.020	0.036	0.015	0.040	0.044	0.072		0.000	0.068	0.035	0.567	0.000					0.569	0.146	0.727	0.100	0.645	0.129
5/24/2006	0.012	0.046	0.021	0.037	0.015	0.040	0.043	0.070		0.000	0.068	0.035	0.566	0.000					0.568	0.147	0.728	0.099	0.645	0.129
5/25/2006	0.012	0.047	0.020	0.036	0.015	0.040	0.041	0.069		0.000	0.068	0.034	0.565	0.000					0.567	0.147	0.727	0.099	0.645	0.129
5/26/2006	0.011	0.046	0.021	0.037	0.014	0.039	0.040	0.067		0.000	0.068	0.034	0.568	0.002					0.570	0.156	0.728	0.100	0.641	0.130
5/27/2006	0.012	0.046	0.021	0.036	0.013	0.038	0.039	0.065		0.000	0.069	0.034	0.572	0.003					0.573	0.171	0.726	0.105	0.642	0.130
5/28/2006	0.012	0.047	0.021	0.036	0.013	0.039	0.037	0.063		0.000	0.068	0.035	0.567	0.000					0.567	0.158	0.726	0.104	0.641	0.130
5/29/2006	0.012	0.047	0.021	0.036	0.014	0.040	0.037	0.064		0.000	0.067	0.035	0.565	0.000					0.565	0.154	0.725	0.104	0.642	0.130
5/30/2006	0.012	0.047	0.021	0.037	0.014	0.040	0.035	0.061		0.000	0.067	0.035	0.564	0.000					0.564	0.153	0.725	0.104	0.643	0.130
5/31/2006	0.011	0.046	0.021	0.036	0.014	0.040	0.034	0.061		0.000	0.066	0.033	0.563	0.000					0.563	0.151	0.723	0.106	0.644	0.129
6/1/2006							0.066	1.194		0.000	0.067	0.035	0.600	0.027					0.596	0.219	0.734	0.105	0.646	0.127
6/2/2006	0.048	0.085	0.019	0.034	0.013	0.038	0.081	0.284		0.000	0.067	0.033	0.579	0.006					0.582	0.199	0.726	0.108	0.645	0.128
6/3/2006	0.046	0.083	0.021	0.036	0.013	0.039	0.072	0.165		0.000	0.067	0.032	0.570	0.000					0.570	0.161	0.725	0.108	0.646	0.127
6/4/2006	0.043	0.078	0.021	0.036	0.013	0.039	0.066	0.130		0.000	0.067	0.030	0.566	0.000					0.566	0.147	0.724	0.109	0.646	0.128
6/5/2006	0.040	0.074	0.021	0.035	0.013	0.039	0.061	0.110		0.000	0.067	0.030	0.565	0.000					0.564	0.144	0.722	0.111	0.645	0.129
6/6/2006	0.039	0.072	0.022	0.035	0.013	0.039	0.057	0.099		0.000	0.067	0.030	0.566	0.000					0.563	0.144	0.723	0.112	0.644	0.130
6/7/2006	0.037	0.069	0.022	0.036	0.013	0.039	0.054	0.092		0.000	0.067	0.030	0.563	0.000					0.562	0.142	0.722	0.115	0.643	0.131
6/8/2006	0.035	0.066	0.022	0.036	0.013	0.039	0.051	0.085		0.000	0.067	0.031	0.562	0.000					0.560	0.141	0.721	0.119	0.643	0.131
6/9/2006	0.034	0.066	0.023	0.036	0.012	0.039	0.048	0.080		0.000	0.066	0.031	0.565	0.002					0.562	0.154	0.722	0.121	0.645	0.130
6/10/2006	0.033	0.064	0.023	0.036	0.012	0.038	0.046	0.077		0.000	0.067	0.031	0.566	0.000					0.563	0.156	0.723	0.121	0.648	0.129
6/11/2006	0.051	0.366	0.028	0.038	0.011	0.036	0.061	0.261		0.000	0.068	0.031	0.591	0.020					0.596	0.196	0.734	0.124	0.647	0.130
6/12/2006	0.065	0.136	0.052	0.052	0.009	0.032	0.082	0.347		0.000	0.069	0.030	0.586	0.010					0.588	0.224	0.742	0.125	0.652	0.128
6/13/2006	0.057	0.104	0.052	0.048	0.015	0.033	0.072	0.165		0.000	0.070	0.031	0.577	0.002					0.576	0.191	0.729	0.126	0.653	0.127
6/14/2006	0.059	0.109	0.051	0.046	0.023	0.035	0.068	0.140		0.000	0.070	0.030	0.575	0.002					0.572	0.173	0.730	0.127	0.653	0.127
6/15/2006	0.053	0.093	0.051	0.046	0.029	0.038	0.063	0.119		0.000	0.070	0.031	0.569	0.000					0.565	0.149	0.729	0.132	0.653	0.127
6/16/2006	0.047	0.082	0.050	0.046	0.031	0.040	0.059	0.105		0.000	0.070	0.030	0.567	0.000					0.564	0.145	0.728	0.135	0.650	0.129
6/17/2006	0.044	0.077	0.049	0.044	0.032	0.040	0.055	0.095		0.000	0.070	0.029	0.566	0.000					0.562	0.139	0.724	0.137	0.651	0.130
6/18/2006	0.071	0.221	0.063	0.073	0.097	0.025	0.085	0.043	0.225	0.000	0.162	0.041	0.651	0.039					0.711	0.201	0.741	0.136	0.653	0.131
6/19/2006	0.059	0.112	0.072	0.097	0.192	0.011	0.087	1.077	0.227	0.000	0.308	0.042	0.721	0.072					0.835	0.241	0.754	0.139	0.654	0.130
6/20/2006	0.049	0.086	0.068	0.085	0.194	0.000	0.071	0.164	0.209	0.000	0.309	0.031	0.719	0.074					0.675	0.246	0.754	0.142	0.653	0.130
6/21/2006	0.045	0.078	0.066	0.082	0.190	0.000	0.061	0.115	0.188	0.000	0.303	0.028	0.698	0.073					0.655	0.254	0.753	0.148	0.651	0.131
6/22/2006	0.041	0.073	0.062	0.074	0.186	0.000	0.055	0.098	0.168	0.000	0.297	0.026	0.638	0.048					0.620	0.245	0.756	0.149	0.652	0.131
6/23/2006	0.038	0.069	0.059	0.070	0.180	0.000	0.051	0.088	0.152	0.000	0.296	0.027	0.604	0.022										

Table A-1. Continued.

	T1-60 (25 cm)		T1-60 (35 cm)		T1-60 (55 cm)		T1-50 (30 cm)		T1-50 (50 cm)		T1-50 (95 cm)		T1-30 (25 cm)		T1-30 (50 cm)		T1-30 (80 cm)		T1-1 (25 cm)		T1-1 (50 cm)		T1-1 (72 cm)	
Date	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w
6/24/2006	0.035	0.064	0.058	0.070	0.173	0.000	0.049	0.083	0.138	0.000	0.294	0.028	0.601	0.023										
6/25/2006	0.034	0.063	0.056	0.065	0.167	0.000	0.046	0.079	0.129	0.000	0.292	0.029	0.597	0.023										
6/26/2006	0.037	0.070	0.055	0.061	0.162	0.000	0.045	0.077	0.121	0.000	0.291	0.030	0.642	0.037										
6/27/2006	0.061	0.115	0.062	0.091	0.174	0.000	0.045	0.077	0.131	0.000	0.293	0.034	0.732	0.066										
6/28/2006	0.063	0.126	0.064	0.113	0.183	0.000	0.062	0.121	0.127	0.000	0.296	0.036	0.732	0.071										
6/29/2006	0.063	0.121	0.066	0.125	0.194	0.000	0.076	0.203	0.143	0.000	0.305	0.039	0.733	0.077										
6/30/2006	0.057	0.103	0.066	0.120	0.200	0.000	0.071	0.159	0.151	0.000	0.313	0.039	0.733	0.082										
7/1/2006	0.052	0.090	0.065	0.113	0.201	0.000	0.066	0.134	0.143	0.000	0.313	0.037	0.733	0.077										
7/2/2006	0.048	0.084	0.063	0.105	0.200	0.000	0.062	0.115	0.139	0.000	0.313	0.036	0.734	0.077										
7/3/2006	0.046	0.080	0.063	0.098	0.199	0.000	0.060	0.110	0.144	0.000	0.314	0.036	0.735	0.074										
7/4/2006	0.047	0.081	0.062	0.092	0.198	0.000	0.057	0.102	0.140	0.000	0.314	0.037	0.735	0.075										
7/5/2006	0.045	0.079	0.061	0.088	0.196	0.000	0.056	0.097	0.137	0.000	0.312	0.036	0.735	0.072										
7/6/2006	0.042	0.073	0.061	0.087	0.193	0.000	0.054	0.092	0.129	0.000	0.312	0.035	0.736	0.071										
7/7/2006	0.052	0.098	0.061	0.084	0.194	0.000	0.066	0.067	0.139	0.000	0.314	0.037	0.737	0.070										
7/8/2006	0.064	0.125	0.067	0.120	0.208	0.000	0.092	0.936	0.167	0.000	0.327	0.041	0.738	0.069										
7/9/2006	0.057	0.103	0.068	0.119	0.217	0.000	0.082	0.300	0.187	0.000	0.334	0.039	0.739	0.071										
7/10/2006	0.054	0.095	0.068	0.114	0.219	0.000	0.078	0.220	0.202	0.000	0.336	0.041	0.738	0.080										
7/11/2006	0.050	0.086	0.067	0.108	0.219	0.000	0.076	0.216	0.209	0.000	0.338	0.041	0.738	0.086										
7/12/2006	0.073	0.247	0.077	0.220	0.252	0.000	0.102	0.244	0.267	0.000	0.341	0.045	0.738	0.086										
7/13/2006	0.068	0.144	0.087	0.371	0.280	0.000	0.108	0.000	0.336	0.002	0.344	0.042	0.739	0.088										
7/14/2006	0.064	0.125	0.087	0.338	0.281	0.000	0.103	0.000	0.338	0.002	0.346	0.039	0.737	0.093										
7/15/2006	0.056	0.100	0.084	0.228	0.282	0.000	0.093	4.478	0.330	0.001	0.346	0.039	0.738	0.093										
7/16/2006	0.051	0.089	0.081	0.172	0.283	0.000	0.086	0.461	0.322	0.000	0.346	0.040	0.738	0.093										
7/17/2006	0.048	0.085	0.078	0.152	0.284	0.000	0.082	0.254	0.253	0.000	0.346	0.041	0.738	0.090	0.755	0.147	0.742	0.087						
7/18/2006	0.047	0.087	0.077	0.150	0.286	0.000	0.086	0.224	0.131	0.000	0.345	0.042	0.739	0.085	0.754	0.150	0.742	0.087						
7/19/2006	0.046	0.085	0.076	0.137	0.287	0.000	0.085	0.205	0.127	0.000	0.345	0.039	0.740	0.083	0.754	0.152	0.743	0.087						
7/20/2006	0.044	0.081	0.075	0.126	0.288	0.000	0.084	0.190	0.124	0.000	0.345	0.039	0.738	0.086	0.753	0.155	0.745	0.087						
7/21/2006	0.042	0.078	0.073	0.113	0.289	0.000	0.083	0.165	0.123	0.000	0.344	0.041	0.739	0.086	0.753	0.156	0.742	0.088						
7/22/2006	0.046	0.090	0.076	0.148	0.290	0.000	0.113	0.101	0.133	0.000	0.343	0.042	0.738	0.090	0.752	0.158	0.743	0.088						
7/23/2006	0.061	0.122	0.087	0.395	0.294	0.000	0.131	0.009	0.168	0.000	0.343	0.042	0.738	0.090	0.752	0.160	0.745	0.088						
7/24/2006	0.055	0.101	0.085	0.281	0.296	0.000	0.113	0.000	0.158	0.000	0.342	0.038	0.738	0.091	0.752	0.159	0.743	0.088						
7/25/2006	0.051	0.093	0.080	0.193	0.297	0.000	0.103	0.000	0.141	0.000	0.341	0.035	0.740	0.083	0.751	0.161	0.742	0.088						
7/26/2006	0.048	0.087	0.077	0.148	0.297	0.000	0.095	0.427	0.132	0.000	0.341	0.036	0.740	0.084	0.752	0.162	0.741	0.089						
7/27/2006	0.045	0.082	0.075	0.127	0.298	0.000	0.090	0.307	0.128	0.000	0.340	0.038	0.738	0.087	0.751	0.164	0.745	0.088						
7/28/2006	0.043	0.079	0.074	0.115	0.298	0.000	0.086	0.157	0.123	0.000	0.336	0.037	0.741	0.080	0.751	0.164	0.743	0.088						
7/29/2006	0.040	0.074	0.072	0.103	0.299	0.000	0.083	0.129	0.115	0.000	0.329	0.035	0.740	0.080	0.751	0.165	0.740	0.089						
7/30/2006	0.038	0.072	0.071	0.093	0.298	0.000	0.079	0.102	0.109	0.000	0.326	0.034	0.740	0.081	0.751	0.166	0.743	0.088						
7/31/2006	0.036	0.069	0.069	0.085	0.298	0.000	0.076	0.089	0.102	0.000	0.324	0.034	0.733	0.077	0.751	0.166	0.740	0.089						
8/1/2006	0.034	0.067	0.067	0.078	0.299	0.000	0.072	0.077	0.096	0.750	0.324	0.034	0.721	0.070	0.751	0.166	0.743	0.088						
8/2/2006	0.033	0.066	0.066	0.075	0.299	0.000	0.070	0.071	0.091	1.329	0.323	0.035	0.702	0.060	0.751	0.167	0.739	0.089						
8/3/2006	0.030	0.063	0.064	0.070	0.299	0.000	0.067	0.066	0.085	0.392	0.322	0.034	0.675	0.046	0.752	0.166	0.742	0.088						
8/4/2006	0.029	0.062	0.062	0.066	0.299	0.000	0.064	0.063	0.082	0.295	0.322	0.036	0.687	0.049	0.751	0.167	0.738	0.089						
8/5/2006	0.027	0.060	0.059	0.062	0.289	0.000	0.062	0.059	0.079	0.235	0.321	0.038	0.675	0.044	0.751	0.167	0.740	0.088						
8/6/2006	0.026	0.059	0.058	0.061	0.245	0.000	0.059	0.056	0.075	0.185	0.321	0.039	0.668	0.041	0.749	0.170	0.739	0.088						
8/7/2006	0.026	0.058	0.056	0.060	0.214	0.000	0.056	0.053	0.072	0.159	0.318	0.039	0.654	0.037	0.749	0.170	0.734	0.089						
8/8/2006	0.025	0.057	0.054	0.059	0.178	0.000	0.054	0.051	0.069	0.136	0.311	0.039	0.641	0.032	0.749	0.171	0.738	0.088						
8/9/2006	0.024	0.056	0.051	0.057	0.158	0.000	0.051	0.049	0.065	0.119	0.290	0.038	0.632	0.027	0.750	0.170	0.737	0.089						
8/10/2006	0.023	0.056	0.049	0.056	0.147	0.000	0.048	0.049	0.063	0.110	0.277	0.038	0.623	0.023	0.749	0.171	0.736	0.089	0.670	0.187	0.758	0.188	0.658	0.146
8/11/2006	0.023	0.056	0.046	0.054	0.125	0.000	0.044	0.053	0.059	0.098	0.258	0.037	0.617	0.020	0.750	0.170	0.734	0.089	0.669	0.192	0.758	0.187	0.661	0.144
8/12/2006	0.023	0.057	0.045	0.056	0.115	0.000	0.041	0.044	0.057	0.093	0.244	0.036	0.611	0.016	0.750	0.169	0.733	0.089	0.663	0.197	0.759	0.185	0.657	0.144

Table A-1. Continued.

	T1-60 (25 cm)		T1-60 (35 cm)		T1-60 (55 cm)		T1-50 (30 cm)		T1-50 (50 cm)		T1-50 (95 cm)		T1-30 (25 cm)		T1-30 (50 cm)		T1-30 (80 cm)		T1-1 (25 cm)		T1-1 (50 cm)		T1-1 (72 cm)	
Date	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w
8/13/2006	0.022	0.056	0.043	0.055	0.104	0.000	0.038	0.042	0.055	0.089	0.232	0.035	0.607	0.015	0.751	0.168	0.733	0.089	0.658	0.201	0.758	0.184	0.654	0.144
8/14/2006	0.021	0.055	0.042	0.054	0.095	2.464	0.035	0.041	0.054	0.087	0.223	0.035	0.606	0.015	0.751	0.167	0.731	0.089	0.653	0.204	0.756	0.181	0.660	0.141
8/15/2006	0.021	0.054	0.041	0.054	0.088	0.619	0.034	0.041	0.052	0.084	0.216	0.036	0.603	0.014	0.751	0.167	0.728	0.090	0.644	0.208	0.749	0.175	0.660	0.140
8/16/2006	0.020	0.054	0.041	0.054	0.082	0.298	0.032	0.039	0.051	0.083	0.210	0.038	0.602	0.015	0.750	0.168	0.730	0.089	0.636	0.209	0.750	0.167	0.661	0.140
8/17/2006	0.018	0.052	0.040	0.053	0.078	0.220	0.031	0.040	0.050	0.081	0.208	0.043	0.601	0.016	0.751	0.167	0.731	0.089	0.634	0.213	0.757	0.162	0.659	0.140
8/18/2006	0.018	0.052	0.039	0.053	0.074	0.176	0.030	0.039	0.050	0.081	0.208	0.050	0.607	0.025	0.751	0.166	0.732	0.089	0.792	0.228	0.759	0.163	0.661	0.137
8/19/2006	0.018	0.052	0.039	0.053	0.072	0.161	0.028	0.039	0.049	0.080	0.210	0.046	0.627	0.044	0.751	0.166	0.732	0.089	0.849	0.208	0.760	0.165	0.661	0.137
8/20/2006	0.017	0.052	0.038	0.053	0.072	0.155	0.072	0.061	0.050	0.079	0.213	0.044	0.713	0.068	0.750	0.167	0.733	0.089	0.855	0.204	0.758	0.170	0.659	0.138
8/21/2006	0.017	0.051	0.038	0.052	0.073	0.166	0.113	0.106	0.051	0.082	0.217	0.044	0.729	0.072	0.751	0.165	0.735	0.088	0.853	0.210	0.757	0.171	0.656	0.140
8/22/2006	0.017	0.052	0.038	0.053	0.074	0.165	0.124	0.114	0.052	0.083	0.221	0.048	0.731	0.070	0.751	0.166	0.735	0.089	0.852	0.214	0.758	0.170	0.660	0.139
8/23/2006	0.018	0.052	0.040	0.054	0.086	2.259	0.126	0.113	0.065	0.117	0.245	0.044	0.733	0.072	0.750	0.168	0.740	0.089	0.855	0.207	0.760	0.168	0.660	0.140
8/24/2006	0.036	0.068	0.064	0.096	0.150	0.000	0.125	0.030	0.147	0.254	0.305	0.045	0.735	0.074	0.752	0.169	0.750	0.089	0.870	0.175	0.760	0.167	0.657	0.144
8/25/2006	0.041	0.075	0.063	0.097	0.205	0.000	0.126	0.035	0.212	0.002	0.318	0.046	0.736	0.077	0.753	0.168	0.748	0.090	0.876	0.163	0.762	0.166	0.658	0.146
8/26/2006	0.055	0.093	0.069	0.126	0.253	0.000	0.129	0.004	0.338	0.010	0.325	0.047	0.735	0.082	0.752	0.168	0.750	0.090	0.880	0.154	0.761	0.167	0.662	0.145
8/27/2006	0.050	0.087	0.070	0.119	0.265	0.000	0.116	0.000	0.323	0.008	0.330	0.049	0.735	0.087	0.752	0.169	0.748	0.090	0.882	0.153	0.761	0.166	0.660	0.147
8/28/2006	0.048	0.083	0.071	0.111	0.266	0.000	0.112	0.000	0.316	0.006	0.334	0.051	0.735	0.093	0.751	0.171	0.744	0.091	0.886	0.147	0.760	0.167	0.659	0.149
8/29/2006	0.046	0.081	0.071	0.104	0.266	0.000	0.102	0.107	0.255	0.003	0.335	0.047	0.736	0.088	0.751	0.168	0.739	0.091	0.886	0.148	0.760	0.166	0.658	0.150
8/30/2006	0.051	0.091	0.076	0.147	0.267	0.000	0.124	0.262	0.284	0.004	0.340	0.047	0.737	0.086	0.750	0.171	0.742	0.090	0.888	0.146	0.762	0.162	0.658	0.150
8/31/2006	0.059	0.109	0.089	1.223	0.271	0.000	0.132	0.000	0.377	0.007	0.346	0.049	0.738	0.089	0.752	0.169	0.745	0.090	0.889	0.142	0.761	0.160	0.663	0.149
9/1/2006	0.061	0.123	0.100	1.375	0.274	0.000	0.138	0.000	0.389	0.008	0.347	0.054	0.738	0.092	0.751	0.171	0.745	0.090	0.891	0.138	0.759	0.159	0.662	0.149
9/2/2006	0.066	0.141	0.124	0.000	0.276	0.000	0.135	0.000	0.398	0.009	0.345	0.055	0.737	0.097	0.749	0.172	0.744	0.090	0.892	0.138	0.762	0.153	0.664	0.149
9/3/2006	0.059	0.115	0.117	0.000	0.278	0.000	0.123	0.000	0.406	0.012	0.344	0.062	0.736	0.102	0.749	0.173	0.743	0.090	0.894	0.134	0.763	0.149	0.664	0.149
9/4/2006	0.056	0.108	0.112	0.000	0.279	0.000	0.118	0.000	0.411	0.013	0.343	0.063	0.735	0.107	0.749	0.173	0.745	0.089	0.897	0.131	0.763	0.148	0.665	0.148
9/5/2006	0.061	0.124	0.117	0.000	0.282	0.000	0.125	0.000	0.414	0.015	0.343	0.059	0.736	0.110	0.749	0.174	0.744	0.089	0.896	0.131	0.762	0.146	0.661	0.150
9/6/2006	0.065	0.140	0.128	0.000	0.285	0.000	0.134	0.001	0.416	0.016	0.343	0.055	0.738	0.110	0.749	0.173	0.742	0.089	0.897	0.128	0.762	0.144	0.658	0.151
9/7/2006	0.064	0.137	0.128	0.000	0.286	0.000	0.128	0.000	0.417	0.009	0.342	0.052	0.737	0.113	0.749	0.173	0.741	0.089	0.895	0.130	0.762	0.143	0.657	0.150
9/8/2006	0.058	0.114	0.119	0.000	0.287	0.000	0.121	0.000	0.417	0.002	0.341	0.052	0.737	0.116	0.748	0.174	0.742	0.089	0.896	0.130	0.762	0.142	0.659	0.150
9/9/2006	0.055	0.104	0.113	0.000	0.289	0.000	0.116	0.000	0.416	0.001	0.341	0.052	0.736	0.120	0.749	0.174	0.744	0.088	0.898	0.128	0.762	0.141	0.660	0.150
9/10/2006	0.052	0.096	0.109	0.000	0.290	0.000	0.113	0.000	0.416	0.001	0.341	0.051	0.736	0.123	0.748	0.174	0.743	0.088	0.898	0.129	0.763	0.140	0.663	0.149
9/11/2006	0.054	0.102	0.109	0.000	0.291	0.000	0.114	0.000	0.415	0.001	0.341	0.052	0.735	0.126	0.748	0.175	0.742	0.088	0.898	0.129	0.766	0.136	0.660	0.151
9/12/2006	0.056	0.107	0.108	0.000	0.293	0.000	0.112	0.000	0.414	0.002	0.340	0.050	0.735	0.128	0.748	0.176	0.743	0.088	0.898	0.128	0.764	0.137	0.664	0.149
9/13/2006	0.053	0.099	0.107	0.000	0.294	0.000	0.113	0.000	0.415	0.004	0.341	0.048	0.735	0.130	0.749	0.174	0.739	0.088	0.901	0.124	0.763	0.137	0.662	0.151
9/14/2006	0.051	0.093	0.105	0.000	0.295	0.000	0.113	0.000	0.415	0.004	0.341	0.047	0.735	0.131	0.748	0.175	0.740	0.088	0.901	0.124	0.763	0.134	0.660	0.152
9/15/2006	0.049	0.090	0.104	0.000	0.296	0.000	0.114	0.000	0.415	0.004	0.341	0.046	0.734	0.133	0.748	0.176	0.742	0.088	0.902	0.122	0.765	0.130	0.657	0.154
9/16/2006	0.048	0.087	0.105	0.000	0.298	0.000	0.116	0.000	0.415	0.004	0.342	0.046	0.734	0.134	0.747	0.177	0.743	0.087	0.904	0.120	0.766	0.126	0.656	0.156
9/17/2006	0.047	0.085	0.105	0.000	0.300	0.000	0.116	0.000	0.416	0.005	0.342	0.046	0.735	0.134	0.747	0.177	0.740	0.088	0.903	0.120	0.764	0.126	0.657	0.156
9/18/2006	0.045	0.082	0.102	0.049	0.301	0.000	0.116	0.000	0.416	0.007	0.341	0.046	0.735	0.135	0.748	0.177	0.740	0.088	0.904	0.119	0.764	0.125	0.658	0.157
9/19/2006	0.043	0.079	0.103	0.000	0.303	0.000	0.117	0.000	0.416	0.011	0.341	0.046	0.735	0.135	0.747	0.178	0.737	0.089	0.903	0.120	0.765	0.122	0.658	0.158
9/20/2006	0.066	0.139	0.155	0.000	0.307	0.000	0.158	0.017	0.416	0.006	0.341	0.046	0.734	0.138	0.747	0.180	0.740	0.088	0.902	0.119	0.766	0.118	0.662	0.157
9/21/2006	0.062	0.123	0.152	0.000	0.308	0.000	0.140	0.004	0.413	0.004	0.339	0.047	0.734	0.142	0.747	0.179	0.735	0.089	0.901	0.121	0.766	0.115	0.660	0.157
9/22/2006	0.057	0.105	0.135	0.000	0.310	0.000	0.126	0.000	0.412	0.005	0.338	0.049	0.733	0.146	0.747	0.180	0.734	0.089	0.899	0.124	0.767	0.113	0.659	0.158
9/23/2006	0.052	0.095	0.124	0.000	0.311	0.000	0.120	0.000	0.412	0.004	0.338	0.049	0.732	0.149	0.746	0.181	0.731	0.089	0.900	0.125	0.766	0.113	0.660	0.158
9/24/2006	0.050	0.090	0.119	0.000	0.311	0.000	0.119	0.000	0.412	0.005	0.337	0.049	0.731	0.150	0.746	0.181	0.732	0.089	0.899	0.124	0.763	0.115	0.663	0.157
9/25/2006	0.047	0.085	0.115	0.000	0.312	0.000	0.116	0.000	0.411	0.004	0.337	0.050	0.731	0.152	0.746	0.182	0.734	0.088	0.900	0.123	0.764	0.113	0.663	0.158
9/26/2006	0.046	0.082	0.111	0.000	0.312	0.000	0.113	0.000	0.411	0.005	0.338	0.050	0.730	0.154	0.746	0.183	0.733	0.088	0.899	0.124	0.765	0.110	0.661	0.159
9/27/2006	0.044	0.079	0.109	0.000	0.312	0.000	0.112	0.000	0.411	0.005	0.338	0.050	0.730	0.156	0.746	0.184	0.728	0.089	0.898	0.124	0.766	0.107	0.660	0.160
9/28/2006	0.042	0.076	0.108	0.000	0.312	0.000	0.111	0.000	0.411	0.006	0.338	0.049	0.729	0.159	0.746	0.184	0.729	0.089	0.899	0.124	0.767	0.105	0.659	0.160
9/29/2006	0.041	0.073	0.105	0.000	0.312	0.000	0.109	0.000	0.411	0.006	0.337	0.049	0.731	0.158	0.745	0.186	0.733	0.088	0.900	0.123	0.767	0.103	0.657	0.162
9/30/2006	0.038	0.069	0.103	0.000	0.312	0.000	0.108	0.000	0.411	0.007	0.337	0.049	0.731	0.160	0.745	0.187	0.727	0.089	0.900	0.123	0.767	0.101	0.656	0.163
10/1/2006			0.103	0.000	0.311	0.000	0.110	0.000	0.412	0.007	0.337	0.049	0.731	0.162	0.744	0.188	0.727	0.089	0.902	0.119	0.767	0.099	0.655	0.163

Table A-1. Continued.

	T1-60 (25 cm)		T1-60 (35 cm)		T1-60 (55 cm)		T1-50 (30 cm)		T1-50 (50 cm)		T1-50 (95 cm)		T1-30 (25 cm)		T1-30 (50 cm)		T1-30 (80 cm)		T1-1 (25 cm)		T1-1 (50 cm)		T1-1 (72 cm)	
Date	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w
10/2/2006			0.102	0.000	0.311	0.000	0.110	0.000	0.411	0.008	0.338	0.049	0.731	0.161	0.744	0.189	0.727	0.089	0.900	0.121	0.767	0.097	0.655	0.163
10/3/2006			0.102	0.000	0.311	0.000	0.109	0.000	0.411	0.008	0.337	0.050	0.731	0.164	0.744	0.189	0.727	0.089	0.901	0.120	0.769	0.094	0.655	0.164
10/4/2006			0.101	0.000	0.310	0.000	0.108	0.000	0.410	0.008	0.337	0.050	0.729	0.167	0.742	0.192	0.725	0.090	0.900	0.121	0.769	0.093	0.655	0.164
10/5/2006			0.101	0.000	0.310	0.000	0.108	0.000	0.409	0.008	0.337	0.049	0.729	0.170	0.742	0.193	0.725	0.090	0.899	0.120	0.768	0.092	0.655	0.164
10/6/2006			0.101	0.000	0.310	0.000	0.108	0.000	0.410	0.009	0.337	0.050	0.729	0.172	0.741	0.193	0.724	0.090	0.899	0.119	0.769	0.090	0.654	0.164
10/7/2006			0.100	0.000	0.310	0.000	0.107	0.000	0.410	0.010	0.338	0.049	0.727	0.176	0.742	0.193	0.727	0.090	0.900	0.118	0.768	0.089	0.656	0.163
10/8/2006			0.098	0.644	0.310	0.000	0.106	0.000	0.410	0.010	0.337	0.050	0.728	0.176	0.742	0.193	0.736	0.088	0.900	0.117	0.768	0.088	0.654	0.164
10/9/2006			0.097	0.771	0.310	0.000	0.105	0.000	0.410	0.011	0.337	0.050	0.728	0.179	0.742	0.194	0.732	0.089	0.900	0.118	0.768	0.086	0.655	0.163
10/10/2006			0.096	3.602	0.310	0.000	0.103	0.000	0.409	0.012	0.336	0.050	0.729	0.175	0.741	0.195	0.729	0.089	0.898	0.120	0.768	0.085	0.655	0.162
10/11/2006			0.093	2.948	0.309	0.000	0.098	0.297	0.387	0.008	0.335	0.048	0.732	0.155	0.741	0.193	0.723	0.089	0.896	0.125	0.768	0.084	0.658	0.161
10/12/2006			0.089	0.678	0.309	0.000	0.093	1.109	0.291	0.000	0.334	0.047	0.736	0.131	0.741	0.193	0.720	0.089	0.893	0.129	0.768	0.083	0.662	0.159
10/13/2006			0.086	0.376	0.309	0.000	0.089	0.181	0.229	0.000	0.333	0.049	0.738	0.121	0.740	0.195	0.722	0.089	0.892	0.128	0.769	0.081	0.663	0.158
10/14/2006			0.084	0.320	0.309	0.000	0.087	0.161	0.211	0.000	0.333	0.056	0.736	0.130	0.740	0.195	0.730	0.087	0.895	0.123	0.769	0.081	0.664	0.158
10/15/2006			0.082	0.273	0.309	0.000	0.085	0.121	0.202	0.000	0.333	0.058	0.735	0.138	0.739	0.197	0.728	0.088	0.895	0.121	0.769	0.080	0.665	0.157
10/16/2006			0.079	0.233	0.308	0.000	0.082	0.095	0.192	0.000	0.332	0.058	0.733	0.144	0.739	0.197	0.726	0.088	0.894	0.119	0.767	0.080	0.665	0.156
10/17/2006			0.076	0.200	0.308	0.000	0.080	0.085	0.183	0.000	0.331	0.056	0.733	0.143	0.739	0.197	0.728	0.087	0.895	0.118	0.769	0.077	0.661	0.157
10/18/2006			0.074	0.182	0.309	0.000	0.079	0.085	0.175	0.000	0.330	0.054	0.735	0.133	0.738	0.198	0.725	0.088	0.895	0.118	0.770	0.075	0.658	0.159
10/19/2006			0.072	0.167	0.309	0.000	0.077	0.073	0.168	0.000	0.327	0.052	0.736	0.123	0.738	0.199	0.726	0.087	0.892	0.122	0.769	0.075	0.658	0.158
10/20/2006			0.070	0.150	0.309	0.000	0.076	0.065	0.161	0.000	0.321	0.048	0.738	0.113	0.738	0.199	0.726	0.087	0.894	0.123	0.770	0.074	0.661	0.157
10/21/2006			0.068	0.142	0.309	0.000	0.075	0.066	0.154	0.000	0.319	0.047	0.739	0.108	0.738	0.199	0.726	0.087	0.891	0.129	0.771	0.073	0.661	0.156
10/22/2006			0.065	0.129	0.310	0.000	0.075	0.066	0.146	0.000	0.318	0.046	0.739	0.104	0.738	0.200	0.727	0.087	0.887	0.137	0.770	0.074	0.662	0.156
10/23/2006			0.063	0.117	0.311	0.000	0.073	0.059	0.141	0.000	0.318	0.046	0.740	0.101	0.738	0.199	0.728	0.087	0.882	0.149	0.770	0.074	0.662	0.156
10/24/2006			0.061	0.106	0.312	0.000	0.071	0.053	0.133	0.000	0.317	0.044	0.740	0.099	0.738	0.200	0.731	0.086	0.878	0.158	0.771	0.074	0.659	0.157
10/25/2006			0.059	0.095	0.304	0.000	0.070	0.052	0.122	0.000	0.316	0.043	0.739	0.098	0.737	0.200	0.731	0.086	0.874	0.157	0.770	0.076	0.658	0.157
10/26/2006			0.056	0.087	0.259	0.000	0.069	0.050	0.114	0.000	0.316	0.043	0.732	0.097	0.736	0.201	0.727	0.087	0.869	0.150	0.768	0.077	0.658	0.156
10/27/2006			0.054	0.081	0.230	0.000	0.068	0.047	0.107	0.000	0.315	0.043	0.723	0.089	0.737	0.198	0.726	0.087	0.856	0.143	0.767	0.078	0.657	0.156
10/28/2006			0.052	0.079	0.201	0.000	0.068	0.046	0.103	0.000	0.315	0.045	0.728	0.087	0.736	0.199	0.725	0.087	0.862	0.140	0.767	0.078	0.659	0.155
10/29/2006			0.052	0.078	0.185	0.000	0.069	0.046	0.101	0.000	0.317	0.046	0.731	0.088	0.737	0.199	0.731	0.086	0.858	0.147	0.768	0.078	0.659	0.155
10/30/2006			0.050	0.075	0.173	0.000	0.070	0.043	0.097	3.626	0.317	0.045	0.721	0.089	0.737	0.198	0.732	0.086	0.843	0.140	0.767	0.079	0.659	0.155
10/31/2006			0.048	0.073	0.164	0.000	0.071	0.039	0.093	3.142	0.317	0.045	0.716	0.081	0.736	0.198	0.729	0.086	0.840	0.133	0.766	0.081	0.659	0.155
11/1/2006			0.048	0.073	0.163	0.000	0.101	0.178	0.097	0.453	0.319	0.052	0.732	0.078	0.737	0.198	0.730	0.086	0.875	0.143	0.767	0.080	0.660	0.153
11/2/2006			0.048	0.074	0.168	0.000	0.094	0.171	0.099	0.000	0.322	0.052	0.733	0.081	0.737	0.198	0.731	0.087	0.872	0.149	0.767	0.081	0.661	0.152
11/3/2006			0.049	0.075	0.168	0.000	0.090	0.001	0.098	0.000	0.324	0.050	0.732	0.083	0.737	0.199	0.732	0.086	0.866	0.157	0.768	0.082	0.661	0.152
11/4/2006			0.060	0.103	0.168	0.000	0.101	0.106	0.099	0.000	0.326	0.053	0.733	0.085	0.737	0.198	0.733	0.087	0.868	0.156	0.767	0.083	0.661	0.152
11/5/2006			0.062	0.112	0.173	0.000	0.097	0.150	0.100	0.000	0.328	0.050	0.732	0.086	0.737	0.198	0.732	0.087	0.870	0.153	0.767	0.084	0.655	0.155
11/6/2006			0.059	0.102	0.173	0.000	0.092	0.047	0.097	0.000	0.329	0.048	0.733	0.086	0.737	0.198	0.732	0.087	0.869	0.154	0.767	0.085	0.654	0.155
11/7/2006			0.057	0.096	0.171	0.000	0.088	0.041	0.095	3.300	0.330	0.049	0.733	0.081	0.737	0.198	0.733	0.086	0.867	0.160	0.766	0.085	0.656	0.154
11/8/2006			0.055	0.092	0.170	0.000	0.086	0.047	0.094	10.244	0.331	0.050	0.734	0.080	0.738	0.196	0.733	0.086	0.866	0.163	0.767	0.086	0.657	0.153
11/9/2006			0.053	0.087	0.165	0.000	0.082	0.043	0.092	1.420	0.332	0.049	0.729	0.079	0.739	0.194	0.733	0.086	0.852	0.161	0.766	0.088	0.657	0.153
11/10/2006			0.051	0.082	0.159	0.000	0.080	0.042	0.089	0.656	0.333	0.048	0.716	0.074	0.739	0.193	0.733	0.086	0.817	0.149	0.766	0.088	0.657	0.154
11/11/2006			0.049	0.078	0.153	0.000	0.078	0.039	0.086	0.435	0.333	0.048	0.710	0.066	0.738	0.192	0.732	0.086	0.798	0.144	0.767	0.088	0.657	0.154
11/12/2006			0.048	0.076	0.146	0.000	0.077	0.043	0.084	0.329	0.331	0.048	0.704	0.059	0.737	0.193	0.732	0.085	0.788	0.141	0.767	0.088	0.657	0.154
11/13/2006	0.028	0.054	0.047	0.075	0.140	0.000	0.075	0.041	0.082	0.274	0.322	0.048	0.693	0.050	0.738	0.192	0.732	0.085	0.768	0.140	0.767	0.089	0.657	0.153
11/14/2006	0.027	0.055	0.047	0.073	0.132	0.000	0.073	0.041	0.078	0.212	0.307	0.044	0.664	0.037	0.736	0.194	0.732	0.085	0.725	0.135	0.765	0.090	0.656	0.154
11/15/2006	0.028	0.055	0.047	0.072	0.123	0.000	0.072	0.037	0.074	0.173	0.289	0.040	0.649	0.027	0.737	0.191	0.728	0.086	0.715	0.134	0.757	0.091	0.659	0.156
11/16/2006	0.028	0.055	0.046	0.072	0.115	0.000	0.071	0.037	0.071	0.146	0.274	0.036	0.643	0.022	0.736	0.192	0.730	0.086	0.711	0.133	0.757	0.090	0.660	0.159
11/17/2006	0.027	0.054	0.046	0.071	0.109	0.000	0.070	0.036	0.069	0.133	0.266	0.036	0.643	0.023	0.735	0.194	0.731	0.086	0.713	0.130	0.767	0.086	0.663	0.158
11/18/2006	0.026	0.054	0.045	0.067	0.102	0.000	0.068	0.036	0.067	0.124	0.258	0.035	0.640	0.022	0.735	0.193	0.732	0.086	0.710	0.127	0.767	0.087	0.656	0.161
11/19/2006	0.025	0.052	0.044	0.066	0.095	1.914	0.066	0.036	0.065	0.114	0.248	0.033	0.636	0.020	0.737	0.190	0.731	0.086	0.703	0.129	0.766	0.087	0.657	0.160
11/20/2006	0.024	0.051	0.044	0.065	0.090	0.736	0.064	0.034	0.064	0.111	0.241	0.032	0.633	0.020	0.736	0.189	0.732	0.086	0.700	0.128	0.767	0.085	0.658	0.158

Table A-1. Continued.

	T1-60 (25 cm)		T1-60 (35 cm)		T1-60 (55 cm)		T1-50 (30 cm)		T1-50 (50 cm)		T1-50 (95 cm)		T1-30 (25 cm)		T1-30 (50 cm)		T1-30 (80 cm)		T1-1 (25 cm)		T1-1 (50 cm)		T1-1 (72 cm)	
Date	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w
11/21/2006	0.023	0.051	0.042	0.063	0.085	0.349	0.063	0.033	0.062	0.103	0.235	0.032	0.632	0.020	0.735	0.190	0.734	0.086	0.696	0.131	0.766	0.086	0.661	0.156
11/22/2006	0.022	0.050	0.041	0.061	0.081	0.252	0.062	0.034	0.061	0.099	0.229	0.032	0.631	0.020	0.734	0.191	0.734	0.086	0.693	0.133	0.768	0.084	0.664	0.154
11/23/2006	0.022	0.049	0.041	0.060	0.077	0.194	0.062	0.035	0.059	0.092	0.224	0.033	0.630	0.020	0.735	0.189	0.735	0.087	0.690	0.136	0.766	0.085	0.665	0.153
11/24/2006	0.022	0.050	0.040	0.059	0.074	0.163	0.061	0.033	0.058	0.092	0.220	0.033	0.629	0.019	0.735	0.186	0.738	0.087	0.688	0.139	0.765	0.085	0.666	0.152
11/25/2006	0.022	0.050	0.040	0.059	0.072	0.143	0.061	0.033	0.057	0.088	0.217	0.035	0.628	0.020	0.734	0.187	0.741	0.086	0.687	0.143	0.765	0.086	0.665	0.151
11/26/2006	0.022	0.050	0.041	0.060	0.070	0.132	0.061	0.034	0.057	0.086	0.215	0.037	0.631	0.022	0.736	0.184	0.745	0.086	0.693	0.146	0.765	0.087	0.662	0.152
11/27/2006	0.023	0.051	0.040	0.060	0.070	0.128	0.060	0.033	0.057	0.086	0.216	0.040	0.634	0.026	0.736	0.183	0.745	0.087	0.702	0.151	0.765	0.088	0.662	0.150
11/28/2006	0.023	0.051	0.041	0.060	0.068	0.117	0.060	0.032	0.056	0.085	0.215	0.041	0.631	0.028	0.736	0.184	0.744	0.087	0.695	0.154	0.766	0.088	0.665	0.148
11/29/2006	0.023	0.051	0.040	0.059	0.067	0.111	0.060	0.033	0.056	0.084	0.214	0.042	0.631	0.030	0.737	0.182	0.744	0.087	0.694	0.155	0.765	0.089	0.666	0.148
11/30/2006	0.044	0.060	0.040	0.058	0.067	0.109	0.060	0.032	0.056	0.083	0.217	0.044	0.680	0.054	0.738	0.181	0.745	0.087	0.720	0.159	0.767	0.089	0.663	0.148
12/1/2006	0.051	0.071	0.040	0.058	0.068	0.113	0.060	0.030	0.057	0.087	0.219	0.044	0.657	0.049	0.738	0.180	0.746	0.087	0.711	0.160	0.766	0.091	0.662	0.148
12/2/2006	0.050	0.072	0.040	0.059	0.068	0.117	0.060	0.030	0.057	0.087	0.219	0.045	0.651	0.050	0.739	0.178	0.740	0.089	0.711	0.159	0.766	0.091	0.663	0.148
12/3/2006	0.049	0.071	0.041	0.059	0.069	0.119	0.060	0.029	0.058	0.088	0.219	0.044	0.648	0.050	0.740	0.177	0.741	0.088	0.711	0.158	0.766	0.092	0.661	0.148
12/4/2006	0.048	0.071	0.042	0.059	0.069	0.120	0.060	0.029	0.058	0.089	0.219	0.046	0.648	0.052	0.741	0.174	0.745	0.087	0.712	0.157	0.766	0.093	0.662	0.149
12/5/2006	0.047	0.070	0.044	0.059	0.069	0.122	0.059	0.028	0.058	0.090	0.219	0.045	0.647	0.052	0.741	0.174	0.745	0.088	0.709	0.159	0.766	0.094	0.661	0.149
12/6/2006	0.046	0.069	0.045	0.059	0.069	0.121	0.059	0.028	0.058	0.089	0.218	0.044	0.643	0.051	0.740	0.174	0.740	0.089	0.705	0.161	0.766	0.095	0.659	0.150
12/7/2006	0.044	0.067	0.046	0.058	0.067	0.114	0.058	0.028	0.057	0.089	0.216	0.043	0.639	0.049	0.740	0.174	0.738	0.089	0.698	0.165	0.766	0.096	0.661	0.149
12/8/2006	0.042	0.066	0.047	0.059	0.067	0.111	0.058	0.028	0.057	0.086	0.215	0.042	0.635	0.049	0.740	0.173	0.737	0.089	0.694	0.166	0.767	0.096	0.661	0.150
12/9/2006	0.040	0.063	0.047	0.058	0.066	0.109	0.057	0.028	0.056	0.086	0.214	0.041	0.633	0.047	0.740	0.173	0.738	0.089	0.691	0.167	0.766	0.099	0.661	0.150
12/10/2006	0.039	0.063	0.047	0.058	0.064	0.103	0.057	0.027	0.055	0.083	0.211	0.040	0.630	0.045	0.738	0.173	0.740	0.089	0.688	0.168	0.765	0.102	0.662	0.149
12/11/2006	0.039	0.062	0.047	0.058	0.063	0.097	0.056	0.027	0.054	0.082	0.208	0.039	0.628	0.044	0.739	0.172	0.742	0.088	0.683	0.173	0.765	0.099	0.661	0.149
12/12/2006	0.040	0.063	0.047	0.058	0.061	0.093	0.056	0.028	0.054	0.081	0.206	0.036	0.628	0.045	0.737	0.173	0.739	0.088	0.683	0.173	0.765	0.099	0.661	0.149
12/13/2006	0.041	0.065	0.046	0.057	0.060	0.091	0.056	0.028	0.054	0.080	0.204	0.035	0.627	0.046	0.738	0.171	0.738	0.089	0.683	0.174	0.763	0.099	0.662	0.149
12/14/2006	0.088	0.169	0.058	0.073	0.068	0.082	0.096	0.057	0.058	0.129	0.220	0.036	0.699	0.063	0.742	0.166	0.744	0.088	0.794	0.175	0.765	0.098	0.662	0.148
12/15/2006	0.075	0.209	0.067	0.086	0.189	0.000	0.119	0.003	0.117	0.055	0.305	0.051	0.739	0.062	0.743	0.164	0.748	0.089	0.850	0.185	0.765	0.098	0.665	0.143
12/16/2006	0.062	0.110	0.065	0.076	0.208	0.000	0.104	0.000	0.122	0.000	0.313	0.050	0.741	0.061	0.743	0.166	0.753	0.089	0.851	0.185	0.767	0.095	0.665	0.143
12/17/2006	0.061	0.105	0.066	0.070	0.215	0.000	0.099	0.250	0.126	0.000	0.318	0.050	0.741	0.063	0.743	0.166	0.755	0.088	0.855	0.180	0.767	0.096	0.666	0.143
12/18/2006	0.056	0.095	0.066	0.063	0.218	0.000	0.094	1.326	0.124	0.000	0.321	0.049	0.741	0.063	0.743	0.164	0.754	0.088	0.854	0.182	0.767	0.096	0.665	0.144
12/19/2006	0.053	0.087	0.066	0.058	0.219	0.000	0.090	0.326	0.121	0.000	0.323	0.047	0.743	0.061	0.744	0.163	0.755	0.088	0.853	0.186	0.768	0.096	0.663	0.145
12/20/2006	0.050	0.081	0.066	0.052	0.219	0.000	0.086	0.178	0.120	0.000	0.325	0.045	0.743	0.063	0.743	0.163	0.755	0.088	0.853	0.183	0.767	0.097	0.662	0.146
12/21/2006	0.048	0.077	0.065	0.046	0.218	0.000	0.083	0.130	0.118	0.000	0.327	0.046	0.742	0.064	0.740	0.166	0.755	0.088	0.851	0.189	0.766	0.098	0.662	0.147
12/22/2006	0.046	0.074	0.064	0.041	0.217	0.000	0.082	0.120	0.115	0.000	0.326	0.045	0.743	0.066	0.739	0.167	0.755	0.088	0.846	0.197	0.766	0.100	0.662	0.146
12/23/2006	0.045	0.072	0.064	0.034	0.216	0.000	0.080	0.106	0.113	0.000	0.324	0.044	0.744	0.068	0.740	0.165	0.750	0.089	0.847	0.195	0.766	0.101	0.663	0.146
12/24/2006	0.049	0.076	0.065	0.028	0.216	0.000	0.079	0.097	0.114	0.000	0.316	0.043	0.743	0.071	0.740	0.165	0.753	0.089	0.852	0.185	0.766	0.102	0.663	0.146
12/25/2006	0.051	0.082	0.065	0.025	0.215	0.000	0.078	0.092	0.113	0.000	0.317	0.044	0.745	0.067	0.741	0.162	0.748	0.089	0.852	0.181	0.765	0.105	0.665	0.144
12/26/2006	0.073	0.158	0.066	0.022	0.216	0.000	0.078	0.091	0.117	0.000	0.320	0.046	0.745	0.067	0.742	0.162	0.750	0.089	0.858	0.175	0.768	0.103	0.666	0.143
12/27/2006	0.064	0.116	0.067	0.021	0.218	0.000	0.081	0.099	0.118	0.000	0.322	0.046	0.745	0.065	0.742	0.161	0.751	0.089	0.861	0.171	0.768	0.103	0.664	0.143
12/28/2006	0.058	0.099	0.067	0.017	0.218	0.000	0.082	0.106	0.116	0.000	0.323	0.046	0.745	0.064	0.742	0.161	0.750	0.089	0.862	0.166	0.767	0.104	0.665	0.142
12/29/2006	0.055	0.092	0.066	0.012	0.217	0.000	0.082	0.096	0.113	0.000	0.324	0.046	0.745	0.063	0.740	0.162	0.749	0.089	0.858	0.171	0.765	0.105	0.665	0.141
12/30/2006	0.053	0.088	0.066	0.011	0.216	0.000	0.081	0.090	0.111	0.000	0.322	0.046	0.744	0.065	0.739	0.163	0.749	0.089	0.857	0.172	0.765	0.105	0.666	0.140
12/31/2006	0.051	0.085	0.065	0.010	0.215	0.000	0.081	0.087	0.111	0.000	0.322	0.047	0.744	0.067	0.740	0.161	0.750	0.088	0.861	0.163	0.765	0.104	0.667	0.139
1/1/2007	0.050	0.083	0.065	0.007	0.213	0.000	0.080	0.081	0.108	0.000	0.322	0.045	0.745	0.067	0.741	0.159	0.747	0.089	0.856	0.166	0.766	0.103	0.669	0.138
1/2/2007	0.048	0.080	0.065	0.004	0.211	0.000	0.079	0.076	0.105	0.000	0.322	0.045	0.745	0.070	0.741	0.159	0.745	0.090	0.828	0.167	0.766	0.103	0.667	0.138
1/3/2007	0.047	0.078	0.065	0.001	0.210	0.000	0.078	0.071	0.103	0.000	0.322	0.045	0.745	0.071	0.741	0.160	0.744	0.090	0.816	0.167	0.766	0.101	0.666	0.138
1/4/2007	0.045	0.076	0.065	0.001	0.208	0.000	0.077	0.066	0.102	0.000	0.322	0.045	0.746	0.071	0.740	0.160	0.743	0.090	0.830	0.167	0.767	0.102	0.667	0.137
1/5/2007	0.043	0.074	0.064	0.000	0.205	0.000	0.076	0.067	0.100	0.000	0.322	0.045	0.746	0.071	0.740	0.159	0.743	0.090	0.822	0.168	0.767	0.102	0.668	0.136
1/6/2007	0.042	0.073	0.064	0.000	0.203	0.000	0.075	0.061	0.099	0.000	0.322	0.045	0.747	0.073	0.740	0.159	0.744	0.090	0.823	0.169	0.767	0.103	0.668	0.136
1/7/2007	0.041	0.071	0.063	0.000	0.200	0.000	0.074	0.060	0.096	8.364	0.322	0.046	0.748	0.072	0.740	0.161	0.743	0.090			0.768	0.104	0.668	0.136
1/8/2007	0.040	0.070	0.062	0.000	0.196	0.000	0.073	0.056	0.094	7.776	0.322	0.047	0.748	0.073	0.739	0.161	0.744	0.089			0.768	0.105	0.670	0.135
1/9/2007	0.039	0.068	0.062	0.000	0.193	0.000	0.072	0.054	0.092	1.432	0.322	0.047	0.748	0.073	0.740	0.161	0.745	0.089			0.767	0.107	0.664	0.137

Table A-1. Continued.

	T1-60 (25 cm)		T1-60 (35 cm)		T1-60 (55 cm)		T1-50 (30 cm)		T1-50 (50 cm)		T1-50 (95 cm)		T1-30 (25 cm)		T1-30 (50 cm)		T1-30 (80 cm)		T1-1 (25 cm)		T1-1 (50 cm)		T1-1 (72 cm)	
Date	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w
1/10/2007	0.037	0.066	0.060	0.000	0.188	0.000	0.070	0.052	0.091	0.872	0.322	0.047	0.749	0.071	0.740	0.160	0.744	0.090			0.767	0.109	0.665	0.137
1/11/2007	0.037	0.065	0.059	0.000	0.180	0.000	0.069	0.047	0.088	0.542	0.321	0.047	0.748	0.072	0.741	0.157	0.742	0.090			0.765	0.111	0.664	0.137
1/12/2007	0.036	0.065	0.058	0.000	0.171	0.000	0.068	0.049	0.086	0.397	0.320	0.047	0.723	0.069	0.740	0.158	0.744	0.090			0.767	0.109	0.666	0.136
1/13/2007	0.035	0.064	0.057	0.000	0.162	0.000	0.068	0.049	0.083	0.298	0.314	0.047	0.689	0.063	0.740	0.157	0.744	0.089			0.767	0.109	0.667	0.135
1/14/2007	0.034	0.063	0.055	0.000	0.153	0.000	0.067	0.046	0.081	0.243	0.310	0.047	0.675	0.056	0.740	0.157	0.739	0.090			0.767	0.110	0.666	0.135
1/15/2007	0.033	0.062	0.056	0.000	0.145	0.000	0.066	0.046	0.078	0.202	0.303	0.047	0.669	0.053	0.741	0.155	0.738	0.090			0.767	0.112	0.666	0.135
1/16/2007	0.033	0.062	0.056	0.000	0.138	0.000	0.065	0.044	0.076	0.177	0.296	0.046	0.667	0.052	0.740	0.156	0.738	0.090			0.768	0.111	0.667	0.134
1/17/2007	0.032	0.062	0.056	0.000	0.132	0.000	0.065	0.044	0.073	0.154	0.288	0.047	0.664	0.052	0.739	0.158	0.739	0.090			0.767	0.113	0.668	0.133
1/18/2007	0.032	0.061	0.055	0.000	0.127	0.000	0.064	0.044	0.072	0.145	0.280	0.046	0.660	0.050	0.741	0.155	0.740	0.090			0.767	0.114	0.669	0.132
1/19/2007	0.032	0.061	0.054	0.000	0.122	0.000	0.064	0.044	0.071	0.138	0.273	0.046	0.657	0.046	0.740	0.156	0.738	0.090			0.766	0.116	0.668	0.133
1/20/2007	0.031	0.060	0.053	0.001	0.117	0.000	0.063	0.041	0.070	0.132	0.269	0.047	0.657	0.046	0.742	0.154	0.739	0.090			0.766	0.116	0.667	0.133
1/21/2007	0.030	0.060	0.052	0.003	0.111	0.000	0.062	0.042	0.069	0.124	0.264	0.048	0.657	0.046	0.741	0.154	0.741	0.090			0.766	0.117	0.664	0.134
1/22/2007	0.030	0.059	0.052	0.004	0.105	0.000	0.062	0.042	0.068	0.119	0.260	0.049	0.656	0.046	0.740	0.155	0.739	0.090			0.766	0.117	0.666	0.133
1/23/2007	0.030	0.059	0.051	0.005	0.101	0.000	0.062	0.042	0.067	0.113	0.256	0.048	0.655	0.047	0.741	0.155	0.739	0.090			0.766	0.117	0.668	0.133
1/24/2007	0.029	0.059	0.050	0.006	0.097	0.173	0.061	0.041	0.066	0.110	0.252	0.047	0.652	0.046	0.742	0.153	0.739	0.090			0.766	0.118	0.669	0.133
1/25/2007	0.029	0.059	0.049	0.007	0.096	0.346	0.060	0.039	0.065	0.108	0.250	0.047	0.653	0.045	0.743	0.153	0.740	0.090			0.766	0.117	0.668	0.134
1/26/2007	0.027	0.056	0.049	0.008	0.094	2.830	0.059	0.040	0.065	0.106	0.248	0.046	0.652	0.047	0.743	0.153	0.739	0.091			0.767	0.116	0.667	0.135
1/27/2007	0.026	0.057	0.048	0.009	0.090	0.756	0.059	0.039	0.064	0.103	0.245	0.045	0.648	0.044	0.744	0.153	0.740	0.090			0.767	0.116	0.665	0.136
1/28/2007	0.027	0.058	0.047	0.011	0.086	0.322	0.059	0.039	0.063	0.099	0.240	0.045	0.644	0.043	0.744	0.152	0.738	0.091			0.766	0.117	0.667	0.136
1/29/2007	0.026	0.056	0.046	0.013	0.083	0.229	0.058	0.038	0.062	0.096	0.236	0.045	0.641	0.045	0.746	0.150	0.740	0.091			0.767	0.116	0.669	0.136
1/30/2007	0.025	0.055	0.045	0.013	0.079	0.181	0.057	0.038	0.061	0.092	0.233	0.045	0.640	0.044	0.746	0.148	0.743	0.090			0.767	0.116	0.669	0.136
1/31/2007	0.025	0.055	0.044	0.013	0.078	0.167	0.056	0.037	0.060	0.090	0.228	0.047	0.639	0.043	0.743	0.147	0.740	0.091						
2/1/2007	0.025	0.055	0.043	0.014	0.075	0.138	0.056	0.037	0.059	0.087	0.225	0.048	0.637	0.041	0.736	0.142	0.738	0.092						
2/2/2007	0.026	0.057	0.043	0.017	0.073	0.124	0.057	0.037	0.059	0.085	0.223	0.048	0.636	0.039	0.732	0.134	0.738	0.091						
2/3/2007	0.026	0.056	0.043	0.017	0.071	0.119	0.057	0.037	0.058	0.084	0.220	0.047	0.635	0.040	0.732	0.128	0.739	0.091						
2/4/2007	0.025	0.057	0.043	0.018	0.071	0.117	0.056	0.037	0.058	0.084	0.220	0.048	0.637	0.042	0.736	0.129	0.741	0.091						
2/5/2007	0.068	0.167	0.042	0.018	0.072	0.122	0.056	0.036	0.058	0.082	0.223	0.047	0.662	0.055	0.738	0.129	0.745	0.091						
2/6/2007	0.071	0.153	0.042	0.018	0.072	0.123	0.056	0.036	0.059	0.085	0.225	0.046	0.659	0.055	0.737	0.131	0.742	0.092						
2/7/2007	0.066	0.129	0.041	0.019	0.072	0.122	0.057	0.035	0.060	0.087	0.225	0.047	0.657	0.055	0.737	0.133	0.743	0.092						
2/8/2007	0.062	0.114	0.041	0.019	0.071	0.118	0.057	0.033	0.060	0.085	0.224	0.048	0.652	0.052	0.739	0.131	0.744	0.091						
2/9/2007	0.059	0.104	0.041	0.019	0.070	0.111	0.057	0.032	0.059	0.086	0.222	0.049	0.645	0.050	0.738	0.132	0.743	0.091						
2/10/2007	0.057	0.099	0.041	0.016	0.068	0.106	0.057	0.032	0.059	0.083	0.220	0.049	0.641	0.048	0.738	0.132	0.742	0.092						
2/11/2007	0.054	0.095	0.042	0.015	0.066	0.099	0.057	0.031	0.058	0.081	0.219	0.049	0.637	0.047	0.743	0.132	0.741	0.092						
2/12/2007	0.053	0.089	0.043	0.012	0.066	0.099	0.057	0.030	0.057	0.078	0.219	0.050	0.638	0.047	0.744	0.133	0.743	0.092						
2/13/2007	0.054	0.093	0.044	0.012	0.067	0.102	0.057	0.030	0.058	0.079	0.219	0.048	0.637	0.047	0.736	0.131	0.739	0.093						
2/14/2007	0.054	0.093	0.044	0.012	0.065	0.096	0.057	0.030	0.058	0.079	0.213	0.044	0.628	0.042	0.714	0.115	0.739	0.092						
2/15/2007	0.052	0.089	0.044	0.012	0.064	0.093	0.057	0.030	0.057	0.078	0.205	0.039	0.623	0.040	0.714	0.106	0.739	0.092						
2/16/2007	0.061	0.112	0.044	0.012	0.063	0.092	0.056	0.029	0.056	0.076	0.204	0.042	0.624	0.041	0.715	0.103	0.739	0.093						
2/17/2007	0.065	0.124	0.043	0.012	0.062	0.089	0.055	0.030	0.055	0.073	0.201	0.042	0.622	0.042	0.716	0.099	0.738	0.093						
2/18/2007	0.063	0.116	0.043	0.011	0.059	0.081	0.054	0.029	0.054	0.070	0.197	0.042	0.620	0.039	0.716	0.097	0.739	0.093						
2/19/2007	0.061	0.110	0.043	0.011	0.058	0.078	0.054	0.029	0.054	0.065	0.194	0.044	0.618	0.039	0.717	0.094	0.739	0.093						
2/20/2007	0.059	0.104	0.043	0.011	0.055	0.074	0.054	0.028	0.053	0.064	0.191	0.046	0.617	0.036	0.716	0.094	0.741	0.092						
2/21/2007	0.056	0.098	0.044	0.012	0.054	0.070	0.055	0.029	0.052	0.062	0.190	0.049	0.616	0.035	0.718	0.091	0.739	0.093						
2/22/2007	0.054	0.093	0.044	0.012	0.052	0.068	0.055	0.029	0.052	0.061	0.190	0.050	0.615	0.035	0.718	0.092	0.742	0.092						
2/23/2007	0.052	0.090	0.044	0.013	0.051	0.066	0.055	0.028	0.051	0.061	0.189	0.050	0.614	0.036	0.718	0.092	0.741	0.092			0.759	0.076	0.668	0.140
2/24/2007	0.050	0.086	0.044	0.014	0.050	0.065	0.055	0.028	0.051	0.061	0.188	0.051	0.613	0.036	0.718	0.092	0.740	0.093			0.761	0.076	0.667	0.141
2/25/2007	0.049	0.083	0.044	0.014	0.049	0.064	0.055	0.028	0.051	0.062	0.186	0.051	0.612	0.036	0.719	0.090	0.738	0.093			0.761	0.078	0.668	0.141
2/26/2007	0.048	0.083	0.044	0.015	0.048	0.063	0.056	0.027	0.051	0.060	0.186	0.048	0.620	0.041	0.728	0.090	0.737	0.093			0.763	0.079	0.669	0.141
2/27/2007	0.047	0.082	0.044	0.017	0.048	0.064	0.072	0.004	0.051	0.060	0.187	0.045	0.619	0.042	0.722	0.089	0.737	0.094			0.764	0.080	0.671	0.140
2/28/2007	0.048	0.083	0.044	0.017	0.047	0.061	0.073	0.001	0.051	0.062	0.186	0.047	0.614	0.041	0.721	0.088	0.737	0.093			0.763	0.082	0.672	0.139

Table A-1. Continued.

	T1-60 (25 cm)		T1-60 (35 cm)		T1-60 (55 cm)		T1-50 (30 cm)		T1-50 (50 cm)		T1-50 (95 cm)		T1-30 (25 cm)		T1-30 (50 cm)		T1-30 (80 cm)		T1-1 (25 cm)		T1-1 (50 cm)		T1-1 (72 cm)	
Date	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w
3/1/2007	0.048	0.083	0.044	0.018	0.046	0.061	0.071	0.004	0.051	0.062	0.183	0.047	0.610	0.038	0.719	0.089	0.734	0.094			0.743	0.082	0.668	0.141
3/2/2007	0.048	0.083	0.043	0.019	0.046	0.061	0.069	0.007	0.051	0.062	0.178	0.043	0.605	0.034	0.719	0.088	0.734	0.093			0.736	0.082	0.665	0.142
3/3/2007	0.046	0.079	0.043	0.021	0.045	0.061	0.067	0.011	0.050	0.061	0.174	0.041	0.601	0.031	0.718	0.089	0.731	0.094			0.735	0.080	0.665	0.143
3/4/2007	0.045	0.078	0.043	0.020	0.045	0.061	0.065	0.015	0.051	0.062	0.172	0.039	0.599	0.030	0.719	0.088	0.734	0.094			0.734	0.080	0.665	0.143
3/5/2007	0.042	0.074	0.038	0.018	0.044	0.060	0.063	0.016	0.050	0.062	0.168	0.039	0.596	0.028	0.719	0.087	0.732	0.094			0.733	0.078	0.665	0.144
3/6/2007	0.039	0.069			0.042	0.057	0.062	0.019	0.049	0.060	0.164	0.042	0.593	0.023	0.718	0.087	0.729	0.094			0.731	0.078	0.665	0.144
3/7/2007	0.038	0.068			0.041	0.057	0.060	0.019	0.049	0.060	0.161	0.044	0.589	0.019	0.717	0.086	0.727	0.093			0.730	0.078	0.671	0.143
3/8/2007	0.037	0.067			0.040	0.055	0.059	0.020	0.049	0.060	0.157	0.046	0.587	0.014	0.717	0.086	0.724	0.092			0.729	0.079	0.667	0.145
3/9/2007	0.037	0.067			0.038	0.054	0.058	0.020	0.049	0.060	0.154	0.047	0.584	0.010	0.717	0.086	0.721	0.092			0.728	0.080	0.663	0.146
3/10/2007	0.035	0.065			0.037	0.054	0.058	0.022	0.048	0.059	0.150	0.048	0.581	0.006	0.717	0.085	0.721	0.091			0.727	0.081	0.662	0.146
3/11/2007	0.034	0.064			0.036	0.053	0.057	0.023	0.048	0.059	0.147	0.049	0.579	0.003	0.717	0.083	0.715	0.090			0.726	0.083	0.663	0.145
3/12/2007	0.033	0.063			0.036	0.053	0.056	0.023	0.047	0.059	0.144	0.050	0.577	0.001	0.716	0.082	0.714	0.089			0.726	0.084	0.665	0.143
3/13/2007	0.032	0.062			0.035	0.052	0.055	0.023	0.047	0.059	0.141	0.051	0.575	0.000	0.714	0.084	0.715	0.088			0.725	0.086	0.664	0.142
3/14/2007	0.032	0.062			0.034	0.052	0.054	0.023	0.047	0.059	0.138	0.051	0.573	0.000	0.714	0.084	0.714	0.087			0.724	0.089	0.665	0.140
3/15/2007	0.031	0.061			0.033	0.051	0.053	0.023	0.047	0.059	0.135	0.053	0.572	0.000	0.714	0.083	0.713	0.087			0.724	0.091	0.666	0.138
3/16/2007	0.049	0.348			0.032	0.051	0.093	0.021	0.046	0.057	0.133	0.055	0.579	0.010	0.715	0.083	0.722	0.086			0.724	0.092	0.667	0.136
3/17/2007	0.078	0.252			0.032	0.050	0.126	0.002	0.046	0.057	0.131	0.053	0.584	0.018	0.717	0.082	0.730	0.085			0.726	0.092	0.663	0.136
3/18/2007	0.066	0.134			0.031	0.050	0.105	0.000	0.046	0.057	0.129	0.053	0.579	0.010	0.717	0.082	0.723	0.086			0.726	0.092	0.665	0.135
3/19/2007	0.060	0.112			0.031	0.049	0.094	0.366	0.045	0.057	0.126	0.055	0.576	0.005	0.716	0.083	0.723	0.086			0.725	0.093	0.666	0.133
3/20/2007	0.057	0.103			0.030	0.049	0.086	0.147	0.045	0.056	0.125	0.059	0.574	0.001	0.716	0.083	0.724	0.086			0.725	0.094	0.665	0.132
3/21/2007	0.054	0.096			0.030	0.049	0.080	0.094	0.045	0.057	0.123	0.064	0.573	0.000	0.715	0.083	0.725	0.086						
3/22/2007	0.051	0.090			0.029	0.049	0.076	0.079	0.045	0.057	0.121	0.066	0.572	0.000	0.715	0.083	0.725	0.086						
3/23/2007	0.048	0.085			0.028	0.048	0.073	0.070	0.044	0.056	0.119	0.067	0.571	0.000	0.715	0.084	0.734	0.085						
3/24/2007	0.045	0.080			0.028	0.048	0.070	0.064	0.044	0.056	0.118	0.073	0.570	0.000	0.715	0.084	0.725	0.085						
3/25/2007	0.043	0.076			0.027	0.048	0.067	0.058	0.044	0.056	0.117	0.076	0.570	0.000	0.715	0.084	0.728	0.084						
3/26/2007	0.041	0.074			0.027	0.048	0.065	0.055	0.044	0.056	0.115		0.569	0.000	0.715	0.084	0.727	0.085						
3/27/2007	0.040	0.073			0.027	0.048	0.062	0.052	0.043	0.055	0.114		0.568	0.000	0.715	0.083	0.725	0.085						
3/28/2007	0.038	0.070			0.026	0.048	0.059	0.048	0.043	0.056	0.113		0.568	0.000	0.715	0.083	0.726	0.085	0.712	0.327	0.722	0.114	0.667	0.120
3/29/2007	0.037	0.069			0.026	0.048	0.057	0.046	0.043	0.056	0.111		0.567	0.000	0.715	0.083	0.730	0.084	0.710	0.330	0.723	0.114	0.668	0.119
3/30/2007	0.035	0.066			0.025	0.047	0.055	0.045	0.043	0.056	0.110		0.566	0.000	0.715	0.082	0.727	0.085	0.711	0.328	0.722	0.117	0.668	0.118
3/31/2007	0.034	0.065			0.025	0.047	0.052	0.043	0.043	0.057	0.109		0.566	0.000	0.715	0.082	0.726	0.085	0.710	0.330	0.721	0.120	0.668	0.117
4/1/2007	0.033	0.064			0.025	0.047	0.050	0.042	0.043	0.057	0.108		0.565	0.000	0.715	0.083	0.729	0.085	0.710	0.331	0.722	0.121	0.667	0.117
4/2/2007	0.032	0.063			0.024	0.047	0.048	0.041	0.043	0.057	0.107		0.564	0.000	0.715	0.083	0.731	0.084	0.709	0.332	0.721	0.123	0.669	0.115
4/3/2007	0.031	0.062			0.024	0.047	0.047	0.040	0.042	0.057	0.106		0.564	0.000	0.715	0.083	0.728	0.085	0.708	0.336	0.721	0.125	0.666	0.115
4/4/2007	0.030	0.061			0.023	0.046	0.045	0.038	0.042	0.057	0.105		0.563	0.000	0.714	0.084	0.728	0.086	0.707	0.339	0.721	0.127	0.665	0.114
4/5/2007	0.028	0.059			0.023	0.046	0.043	0.038	0.042	0.056	0.103		0.562	0.000	0.714	0.083	0.728	0.086	0.706	0.343	0.720	0.128	0.665	0.113
4/6/2007	0.027	0.058			0.022	0.046	0.042	0.037	0.042	0.056	0.103		0.563	0.000	0.714	0.082	0.730	0.085	0.705	0.345	0.720	0.128	0.667	0.113
4/7/2007	0.026	0.057			0.023	0.046	0.040	0.036	0.042	0.057	0.103		0.562	0.000	0.714	0.082	0.729	0.086	0.707	0.338	0.719	0.128	0.669	0.112
4/8/2007	0.024	0.056			0.022	0.046	0.038	0.036	0.041	0.056	0.101		0.562	0.000	0.713	0.082	0.733	0.085	0.708	0.333	0.719	0.126	0.668	0.112
4/9/2007	0.024	0.056			0.021	0.046	0.036	0.035	0.040	0.055	0.100		0.561	0.000	0.713	0.083	0.731	0.085	0.706	0.337	0.719	0.127	0.665	0.113
4/10/2007	0.050	0.042			0.021	0.045	0.081	0.032	0.040	0.055	0.100		0.598	0.021	0.726	0.084	0.737	0.085	0.720	0.331	0.734	0.123	0.666	0.113
4/11/2007	0.087	1.956			0.053	0.111	0.140	0.006	0.071	0.121	0.100		0.615	0.051	0.740	0.085	0.756	0.083	0.753	0.299	0.761	0.111	0.668	0.114
4/12/2007	0.063	0.120			0.079	0.203	0.103	0.576	0.070	0.102	0.100		0.586	0.027	0.718	0.083	0.751	0.085	0.749	0.303	0.735	0.126	0.668	0.115
4/13/2007	0.056	0.099			0.075	0.170	0.090	0.520	0.066	0.085	0.101		0.577	0.014	0.715	0.086	0.747	0.086	0.746	0.305	0.724	0.139	0.668	0.116
4/14/2007	0.051	0.089			0.072	0.148	0.081	0.124	0.062	0.074	0.102		0.573	0.008	0.715	0.086	0.742	0.087	0.738	0.315	0.723	0.141	0.668	0.117
4/15/2007	0.049	0.086			0.069	0.130	0.073	0.080	0.060	0.069	0.104		0.578	0.019	0.715	0.087	0.737	0.088	0.737	0.317	0.722	0.142	0.667	0.118
4/16/2007	0.059	0.107			0.066	0.120	0.069	0.070	0.059	0.066	0.107		0.581	0.031	0.716	0.087	0.739	0.088	0.750	0.297	0.722	0.141	0.670	0.119
4/17/2007	0.054	0.094			0.063	0.106	0.063	0.060	0.057	0.062	0.107		0.574	0.016	0.716	0.088	0.733	0.089	0.742	0.299	0.722	0.141	0.669	0.120
4/18/2007	0.050	0.087			0.061	0.099	0.058	0.053	0.055	0.060	0.107		0.570	0.011	0.715	0.089	0.729	0.090	0.740	0.297	0.720	0.144	0.671	0.120
4/19/2007	0.047	0.081			0.059	0.093	0.053	0.049	0.054	0.058	0.108		0.569	0.007	0.715	0.089	0.728	0.090	0.739	0.300	0.721	0.144	0.669	0.121

Table A-1. Continued.

	T1-60 (25 cm)		T1-60 (35 cm)		T1-60 (55 cm)		T1-50 (30 cm)		T1-50 (50 cm)		T1-50 (95 cm)		T1-30 (25 cm)		T1-30 (50 cm)		T1-30 (80 cm)		T1-1 (25 cm)		T1-1 (50 cm)		T1-1 (72 cm)	
Date	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w
4/20/2007	0.044	0.077			0.057	0.089	0.050	0.046	0.053	0.058	0.108		0.567	0.005	0.714	0.090	0.728	0.089	0.736	0.303	0.720	0.147	0.668	0.122
4/21/2007	0.042	0.074			0.056	0.085	0.047	0.044	0.053	0.056	0.108		0.567	0.005	0.715	0.090	0.722	0.090	0.743	0.300	0.720	0.151	0.667	0.123
4/22/2007	0.041	0.073			0.055	0.084	0.045	0.043	0.052	0.055	0.108		0.566	0.004	0.714	0.091	0.720	0.091	0.740	0.303	0.719	0.153	0.668	0.122
4/23/2007	0.041	0.072			0.052	0.079	0.043	0.042	0.051	0.055	0.107		0.565	0.004	0.714	0.092	0.722	0.090	0.739	0.301	0.718	0.157	0.669	0.121
4/24/2007	0.040	0.071			0.051	0.076	0.041	0.040	0.051	0.054	0.107		0.564	0.005	0.714	0.092	0.723	0.090	0.731	0.314	0.718	0.158	0.671	0.120
4/25/2007	0.038	0.069			0.049	0.072	0.040	0.040	0.050	0.054	0.106		0.564	0.004	0.714	0.092	0.722	0.090	0.729	0.317	0.717	0.163	0.669	0.120
4/26/2007	0.037	0.068			0.047	0.068	0.038	0.039	0.050	0.053	0.106		0.563	0.005	0.713	0.093	0.721	0.090	0.729	0.319	0.716	0.166	0.667	0.119
4/27/2007	0.035	0.065			0.045	0.067	0.037	0.040	0.049	0.053	0.105		0.562	0.005	0.713	0.094	0.720	0.090	0.728	0.319	0.716	0.170	0.667	0.118
4/28/2007	0.035	0.065			0.044	0.064	0.036	0.039	0.049	0.053	0.105		0.562	0.005	0.713	0.094	0.716	0.090	0.726	0.324	0.715	0.173	0.667	0.117
4/29/2007	0.033	0.064			0.042	0.063	0.035	0.039	0.048	0.052	0.105		0.561	0.006	0.712	0.095	0.712	0.090	0.724	0.329	0.715	0.177	0.665	0.117
4/30/2007	0.032	0.062			0.041	0.062	0.033	0.038	0.048	0.052	0.104		0.560	0.005	0.711	0.098	0.714	0.090	0.721	0.334	0.714	0.182	0.665	0.116
5/1/2007	0.030	0.061			0.039	0.060	0.032	0.037	0.047	0.052	0.103		0.560	0.006	0.711	0.098	0.716	0.089	0.720	0.336	0.713	0.187	0.666	0.114
5/2/2007	0.029	0.059			0.038	0.058	0.030	0.037	0.047	0.052	0.103		0.560	0.009	0.711	0.099	0.716	0.089	0.717	0.341	0.714	0.190	0.663	0.114
5/3/2007	0.028	0.058			0.037	0.058	0.030	0.037	0.047	0.052	0.103		0.560	0.010	0.711	0.099	0.715	0.089	0.720	0.337	0.713	0.192	0.664	0.114
5/4/2007	0.027	0.058			0.037	0.058	0.029	0.037	0.047	0.052	0.103		0.560	0.010	0.711	0.100	0.716	0.089	0.716	0.345	0.713	0.196	0.663	0.113
5/5/2007	0.026	0.057			0.036	0.057	0.029	0.037	0.046	0.052	0.102		0.559	0.010	0.711	0.100	0.714	0.089	0.713	0.354	0.711	0.203	0.661	0.114
5/6/2007	0.025	0.056			0.035	0.056	0.028	0.037	0.046	0.052	0.101		0.559	0.011	0.711	0.102	0.713	0.090	0.711	0.357	0.710	0.207	0.662	0.114
5/7/2007	0.024	0.055			0.033	0.055	0.027	0.036	0.045	0.052	0.100		0.562	0.021	0.711	0.102	0.714	0.089	0.716	0.350	0.714	0.203	0.663	0.114
5/8/2007	0.023	0.054			0.033	0.055	0.026	0.036	0.045	0.052	0.100		0.559	0.011	0.710	0.105	0.714	0.089	0.716	0.345	0.712	0.205	0.662	0.115
5/9/2007	0.024	0.055			0.032	0.054	0.026	0.036	0.045	0.052	0.099		0.558	0.009	0.710	0.106	0.713	0.089	0.717	0.341	0.712	0.206	0.662	0.115
5/10/2007	0.026	0.057			0.031	0.052	0.025	0.036	0.044	0.051	0.099		0.558	0.008	0.709	0.108	0.713	0.089	0.713	0.351	0.711	0.208	0.661	0.115
5/11/2007	0.026	0.056			0.030	0.053	0.026	0.037	0.044	0.051	0.098		0.558	0.009	0.708	0.110	0.712	0.089	0.709	0.361	0.711	0.210	0.663	0.115
5/12/2007	0.026	0.057			0.030	0.052	0.025	0.036	0.044	0.051	0.098		0.557	0.010	0.707	0.111	0.712	0.089	0.709	0.363	0.710	0.212	0.664	0.115
5/13/2007	0.026	0.057			0.030	0.052	0.025	0.036	0.043	0.051	0.098		0.557	0.012	0.707	0.111	0.713	0.089	0.711	0.360	0.710	0.214	0.666	0.115
5/14/2007	0.026	0.057			0.029	0.052	0.026	0.037	0.043	0.051	0.098		0.558	0.016	0.707	0.112	0.714	0.089	0.709	0.365	0.709	0.215	0.665	0.116
5/15/2007	0.026	0.057			0.028	0.051	0.025	0.036	0.043	0.051	0.098		0.560	0.016	0.707	0.114	0.715	0.089	0.714	0.356	0.711	0.213	0.666	0.116
5/16/2007	0.025	0.056			0.028	0.051	0.024	0.036	0.043	0.051	0.097		0.558	0.008	0.708	0.115	0.715	0.089	0.709	0.368	0.709	0.215	0.665	0.117
5/17/2007	0.025	0.056	0.039	0.042	0.027	0.050	0.025	0.037	0.043	0.052	0.097		0.558	0.009	0.707	0.116	0.712	0.089	0.702	0.382	0.708	0.218	0.665	0.117
5/18/2007	0.028	0.055	0.040	0.043	0.026	0.050	0.032	0.035	0.043	0.053	0.096		0.563	0.015	0.708	0.118	0.711	0.090	0.707	0.375	0.710	0.218	0.664	0.119
5/19/2007	0.084	0.332	0.063	0.067	0.097	0.415	0.134	0.002	0.081	0.637	0.096		0.728	0.088	0.758	0.119	0.730	0.087	0.805	0.278	0.802	0.145	0.667	0.116
5/20/2007	0.059	0.107	0.058	0.055	0.084	0.330	0.091	0.715	0.069	0.099	0.105		0.643	0.075	0.757	0.122	0.731	0.090	0.785	0.295	0.772	0.188	0.667	0.118
5/21/2007	0.053	0.090	0.055	0.051	0.076	0.188	0.082	0.156	0.065	0.085	0.135	0.067	0.603	0.060	0.751	0.122	0.730	0.092	0.764	0.311	0.770	0.190	0.666	0.119
5/22/2007	0.049	0.083	0.054	0.050	0.072	0.153	0.076	0.110	0.062	0.077	0.144	0.063	0.595	0.059	0.742	0.120	0.730	0.093	0.760	0.320	0.770	0.187	0.665	0.120
5/23/2007	0.045	0.077	0.054	0.048	0.069	0.133	0.071	0.093	0.060	0.073	0.144	0.062	0.588	0.055	0.726	0.120	0.729	0.093	0.767	0.308	0.769	0.188	0.665	0.122
5/24/2007	0.043	0.073	0.053	0.046	0.065	0.118	0.068	0.085	0.058	0.068	0.143	0.062	0.583	0.049	0.718	0.121	0.729	0.093	0.771	0.304	0.769	0.190	0.663	0.123
5/25/2007	0.041	0.071	0.052	0.044	0.063	0.110	0.065	0.077	0.057	0.066	0.142	0.062	0.581	0.048	0.717	0.121	0.729	0.094	0.767	0.310	0.765	0.189	0.666	0.123
5/26/2007	0.039	0.068	0.052	0.043	0.061	0.101	0.063	0.071	0.055	0.063	0.140	0.060	0.577	0.044	0.713	0.123	0.730	0.094	0.759	0.317	0.734	0.204	0.669	0.122
5/27/2007	0.037	0.067	0.051	0.042	0.059	0.096	0.061	0.068	0.054	0.061	0.137	0.061	0.573	0.039	0.712	0.124	0.731	0.094	0.755	0.319	0.734	0.199	0.667	0.124
5/28/2007	0.035	0.064	0.051	0.043	0.056	0.089	0.059	0.065	0.053	0.060	0.135	0.061	0.571	0.036	0.712	0.124	0.730	0.094	0.746	0.331	0.745	0.183	0.665	0.126
5/29/2007	0.034	0.064	0.050	0.042	0.054	0.085	0.057	0.062	0.052	0.058	0.133	0.064	0.570	0.033	0.710	0.125	0.729	0.094	0.745	0.332	0.743	0.187	0.669	0.126
5/30/2007	0.034	0.064	0.050	0.042	0.052	0.081	0.055	0.059	0.051	0.057	0.131	0.065	0.568	0.030	0.709	0.127	0.727	0.094	0.739	0.340	0.722	0.219	0.667	0.128
5/31/2007	0.032	0.062	0.050	0.042	0.050	0.077	0.053	0.057	0.050	0.056	0.128	0.068	0.566	0.028	0.709	0.128	0.724	0.094	0.735	0.344	0.722	0.219	0.672	0.128
6/1/2007	0.036	0.070	0.049	0.041	0.049	0.074	0.054	0.055	0.050	0.056	0.128	0.068	0.587	0.039	0.715	0.126	0.727	0.093	0.741	0.339	0.728	0.217	0.673	0.128
6/2/2007	0.103	0.499	0.088	0.260	0.241	0.013	0.170	0.001	0.286	0.055	0.274	0.064	0.737	0.067	0.766	0.116	0.733	0.093	0.808	0.282	0.777	0.186	0.672	0.136
6/3/2007	0.071	0.179	0.088	0.204	0.280	0.000	0.125	0.000	0.328	0.000	0.305	0.052	0.734	0.086	0.767	0.116	0.737	0.092	0.810	0.281	0.778	0.188	0.675	0.135
6/4/2007	0.063	0.127	0.084	0.099	0.282	0.000	0.112	0.000	0.318	0.000	0.307	0.052	0.732	0.100	0.766	0.118	0.740	0.092	0.803	0.292	0.778	0.191	0.674	0.136
6/5/2007	0.057	0.109	0.082	0.060	0.283	0.000	0.103	0.000	0.306	0.000	0.310	0.058	0.732	0.103	0.767	0.118	0.742	0.092	0.799	0.299	0.780	0.191	0.673	0.138
6/6/2007	0.054	0.101	0.080	0.037	0.285	0.000	0.096	1.610	0.282	0.000	0.312	0.062	0.733	0.095	0.766	0.116	0.743	0.092	0.801	0.293	0.781	0.190	0.674	0.138
6/7/2007	0.052	0.096	0.079	0.025	0.286	0.000	0.091	1.398	0.263	0.000	0.316	0.068	0.734	0.100	0.766	0.114	0.746	0.091	0.802	0.291	0.782	0.186	0.674	0.138
6/8/2007	0.056	0.110	0.079	0.021	0.288	0.000	0.088	0.339	0.230	0.000	0.320	0.073	0.734	0.096	0.767	0.113	0.747	0.091	0.801	0.292	0.779	0.190	0.675	0.137

Table A-1. Continued.

	T1-60 (25 cm)		T1-60 (35 cm)		T1-60 (55 cm)		T1-50 (30 cm)		T1-50 (50 cm)		T1-50 (95 cm)		T1-30 (25 cm)		T1-30 (50 cm)		T1-30 (80 cm)		T1-1 (25 cm)		T1-1 (50 cm)		T1-1 (72 cm)	
Date	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w
6/9/2007	0.064	0.131	0.081	0.007	0.290	0.000	0.091	0.890	0.229	0.003	0.325	0.079	0.734	0.099	0.767	0.112	0.747	0.091	0.792	0.305	0.779	0.189	0.675	0.137
6/10/2007	0.058	0.111	0.080	0.004	0.291	0.000	0.088	0.317	0.216	0.001	0.328	0.082	0.735	0.092	0.767	0.112	0.746	0.092	0.796	0.300	0.782	0.187	0.674	0.138
6/11/2007	0.054	0.099	0.079	0.003	0.292	0.000	0.083	0.180	0.190	0.000	0.331	0.074	0.738	0.077	0.767	0.111	0.745	0.093	0.803	0.288	0.783	0.188	0.675	0.138
6/12/2007	0.051	0.092	0.077	0.004	0.294	0.000	0.080	0.145	0.174	0.000	0.333	0.070	0.738	0.073	0.767	0.110	0.743	0.093	0.799	0.294	0.782	0.190	0.674	0.137
6/13/2007	0.052	0.096	0.077	0.001	0.295	0.000	0.079	0.129	0.169	0.000	0.334	0.072	0.738	0.070	0.768	0.108	0.744	0.093	0.799	0.292	0.783	0.185	0.674	0.136
6/14/2007	0.056	0.104	0.077	0.000	0.296	0.000	0.077	0.115	0.165	0.000	0.334	0.068	0.738	0.068	0.768	0.108	0.745	0.093	0.801	0.288	0.784	0.184	0.674	0.135
6/15/2007	0.055	0.102	0.076	0.000	0.298	0.000	0.075	0.103	0.160	0.000	0.334	0.062	0.738	0.068	0.768	0.109	0.745	0.093	0.802	0.286	0.784	0.186	0.673	0.136
6/16/2007	0.052	0.095	0.075	0.001	0.299	0.000	0.072	0.095	0.155	0.000	0.334	0.058	0.738	0.068	0.768	0.109	0.745	0.093	0.803	0.283	0.785	0.185	0.675	0.135
6/17/2007	0.050	0.089	0.074	0.001	0.300	0.000	0.070	0.086	0.149	0.000	0.332	0.053	0.739	0.066	0.768	0.109	0.746	0.093	0.804	0.282	0.787	0.182	0.674	0.138
6/18/2007	0.047	0.085	0.075	0.000	0.302	0.000	0.068	0.082	0.146	0.000	0.332	0.051	0.738	0.066	0.769	0.109	0.747	0.092	0.806	0.276	0.787	0.178	0.675	0.139
6/19/2007	0.046	0.082	0.074	0.000	0.302	0.000	0.066	0.077	0.142	0.000	0.332	0.050	0.737	0.067	0.769	0.109	0.747	0.092	0.806	0.276	0.787	0.177	0.673	0.141
6/20/2007	0.044	0.080	0.073	0.000	0.303	0.000	0.064	0.072	0.137	0.000	0.331	0.049	0.737	0.068	0.769	0.110	0.747	0.092	0.806	0.277	0.787	0.177	0.673	0.144
6/21/2007	0.042	0.077	0.072	0.000	0.303	0.000	0.062	0.068	0.131	0.000	0.325	0.046	0.737	0.069	0.769	0.110	0.747	0.092	0.806	0.279	0.788	0.176	0.672	0.147
6/22/2007	0.040	0.074	0.072	0.000	0.304	0.000	0.060	0.067	0.125	0.000	0.312	0.045	0.717	0.070	0.769	0.110	0.748	0.092	0.806	0.279	0.790	0.174	0.673	0.146
6/23/2007	0.039	0.072	0.071	0.000	0.305	0.000	0.058	0.063	0.119	0.000	0.311	0.045	0.693	0.062	0.769	0.109	0.748	0.091	0.806	0.280	0.793	0.171	0.675	0.145
6/24/2007	0.038	0.070	0.070	0.000	0.305	0.000	0.056	0.060	0.113	0.000	0.310	0.046	0.676	0.052	0.769	0.109	0.746	0.091	0.807	0.278	0.794	0.170	0.671	0.146
6/25/2007	0.036	0.069	0.069	0.000	0.307	0.000	0.055	0.058	0.107	0.000	0.310	0.047	0.668	0.046	0.768	0.110	0.744	0.092	0.807	0.279	0.795	0.170	0.672	0.145
6/26/2007	0.035	0.067	0.068	0.000	0.307	0.000	0.052	0.055	0.102	0.000	0.309	0.049	0.658	0.041	0.768	0.110	0.744	0.092	0.800	0.283	0.798	0.167	0.675	0.143
6/27/2007	0.034	0.066	0.067	0.000	0.305	0.000	0.051	0.054	0.098	0.000	0.309	0.051	0.662	0.042	0.768	0.110	0.747	0.091	0.794	0.284	0.799	0.167	0.677	0.142
6/28/2007	0.036	0.071	0.066	0.000	0.283	0.000	0.085	0.114	0.098	0.244	0.310	0.058	0.714	0.057	0.769	0.108	0.748	0.091	0.800	0.277	0.791	0.177	0.676	0.144
6/29/2007	0.095	0.367	0.113	0.036	0.294	0.000	0.163	0.000	0.282	0.002	0.333	0.063	0.747	0.056	0.771	0.107	0.751	0.090	0.803	0.272	0.789	0.175	0.675	0.152
6/30/2007	0.087	0.764	0.152	0.033	0.300	0.000	0.133	0.000	0.365	0.000	0.343	0.055	0.746	0.070	0.771	0.106	0.751	0.089	0.800	0.278	0.790	0.174	0.677	0.148
7/1/2007	0.076	0.219	0.133	0.046	0.301	0.000	0.119	0.000	0.374	0.005	0.346	0.067	0.744	0.076	0.772	0.106	0.751	0.088	0.795	0.289	0.792	0.172	0.675	0.148
7/2/2007	0.086	0.158	0.158	0.041	0.304	0.000	0.131	0.000	0.386	0.002	0.350	0.079	0.744	0.079	0.771	0.107	0.750	0.088	0.791	0.296	0.794	0.171	0.673	0.148
7/3/2007	0.115	0.000	0.359	0.000	0.309	0.000	0.169	0.000	0.398	0.000	0.353	0.082	0.745	0.081	0.771	0.109	0.749	0.088	0.786	0.308	0.797	0.170	0.675	0.146
7/4/2007	0.098	2.004	0.358	0.000	0.310	0.000	0.163	0.000	0.405	0.000	0.354	0.082	0.746	0.081	0.773	0.107	0.749	0.088	0.787	0.310	0.796	0.171	0.677	0.146
7/5/2007	0.120	0.000	0.358	0.000	0.313	0.000	0.211	0.001	0.414	0.001	0.356	0.072	0.747	0.080	0.773	0.109	0.750	0.088	0.786	0.310	0.797	0.169	0.677	0.146
7/6/2007	0.131	0.000	0.360	0.000	0.315	0.000	0.233	0.003	0.418	0.005	0.355	0.072	0.748	0.080	0.773	0.110	0.749	0.088	0.790	0.299	0.797	0.169	0.673	0.147
7/7/2007	0.111	0.000	0.359	0.000	0.314	0.000	0.189	0.000	0.422	0.001	0.353	0.071	0.747	0.083	0.773	0.111	0.747	0.089	0.794	0.292	0.796	0.168	0.674	0.144
7/8/2007	0.103	0.000	0.360	0.000	0.315	0.000	0.187	0.000	0.428	0.001	0.353	0.070	0.748	0.083	0.773	0.112	0.748	0.089	0.799	0.284	0.796	0.168	0.676	0.142
7/9/2007	0.091	3.301	0.360	0.000	0.315	0.000	0.163	0.000	0.431	0.001	0.351	0.070	0.747	0.088	0.773	0.113	0.748	0.089	0.800	0.281	0.796	0.171	0.673	0.142
7/10/2007	0.080	0.290	0.346	0.000	0.315	0.000	0.145	0.000	0.434	0.003	0.350	0.070	0.747	0.093	0.773	0.113	0.750	0.088	0.796	0.288	0.795	0.175	0.673	0.142
7/11/2007	0.074	0.202	0.294	0.000	0.315	0.000	0.134	0.000	0.437	0.003	0.348	0.066	0.745	0.099	0.773	0.113	0.751	0.088	0.789	0.299	0.796	0.177	0.675	0.142
7/12/2007	0.070	0.171	0.252	0.000	0.316	0.000	0.131	0.000	0.439	0.003	0.348	0.063	0.745	0.100	0.774	0.114	0.753	0.087	0.792	0.295	0.799	0.175	0.673	0.144
7/13/2007	0.067	0.150	0.237	0.000	0.317	0.000	0.128	0.000	0.441	0.002	0.347	0.061	0.746	0.101	0.774	0.115	0.754	0.087	0.794	0.293	0.797	0.178	0.676	0.146
7/14/2007	0.064	0.139	0.227	0.000	0.318	0.000	0.127	0.000	0.441	0.003	0.347	0.059	0.747	0.101	0.774	0.116	0.751	0.088	0.789	0.300	0.799	0.173	0.674	0.150
7/15/2007	0.063	0.132	0.220	0.000	0.319	0.000	0.124	0.000	0.441	0.002	0.346	0.059	0.746	0.104	0.775	0.116	0.752	0.088	0.790	0.298	0.798	0.171	0.674	0.153
7/16/2007	0.066	0.152	0.220	0.000	0.322	0.000	0.132	0.000	0.443	0.002	0.347	0.058	0.745	0.106	0.776	0.115	0.750	0.089	0.791	0.296	0.799	0.167	0.675	0.155
7/17/2007	0.073	0.199	0.226	0.000	0.325	0.000	0.133	0.000	0.443	0.001	0.346	0.058	0.745	0.108	0.776	0.115	0.752	0.088	0.794	0.291	0.798	0.164	0.673	0.156
7/18/2007	0.067	0.150	0.219	0.000	0.326	0.000	0.122	0.000	0.443	0.001	0.345	0.056	0.744	0.112	0.776	0.115	0.751	0.088	0.796	0.287	0.798	0.164	0.672	0.156
7/19/2007	0.065	0.141	0.216	0.000	0.327	0.000	0.126	0.000	0.443	0.001	0.346	0.057	0.744	0.112	0.775	0.116	0.752	0.088	0.788	0.299	0.796	0.162	0.672	0.159
7/20/2007	0.067	0.149	0.215	0.000	0.328	0.000	0.127	0.000	0.443	0.001	0.345	0.057	0.745	0.113	0.776	0.117	0.753	0.088	0.786	0.302	0.797	0.159	0.672	0.160
7/21/2007	0.092	0.091	0.233	0.000	0.331	0.000	0.187	0.003	0.443	0.001	0.346	0.057	0.744	0.114	0.776	0.118	0.754	0.088	0.788	0.299	0.796	0.157	0.675	0.161
7/22/2007	0.127	0.000	0.269	0.000	0.334	0.000	0.260	0.006	0.444	0.001	0.347	0.056	0.745	0.114	0.775	0.118	0.755	0.087	0.793	0.288	0.792	0.159	0.675	0.160
7/23/2007	0.116	0.000	0.269	0.000	0.334	0.000	0.240	0.003	0.442	0.001	0.346	0.056	0.745	0.114	0.776	0.116	0.756	0.086	0.797	0.280	0.790	0.160	0.672	0.158
7/24/2007	0.109	0.651	0.269	0.000	0.335	0.000	0.211	0.002	0.441	0.001	0.346	0.056	0.745	0.114	0.775	0.116	0.755	0.086	0.798	0.278	0.790	0.161	0.673	0.155
7/25/2007	0.128	0.000	0.271	0.000	0.337	0.000	0.224	0.002	0.441	0.000	0.340	0.056	0.745	0.113	0.776	0.116	0.755	0.085	0.799	0.275	0.789	0.163	0.675	0.150
7/26/2007	0.105	0.000	0.270	0.000	0.336	0.000	0.188	0.000	0.440	0.000	0.332	0.055	0.747	0.108	0.775	0.115	0.755	0.085	0.798	0.276	0.787	0.166	0.675	0.146
7/27/2007	0.103	3.280	0.271	0.000	0.337	0.000	0.177	0.000	0.440	0.000	0.331	0.056	0.747	0.104	0.775	0.115	0.754	0.084	0.800	0.274	0.791	0.162	0.673	0.143
7/28/2007	0.101	0.566	0.271	0.000	0.338	0.000	0.177	0.000	0.439	0.000	0.331	0.057	0.747	0.105	0.775	0.115	0.754	0.084	0.795	0.281	0.790	0.165	0.671	0.140

Table A-1. Continued.

	T1-60 (25 cm)		T1-60 (35 cm)		T1-60 (55 cm)		T1-50 (30 cm)		T1-50 (50 cm)		T1-50 (95 cm)		T1-30 (25 cm)		T1-30 (50 cm)		T1-30 (80 cm)		T1-1 (25 cm)		T1-1 (50 cm)		T1-1 (72 cm)	
Date	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w
7/29/2007	0.090	0.448	0.271	0.000	0.338	0.000	0.168	0.000	0.438	0.000	0.330	0.056	0.746	0.108	0.775	0.116	0.753	0.084	0.790	0.290	0.791	0.166	0.669	0.140
7/30/2007	0.093	1.699	0.273	0.000	0.339	0.000	0.167	0.000	0.438	0.000	0.329	0.056	0.745	0.110	0.775	0.116	0.754	0.084	0.783	0.301	0.793	0.165	0.675	0.136
7/31/2007	0.081	0.303	0.264	0.000	0.339	0.000	0.146	0.000	0.436	0.000	0.328	0.056	0.746	0.108	0.775	0.116	0.754	0.084	0.780	0.306	0.794	0.167	0.669	0.137
8/1/2007	0.092	0.178	0.263	0.000	0.341	0.000	0.159	0.000	0.437	0.000	0.329	0.056	0.745	0.108	0.774	0.116	0.754	0.084	0.782	0.305	0.794	0.168	0.671	0.136
8/2/2007	0.100	0.507	0.267	0.000	0.343	0.000	0.168	0.000	0.437	0.000	0.329	0.054	0.746	0.109	0.775	0.115	0.754	0.084	0.783	0.306	0.794	0.167	0.669	0.135
8/3/2007	0.084	0.426	0.268	0.000	0.343	0.000	0.153	0.000	0.435	0.000	0.328	0.057	0.745	0.112	0.774	0.116	0.754	0.084	0.782	0.308	0.794	0.169	0.670	0.134
8/4/2007	0.080	0.297	0.269	0.000	0.343	0.000	0.155	0.000	0.435	0.000	0.328	0.058	0.746	0.113	0.774	0.116	0.754	0.084	0.780	0.311	0.792	0.171	0.671	0.134
8/5/2007	0.077	0.233	0.267	0.000	0.344	0.000	0.153	0.000	0.434	0.000	0.328	0.058	0.745	0.113	0.775	0.117	0.754	0.084	0.776	0.316	0.795	0.168	0.669	0.135
8/6/2007	0.074	0.199	0.260	0.000	0.345	0.000	0.147	0.000	0.434	0.000	0.328	0.059	0.745	0.113	0.775	0.117	0.755	0.084	0.775	0.320	0.795	0.168	0.669	0.137
8/7/2007	0.071	0.176	0.256	0.000	0.345	0.000	0.144	0.000	0.433	0.000	0.327	0.059	0.745	0.113	0.775	0.118	0.756	0.084	0.774	0.322	0.795	0.169	0.669	0.139
8/8/2007	0.068	0.158	0.252	0.000	0.346	0.000	0.144	0.000	0.433	0.000	0.327	0.059	0.747	0.111	0.776	0.120	0.756	0.084	0.774	0.322	0.795	0.168	0.669	0.143
8/9/2007	0.067	0.150	0.206	0.000	0.347	0.000	0.142	0.000	0.432	0.000	0.327	0.059	0.747	0.110	0.776	0.121	0.754	0.086	0.776	0.319	0.796	0.164	0.672	0.145
8/10/2007	0.083	0.343	0.182	0.000	0.349	0.000	0.154	0.000	0.433	0.000	0.328	0.059	0.748	0.109	0.776	0.121	0.754	0.086	0.773	0.324	0.798	0.159	0.671	0.148
8/11/2007	0.089	0.739	0.206	0.000	0.350	0.000	0.159	0.000	0.433	0.000	0.327	0.057	0.747	0.110	0.777	0.120	0.755	0.085	0.778	0.315	0.798	0.157	0.677	0.145
8/12/2007	0.081	0.320	0.190	0.000	0.350	0.000	0.152	0.000	0.432	0.000	0.327	0.058	0.745	0.113	0.777	0.121	0.755	0.085	0.771	0.325	0.798	0.157	0.671	0.146
8/13/2007	0.074	0.205	0.175	0.000	0.349	0.000	0.147	0.000	0.431	0.000	0.327	0.059	0.745	0.114	0.777	0.122	0.757	0.084	0.770	0.326	0.800	0.154	0.673	0.146
8/14/2007	0.084	0.136	0.188	0.000	0.350	0.000	0.157	0.002	0.432	0.000	0.327	0.059	0.745	0.113	0.777	0.122	0.758	0.084	0.771	0.325	0.802	0.149	0.674	0.147
8/15/2007	0.118	0.000	0.343	0.000	0.353	0.000	0.340	0.020	0.434	0.000	0.331	0.061	0.748	0.099	0.776	0.124	0.758	0.085	0.780	0.310	0.802	0.146	0.675	0.148
8/16/2007	0.106	0.533	0.314	0.000	0.353	0.000	0.270	0.015	0.433	0.000	0.330	0.060	0.750	0.097	0.775	0.127	0.758	0.085	0.789	0.292	0.803	0.142	0.676	0.149
8/17/2007	0.085	0.521	0.267	0.000	0.351	0.000	0.192	0.004	0.431	0.000	0.329	0.060	0.746	0.106	0.775	0.128	0.758	0.085	0.795	0.282	0.804	0.140	0.672	0.150
8/18/2007	0.076	0.225	0.218	0.000	0.350	0.000	0.167	0.000	0.430	0.000	0.328	0.060	0.745	0.112	0.774	0.129	0.758	0.085	0.790	0.290	0.804	0.138	0.673	0.150
8/19/2007	0.072	0.185	0.185	0.000	0.351	0.000	0.155	0.003	0.430	0.000	0.328	0.061	0.744	0.115	0.774	0.129	0.757	0.085	0.796	0.281	0.804	0.137	0.672	0.151
8/20/2007	0.069	0.163	0.169	0.000	0.350	0.000			0.429	0.000	0.328	0.061	0.744	0.117	0.773	0.130	0.757	0.085	0.795	0.283	0.805	0.136	0.674	0.152
8/21/2007	0.066	0.147	0.158	0.000	0.350	0.000			0.428	0.000	0.327	0.062	0.744	0.119	0.773	0.131	0.758	0.085	0.795	0.283	0.807	0.132	0.673	0.154
8/22/2007	0.064	0.139	0.153	0.000	0.349	0.000			0.428	0.001	0.328	0.062	0.744	0.120	0.774	0.131	0.757	0.085	0.795	0.283	0.808	0.128	0.673	0.156
8/23/2007	0.065	0.140	0.150	0.000	0.349	0.000			0.428	0.001	0.327	0.062	0.744	0.120	0.774	0.133	0.759	0.085	0.795	0.283	0.804	0.130	0.672	0.159
8/24/2007	0.064	0.138	0.146	0.000	0.348	0.000			0.427	0.001	0.326	0.062	0.744	0.120	0.774	0.134	0.758	0.086	0.796	0.281	0.808	0.123	0.674	0.161
8/25/2007	0.063	0.133	0.144	0.000	0.347	0.000			0.428	0.001	0.326	0.062	0.744	0.122	0.775	0.133	0.760	0.085	0.794	0.285	0.805	0.124	0.674	0.163
8/26/2007	0.080	0.535	0.168	0.000	0.349	0.000			0.429	0.001	0.327	0.060	0.744	0.123	0.776	0.132	0.760	0.085	0.796	0.282	0.806	0.119	0.674	0.163
8/27/2007	0.080	0.301	0.175	0.000	0.349	0.000			0.428	0.001	0.326	0.059	0.743	0.124	0.776	0.131	0.759	0.085	0.797	0.280	0.806	0.119	0.675	0.161
8/28/2007	0.072	0.187	0.159	0.000	0.348	0.000			0.427	0.000	0.326	0.060	0.743	0.125	0.777	0.130	0.759	0.085	0.795	0.281	0.809	0.115	0.675	0.162
8/29/2007	0.068	0.159	0.150	0.000	0.347	0.000			0.426	0.001	0.325	0.061	0.744	0.125	0.777	0.131	0.759	0.085	0.788	0.291	0.806	0.117	0.675	0.163
8/30/2007	0.065	0.142	0.144	0.000	0.346	0.000			0.425	0.001	0.325	0.062	0.744	0.124	0.777	0.133	0.759	0.085	0.788	0.292	0.803	0.118	0.677	0.164
8/31/2007	0.064	0.139	0.143	0.000	0.347	0.000			0.426	0.001	0.325	0.062	0.744	0.124	0.777	0.134	0.758	0.086	0.789	0.291	0.805	0.113	0.676	0.166
9/1/2007	0.071	0.176	0.148	0.000	0.347	0.000			0.426	0.001	0.325	0.062	0.744	0.125	0.777	0.134	0.758	0.086	0.790	0.289	0.805	0.110	0.673	0.168
9/2/2007	0.067	0.149	0.141	0.000	0.347	0.000			0.425	0.001	0.325	0.062	0.744	0.126	0.776	0.136	0.757	0.086	0.791	0.287	0.804	0.109	0.673	0.169
9/3/2007	0.064	0.137	0.138	0.000	0.347	0.000			0.425	0.001	0.325	0.062	0.743	0.127	0.776	0.138	0.755	0.087	0.792	0.286	0.802	0.109	0.676	0.170
9/4/2007	0.066	0.144	0.139	0.000	0.347	0.000			0.425	0.001	0.325	0.062	0.742	0.127	0.775	0.140	0.757	0.087	0.792	0.285	0.804	0.105	0.675	0.171
9/5/2007	0.065	0.142	0.138	0.000	0.346	0.000			0.424	0.001	0.324	0.062	0.743	0.127	0.774	0.142	0.754	0.087	0.793	0.284	0.801	0.104	0.675	0.172
9/6/2007	0.062	0.129	0.132	0.000	0.346	0.000			0.424	0.001	0.325	0.061	0.743	0.127	0.774	0.144	0.759	0.087	0.792	0.286	0.800	0.104	0.677	0.173
9/7/2007	0.061	0.125	0.131	0.000	0.346	0.000			0.424	0.001	0.324	0.062	0.743	0.130	0.774	0.146	0.763	0.086	0.789	0.291	0.799	0.105	0.677	0.173
9/8/2007	0.061	0.124	0.143	0.000	0.346	0.000			0.424	0.002	0.324	0.061	0.741	0.134	0.773	0.148	0.762	0.087	0.788	0.295	0.798	0.107	0.676	0.174
9/9/2007	0.070	0.173	0.170	0.000	0.347	0.000			0.425	0.002	0.325	0.061	0.742	0.134	0.773	0.147	0.762	0.087	0.788	0.295	0.798	0.106	0.675	0.174
9/10/2007	0.069	0.163	0.167	0.000	0.346	0.000			0.424	0.002	0.324	0.061	0.742	0.135	0.774	0.146	0.761	0.087	0.789	0.296	0.799	0.105	0.675	0.174
9/11/2007	0.072	0.179	0.170	0.000	0.347	0.000			0.424	0.002	0.324	0.061	0.741	0.137	0.774	0.145	0.761	0.087	0.788	0.298	0.799	0.105	0.675	0.174
9/12/2007	0.068	0.157	0.164	0.000	0.346	0.000			0.423	0.001	0.323	0.060	0.739	0.139	0.776	0.142	0.761	0.086	0.786	0.301	0.802	0.102	0.675	0.172
9/13/2007	0.064	0.137	0.158	0.000	0.346	0.000			0.422	0.000	0.323	0.060	0.741	0.131	0.777	0.142	0.756	0.086	0.787	0.293	0.802	0.102	0.670	0.174
9/14/2007	0.061	0.123	0.153	0.000	0.345	0.000			0.422	0.000	0.322	0.060	0.744	0.119	0.777	0.141	0.760	0.085	0.791	0.280	0.802	0.101	0.674	0.172
9/15/2007	0.060	0.118	0.151	0.000	0.345	0.000			0.422	0.000	0.322	0.060	0.744	0.114	0.776	0.141	0.759	0.085	0.791	0.277	0.801	0.101	0.673	0.172
9/16/2007	0.064	0.140	0.151	0.000	0.345	0.000			0.421	0.001	0.322	0.061	0.747	0.107	0.776	0.142	0.760	0.085	0.794	0.269	0.801	0.102	0.674	0.171

Table A-1. Continued.

	T1-60 (25 cm)		T1-60 (35 cm)		T1-60 (55 cm)		T1-50 (30 cm)		T1-50 (50 cm)		T1-50 (95 cm)		T1-30 (25 cm)		T1-30 (50 cm)		T1-30 (80 cm)		T1-1 (25 cm)		T1-1 (50 cm)		T1-1 (72 cm)	
Date	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w
9/17/2007	0.070	0.169	0.156	0.000	0.345	0.000			0.421	0.000	0.323	0.060	0.747	0.107	0.775	0.143	0.756	0.085	0.794	0.269	0.800	0.103	0.670	0.173
9/18/2007	0.103	0.079	0.284	0.006	0.347	0.000			0.423	0.001	0.324	0.061	0.746	0.110	0.776	0.142	0.756	0.085	0.793	0.272	0.801	0.102	0.671	0.172
9/19/2007	0.099	0.543	0.358	0.002	0.347	0.000			0.421	0.001	0.325	0.060	0.747	0.110	0.777	0.138	0.755	0.085	0.794	0.272	0.802	0.098	0.670	0.173
9/20/2007	0.084	0.425	0.309	0.000	0.346	0.000			0.419	0.001	0.324	0.061	0.746	0.113	0.778	0.135	0.754	0.086	0.792	0.275	0.803	0.096	0.668	0.173
9/21/2007	0.087	0.183	0.271	0.000	0.347	0.000			0.420	0.000	0.324	0.061	0.744	0.118	0.779	0.133	0.754	0.086	0.791	0.280	0.804	0.094	0.669	0.173
9/22/2007	0.106	0.000	0.315	0.000	0.349	0.000			0.422	0.000	0.325	0.057	0.744	0.115	0.777	0.134	0.755	0.085	0.791	0.277	0.802	0.095	0.670	0.172
9/23/2007	0.100	0.108	0.307	0.000	0.349	0.000			0.422	0.000	0.325	0.059	0.745	0.109	0.776	0.132	0.753	0.085	0.792	0.271	0.802	0.093	0.668	0.172
9/24/2007	0.103	0.000	0.312	0.000	0.349	0.000			0.422	0.000	0.325	0.059	0.746	0.106	0.775	0.132	0.753	0.085	0.793	0.269	0.801	0.093	0.668	0.172
9/25/2007	0.121	0.000	0.344	0.000	0.350	0.000			0.423	0.000	0.326	0.060	0.749	0.101	0.776	0.131	0.754	0.084	0.796	0.263	0.801	0.092	0.669	0.172
9/26/2007	0.160	0.000	0.357	0.000	0.351	0.000			0.423	0.000	0.326	0.061	0.749	0.099	0.776	0.129	0.755	0.084	0.796	0.261	0.801	0.090	0.670	0.171
9/27/2007	0.165	0.000	0.364	0.000	0.350	0.000			0.422	0.000	0.326	0.060	0.748	0.097	0.777	0.127	0.757	0.083	0.795	0.260	0.803	0.088	0.672	0.170
9/28/2007	0.114	0.000	0.365	0.000	0.347	0.000			0.420	0.000	0.324	0.059	0.748	0.097	0.779	0.124	0.757	0.083	0.795	0.260	0.804	0.086	0.671	0.170
9/29/2007	0.098	2.710	0.325	0.000	0.346	0.000			0.420	0.000	0.324	0.058	0.747	0.099	0.779	0.124	0.760	0.082	0.794	0.262	0.805	0.085	0.674	0.169
9/30/2007	0.120	0.000	0.358	0.000	0.347	0.000			0.420	0.000	0.325	0.058	0.748	0.102	0.780	0.124	0.759	0.082	0.795	0.264	0.805	0.085	0.673	0.169
10/1/2007	0.103	0.541	0.326	0.000	0.346	0.000			0.419	0.000	0.324	0.058	0.748	0.101	0.780	0.123	0.759	0.082	0.795	0.263	0.805	0.085	0.673	0.169
10/2/2007	0.124	0.000	0.366	0.000	0.347	0.000			0.419	0.000	0.325	0.058	0.748	0.099	0.780	0.123	0.759	0.082	0.795	0.262	0.805	0.084	0.673	0.169
10/3/2007	0.104	0.000	0.331	0.000	0.345	0.000			0.418	0.000	0.323	0.058	0.747	0.099	0.779	0.122	0.758	0.082	0.794	0.262	0.805	0.084	0.673	0.168
10/4/2007	0.092	2.849	0.324	0.000	0.344	0.000			0.417	0.000	0.323	0.057	0.748	0.098	0.778	0.122	0.757	0.082	0.794	0.264	0.805	0.083	0.672	0.162
10/5/2007	0.088	0.587	0.310	0.000	0.344	0.000			0.416	0.000	0.323	0.056	0.748	0.097	0.775	0.125	0.758	0.082	0.792	0.276			0.678	0.144
10/6/2007	0.083	0.373	0.290	0.000	0.343	0.000			0.415	0.000	0.323	0.056	0.747	0.099	0.775	0.125	0.758	0.082	0.793	0.276			0.683	0.142
10/7/2007	0.079	0.270	0.266	0.000	0.342	0.000			0.415	0.000	0.322	0.055	0.746	0.101	0.775	0.125	0.758	0.082	0.792	0.278			0.682	0.142
10/8/2007	0.077	0.234	0.249	0.000	0.342	0.000			0.414	0.000	0.323	0.055	0.746	0.104	0.776	0.124	0.758	0.082	0.791	0.281			0.679	0.143
10/9/2007	0.074	0.202	0.227	0.000	0.341	0.000			0.414	0.000	0.322	0.055	0.745	0.109	0.776	0.125	0.758	0.082	0.791	0.281			0.684	0.141
10/10/2007	0.072	0.184	0.206	0.000	0.340	0.000			0.413	0.000	0.322	0.055	0.745	0.111	0.776	0.124	0.758	0.082	0.790	0.282			0.681	0.142
10/11/2007	0.069	0.169	0.195	0.000	0.340	0.000			0.412	0.000	0.322	0.055	0.744	0.114	0.776	0.124	0.757	0.082	0.791	0.281			0.677	0.144
10/12/2007	0.067	0.157	0.186	0.000	0.339	0.000			0.412	0.000	0.322	0.054	0.744	0.116	0.776	0.125	0.758	0.082	0.791	0.280			0.675	0.146
10/13/2007	0.065	0.142	0.179	0.000	0.339	0.000			0.412	0.000	0.322	0.054	0.744	0.117	0.775	0.126	0.758	0.082	0.792	0.278			0.677	0.146
10/14/2007	0.063	0.136	0.173	0.000	0.339	0.000			0.412	0.000	0.322	0.055	0.743	0.120	0.775	0.127	0.758	0.082	0.793	0.275			0.675	0.147
10/15/2007	0.062	0.131	0.168	0.000	0.339	0.000			0.412	0.000	0.322	0.055	0.743	0.122	0.775	0.128	0.758	0.082	0.795	0.271			0.683	0.146
10/16/2007	0.061	0.129	0.166	0.000	0.339	0.000			0.412	0.000	0.322	0.055	0.742	0.124	0.774	0.128	0.758	0.082	0.794	0.271			0.680	0.148
10/17/2007	0.066	0.147	0.175	0.000	0.340	0.000			0.413	0.000	0.322	0.056	0.743	0.123	0.775	0.127	0.756	0.082	0.794	0.270			0.679	0.148
10/18/2007	0.067	0.157	0.175	0.000	0.339	0.000	0.120	0.000	0.412	0.000	0.322	0.056	0.743	0.122	0.777	0.124	0.755	0.083	0.796	0.266			0.679	0.148
10/19/2007	0.070	0.168	0.181	0.000	0.339	0.000	0.132	0.002	0.412	0.000	0.323	0.055	0.744	0.119	0.781	0.122	0.753	0.083						
10/20/2007	0.095	3.197	0.259	0.000	0.341	0.000	0.181	0.009	0.413	0.000	0.325	0.052	0.745	0.113	0.782	0.120	0.754	0.083						
10/21/2007	0.084	0.390	0.239	0.000	0.341	0.000	0.163	0.001	0.412	0.000	0.324	0.053	0.746	0.110	0.781	0.120	0.753	0.083						
10/22/2007	0.079	0.254	0.228	0.000	0.340	0.000	0.154	0.000	0.411	0.000	0.324	0.054	0.745	0.112	0.782	0.119	0.752	0.083						
10/23/2007	0.074	0.196	0.209	0.000	0.339	0.000	0.144	0.000	0.410	0.000	0.323	0.055	0.744	0.114	0.782	0.120	0.752	0.083						
10/24/2007	0.072	0.180	0.199	0.000	0.338	0.000	0.148	0.000	0.410	0.000	0.323	0.055	0.745	0.115	0.782	0.119	0.754	0.083						
10/25/2007	0.072	0.184	0.199	0.000	0.339	0.000	0.152	0.000	0.410	0.000	0.323	0.055	0.744	0.118	0.782	0.120	0.756	0.082						
10/26/2007	0.087	0.959	0.215	0.000	0.340	0.000	0.166	0.000	0.411	0.000	0.324	0.055	0.744	0.118	0.782	0.119	0.756	0.082						
10/27/2007	0.086	0.470	0.221	0.000	0.340	0.000	0.159	0.000	0.411	0.000	0.324	0.054	0.744	0.114	0.783	0.117	0.754	0.083						
10/28/2007	0.077	0.232	0.205	0.000	0.339	0.000	0.146	0.000	0.409	0.000	0.323	0.054	0.745	0.108	0.782	0.117	0.754	0.082						
10/29/2007	0.077	0.239	0.201	0.000	0.339	0.000	0.145	0.000	0.410	0.000	0.323	0.055	0.747	0.105	0.782	0.117	0.753	0.083						
10/30/2007	0.077	0.230	0.200	0.000	0.339	0.000	0.145	0.000	0.409	0.000	0.323	0.055	0.748	0.103	0.782	0.117	0.752	0.083						
10/31/2007	0.080	0.365	0.203	0.000	0.338	0.000	0.149	0.000	0.409	0.000	0.323	0.055	0.747	0.104	0.781	0.117	0.751	0.083						
11/1/2007	0.088	0.632	0.221	0.000	0.339	0.000	0.166	0.000	0.409	0.000	0.323	0.055	0.747	0.107	0.781	0.116	0.751	0.083						
11/2/2007	0.081	0.312	0.213	0.000	0.338	0.000	0.160	0.000	0.408	0.000	0.324	0.055	0.746	0.110	0.782	0.115	0.752	0.083	0.806	0.244			0.676	0.141
11/3/2007	0.076	0.219	0.201	0.000	0.337	0.000	0.149	0.000	0.408	0.000	0.324	0.055	0.746	0.109	0.783	0.114	0.754	0.082	0.807	0.242			0.676	0.141
11/4/2007	0.071	0.172	0.190	0.000	0.337	0.000	0.140	0.000	0.408	0.000	0.324	0.055	0.746	0.107	0.783	0.114	0.754	0.082	0.807	0.241			0.679	0.139
11/5/2007	0.068	0.155	0.183	0.000	0.337	0.000	0.136	0.000	0.408	0.000	0.323	0.056	0.745	0.109	0.782	0.115	0.755	0.082	0.807	0.241			0.678	0.140

Table A-1. Continued.

	T1-60 (25 cm)		T1-60 (35 cm)		T1-60 (55 cm)		T1-50 (30 cm)		T1-50 (50 cm)		T1-50 (95 cm)		T1-30 (25 cm)		T1-30 (50 cm)		T1-30 (80 cm)		T1-1 (25 cm)		T1-1 (50 cm)		T1-1 (72 cm)	
Date	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w
11/6/2007	0.066	0.144	0.178	0.000	0.336	0.000	0.134	0.000	0.408	0.000	0.323	0.055	0.745	0.109	0.781	0.116	0.757	0.081	0.807	0.239			0.679	0.139
11/7/2007	0.064	0.137	0.174	0.000	0.336	0.000	0.131	0.000	0.408	0.000	0.324	0.055	0.745	0.108	0.781	0.116	0.756	0.081	0.808	0.238			0.682	0.138
11/8/2007	0.068	0.133	0.171	0.000	0.336	0.000	0.130	0.000	0.408	0.000	0.323	0.055	0.745	0.108	0.781	0.116	0.754	0.082	0.814	0.229			0.682	0.138
11/9/2007	0.071	0.132	0.169	0.000	0.336	0.000	0.130	0.000	0.408	0.000	0.324	0.055	0.746	0.108	0.780	0.116	0.753	0.082	0.818	0.220			0.681	0.139
11/10/2007	0.068	0.152	0.166	0.000	0.336	0.000	0.128	0.000	0.408	0.000	0.323	0.055	0.746	0.109	0.781	0.116	0.752	0.082	0.819	0.218			0.680	0.140
11/11/2007	0.067	0.143	0.164	0.000	0.336	0.000	0.127	0.000	0.408	0.000	0.323	0.056	0.745	0.112	0.782	0.113	0.752	0.082	0.818	0.218			0.677	0.141
11/12/2007	0.066	0.139	0.163	0.000	0.336	0.000	0.127	0.000	0.409	0.000	0.324	0.056	0.744	0.114	0.782	0.113	0.753	0.082	0.818	0.216			0.676	0.142
11/13/2007	0.078	0.816	0.180	0.000	0.338	0.000	0.142	0.000	0.410	0.000	0.324	0.056	0.743	0.115	0.782	0.113	0.754	0.082	0.817	0.217			0.675	0.142
11/14/2007	0.085	0.410	0.196	0.000	0.338	0.000	0.148	0.000	0.409	0.000	0.324	0.057	0.744	0.112	0.782	0.111	0.756	0.081	0.817	0.217			0.680	0.139
11/15/2007	0.079	0.252	0.186	0.000	0.336	0.000	0.143	0.000	0.409	0.000	0.324	0.058	0.744	0.112	0.781	0.112	0.754	0.081	0.818	0.215			0.683	0.137
11/16/2007	0.075	0.199	0.179	0.000	0.336	0.000	0.138	0.000	0.408	0.000	0.324	0.058	0.744	0.113	0.782	0.112	0.754	0.081	0.817	0.217			0.682	0.138
11/17/2007	0.072	0.173	0.173	0.000	0.336	0.000	0.135	0.000	0.408	0.000	0.324	0.059	0.745	0.110	0.781	0.112	0.752	0.082	0.818	0.214			0.682	0.138
11/18/2007	0.070	0.161	0.168	0.000	0.336	0.000	0.131	0.000	0.409	0.000	0.324	0.059	0.745	0.108	0.781	0.112	0.750	0.082	0.821	0.209			0.682	0.138
11/19/2007	0.069	0.154	0.166	0.000	0.336	0.000	0.130	0.000	0.409	0.000	0.324	0.059	0.745	0.108	0.780	0.113	0.748	0.083	0.822	0.207			0.681	0.138
11/20/2007	0.068	0.152	0.165	0.000	0.336	0.000	0.129	0.000	0.409	0.000	0.324	0.059	0.745	0.106	0.779	0.114	0.750	0.082	0.821	0.207			0.680	0.138
11/21/2007	0.066	0.142	0.162	0.000	0.335	0.000	0.127	0.000	0.408	0.000	0.324	0.060	0.746	0.105	0.779	0.114	0.754	0.081	0.821	0.207			0.679	0.139
11/22/2007	0.066	0.143	0.161	0.000	0.335	0.000	0.126	0.000	0.408	0.000	0.324	0.060	0.746	0.106	0.779	0.114	0.754	0.081	0.821	0.207			0.678	0.140
11/23/2007	0.066	0.138	0.160	0.000	0.335	0.000	0.126	0.000	0.408	0.000	0.323	0.060	0.746	0.106	0.779	0.113	0.754	0.081	0.822	0.207			0.677	0.140
11/24/2007	0.065	0.137	0.159	0.000	0.335	0.000	0.124	0.000	0.408	0.000	0.324	0.060	0.746	0.103	0.779	0.113	0.753	0.081	0.822	0.207			0.677	0.140
11/25/2007	0.065	0.134	0.155	0.000	0.335	0.000	0.116	0.000	0.407	0.000	0.323	0.060	0.750	0.080	0.779	0.111	0.751	0.081	0.816	0.214			0.682	0.137
11/26/2007	0.064	0.133	0.150	0.000	0.334	0.000	0.109	0.000	0.405	0.000	0.323	0.056	0.753	0.068	0.780	0.109	0.750	0.081	0.815	0.218			0.678	0.137
11/27/2007	0.066	0.151	0.159	0.000	0.334	0.000	0.111	0.000	0.403	0.000	0.324	0.051	0.754	0.064	0.780	0.108	0.749	0.081	0.815	0.218			0.680	0.136
11/28/2007	0.076	0.220	0.177	0.000	0.335	0.000	0.117	0.000	0.408	0.000	0.326	0.047	0.753	0.068	0.781	0.107	0.749	0.081	0.812	0.224			0.680	0.134
11/29/2007	0.078	0.236	0.178	0.000	0.336	0.000	0.117	0.000	0.411	0.000	0.326	0.051	0.753	0.067	0.781	0.105	0.749	0.081	0.809	0.230			0.678	0.133
11/30/2007	0.075	0.201	0.172	0.000	0.335	0.000	0.117	0.000	0.412	0.000	0.326	0.061	0.753	0.064	0.781	0.106	0.754	0.080	0.806	0.237			0.676	0.133
12/1/2007	0.072	0.174	0.166	0.000	0.334	0.000	0.117	0.000	0.413	0.000	0.326	0.071	0.753	0.064	0.781	0.106	0.754	0.080	0.800	0.248			0.678	0.132
12/2/2007	0.070	0.159	0.161	0.000	0.334	0.000	0.114	0.000	0.414	0.000	0.326	0.078	0.753	0.064	0.781	0.106	0.754	0.080	0.799	0.251			0.680	0.131
12/3/2007	0.068	0.147	0.158	0.000	0.333	0.000	0.112	0.000	0.414	0.000	0.325	0.080	0.753	0.066	0.781	0.104	0.751	0.080	0.799	0.252			0.678	0.131
12/4/2007	0.066	0.138	0.154	0.000	0.332	0.000	0.106	0.000	0.412	0.000	0.325	0.074	0.755	0.060	0.782	0.102	0.750	0.081	0.797	0.255			0.676	0.131
12/5/2007	0.063	0.129	0.149	0.000	0.332	0.000	0.102	0.000	0.377	0.000	0.324	0.074	0.755	0.057	0.781	0.102	0.753	0.080						
12/6/2007	0.062	0.122	0.145	0.000	0.332	0.000	0.100	0.000	0.301	0.000	0.325	0.072	0.755	0.057	0.780	0.103	0.753	0.080						
12/7/2007	0.061	0.119	0.142	0.000	0.332	0.000	0.097	0.000	0.259	0.000	0.325	0.071	0.756	0.055	0.780	0.103	0.750	0.081						
12/8/2007	0.060	0.116	0.139	0.000	0.332	0.000	0.096	0.568	0.235	0.000	0.325	0.071	0.755	0.055	0.780	0.103	0.748	0.081						
12/9/2007	0.059	0.111	0.137	0.000	0.332	0.000	0.094	5.344	0.218	0.000	0.324	0.071	0.754	0.058	0.780	0.103	0.748	0.082						
12/10/2007	0.058	0.109	0.134	0.000	0.332	0.000	0.093	1.567	0.205	0.000	0.324	0.071	0.755	0.057	0.780	0.103	0.747	0.082						
12/11/2007	0.057	0.105	0.131	0.000	0.332	0.000	0.092	0.777	0.194	0.000	0.324	0.070	0.755	0.056	0.780	0.103	0.747	0.082						
12/12/2007	0.056	0.102	0.129	0.000	0.332	0.000	0.091	0.596	0.187	0.000	0.324	0.070	0.756	0.055	0.780	0.103	0.747	0.082						
12/13/2007	0.063	1.152	0.131	0.000	0.333	0.000	0.093	0.425	0.191	0.000	0.324	0.071	0.756	0.055	0.780	0.103	0.747	0.082						
12/14/2007	0.087	0.532	0.163	0.000	0.336	0.000	0.115	0.000	0.305	0.000	0.328	0.088	0.755	0.054	0.780	0.102	0.750	0.081						
12/15/2007	0.081	0.294	0.168	0.000	0.335	0.000	0.127	0.000	0.340	0.000	0.327	0.082	0.754	0.057	0.781	0.102	0.749	0.081						
12/16/2007	0.081	0.323	0.169	0.000	0.335	0.000	0.128	0.000	0.354	0.000	0.327	0.078	0.755	0.057	0.781	0.102	0.748	0.082						
12/17/2007	0.080	0.273	0.171	0.000	0.335	0.000	0.132	0.000	0.370	0.000	0.328	0.084	0.754	0.059	0.780	0.104	0.750	0.081						
12/18/2007	0.075	0.202	0.165	0.000	0.335	0.000	0.128	0.000	0.382	0.001	0.328	0.088	0.754	0.059	0.780	0.104	0.750	0.081						
12/19/2007	0.072	0.176	0.160	0.000	0.335	0.000	0.126	0.000	0.390	0.001	0.327	0.091	0.754	0.059	0.780	0.103	0.750	0.081						
12/20/2007	0.070	0.165	0.159	0.000	0.335	0.000	0.130	0.000	0.395	0.002	0.326	0.096	0.753	0.061	0.781	0.101	0.751	0.081						
12/21/2007	0.070	0.162	0.160	0.000	0.334	0.000	0.128	0.000	0.396	0.001	0.325	0.086	0.752	0.062	0.781	0.101	0.753	0.080						
12/22/2007	0.069	0.155	0.157	0.000	0.334	0.000	0.124	0.000	0.398	0.001	0.324	0.082	0.752	0.061	0.782	0.100	0.752	0.080						
12/23/2007	0.068	0.150	0.155	0.000	0.334	0.000	0.122	0.000	0.401	0.000	0.324	0.080	0.753	0.060	0.781	0.101	0.749	0.081						
12/24/2007	0.066	0.141	0.153	0.000	0.334	0.000	0.121	0.000	0.402	0.000	0.324	0.078	0.753	0.060	0.781	0.101	0.749	0.081						
12/25/2007	0.073	0.202	0.156	0.000	0.334	0.000	0.123	0.000	0.404	0.000	0.323	0.073	0.753	0.059	0.781	0.100	0.748	0.081						

Table A-1. Continued.

	T1-60 (25 cm)		T1-60 (35 cm)		T1-60 (55 cm)		T1-50 (30 cm)		T1-50 (50 cm)		T1-50 (95 cm)		T1-30 (25 cm)		T1-30 (50 cm)		T1-30 (80 cm)		T1-1 (25 cm)		T1-1 (50 cm)		T1-1 (72 cm)	
Date	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w
12/26/2007	0.075	0.209	0.158	0.000	0.334	0.000	0.123	0.000	0.406	0.000	0.323	0.070	0.753	0.060	0.781	0.100	0.748	0.081						
12/27/2007	0.072	0.175	0.155	0.000	0.334	0.000	0.120	0.000	0.407	0.001	0.323	0.070	0.753	0.059	0.781	0.099	0.749	0.081						
12/28/2007	0.070	0.161	0.153	0.000	0.334	0.000	0.117	0.000	0.407	0.002	0.323	0.067	0.753	0.060	0.781	0.099	0.749	0.081						
12/29/2007	0.068	0.154	0.150	0.000	0.334	0.000	0.110	0.000	0.408	0.001	0.322	0.060	0.755	0.059	0.782	0.097	0.749	0.080						
12/30/2007	0.067	0.146	0.146	0.000	0.333	0.000	0.105	0.000	0.407	0.001	0.322	0.056	0.755	0.058	0.782	0.096	0.749	0.080						
12/31/2007	0.065	0.136	0.143	0.000	0.333	0.000	0.103	0.000	0.379	0.000	0.323	0.064	0.755	0.056	0.782	0.096	0.749	0.080						
1/1/2008	0.064	0.133	0.143	0.000	0.333	0.000	0.105	0.000	0.382	0.000	0.324	0.081	0.755	0.055	0.782	0.096	0.750	0.080						
1/2/2008	0.062	0.124	0.142	0.000	0.333	0.000	0.105	0.000	0.385	0.001	0.324	0.081	0.754	0.057	0.783	0.096	0.753	0.080						
1/3/2008	0.060	0.116	0.140	0.000	0.334	0.000	0.103	0.000	0.384	0.001	0.325	0.078	0.754	0.055	0.782	0.096	0.752	0.080						
1/4/2008	0.059	0.115	0.139	0.000	0.335	0.000	0.100	0.000	0.373	0.000	0.324	0.074	0.755	0.054	0.780	0.096	0.749	0.080						
1/5/2008	0.059	0.116	0.138	0.000	0.335	0.000	0.099	0.000	0.332	0.000	0.324	0.071	0.755	0.051	0.781	0.093	0.748	0.080						
1/6/2008	0.059	0.113	0.137	0.000	0.334	0.000	0.097	0.434	0.290	0.000	0.324	0.069	0.756	0.048	0.781	0.093	0.749	0.080						
1/7/2008	0.059	0.112	0.135	0.000	0.334	0.000	0.096	0.509	0.266	0.000	0.324	0.072	0.756	0.048	0.780	0.093	0.747	0.081						
1/8/2008	0.058	0.109	0.133	0.000	0.334	0.000	0.095	3.359	0.250	0.000	0.324	0.073	0.755	0.049	0.780	0.092	0.746	0.081						
1/9/2008	0.057	0.109	0.132	0.000	0.333	0.000	0.094	7.297	0.240	0.000	0.323	0.075	0.756	0.049	0.781	0.092	0.745	0.081						
1/10/2008	0.056	0.105	0.131	0.000	0.333	0.000	0.094	5.918	0.232	0.000	0.323	0.076	0.756	0.049	0.780	0.092	0.746	0.081						
1/11/2008	0.055	0.104	0.129	0.000	0.333	0.000	0.094	2.206	0.225	0.000	0.322	0.076	0.755	0.049	0.779	0.093	0.745	0.081						
1/12/2008	0.055	0.103	0.128	0.000	0.333	0.000	0.093	1.167	0.218	0.000	0.322	0.074	0.755	0.050	0.778	0.094	0.745	0.081						
1/13/2008	0.054	0.101	0.127	0.000	0.333	0.000	0.093	1.059	0.212	0.000	0.322	0.074	0.756	0.049	0.779	0.094	0.747	0.081						
1/14/2008	0.054	0.098	0.127	0.000	0.334	0.000	0.093	1.255	0.212	0.000	0.323	0.074	0.756	0.049	0.779	0.094	0.749	0.080						
1/15/2008	0.052	0.096	0.126	0.000	0.334	0.000	0.093	0.906	0.209	0.000	0.322	0.073	0.755	0.050	0.779	0.094	0.750	0.080						
1/16/2008	0.052	0.094	0.124	0.000	0.334	0.000	0.092	0.637	0.204	0.000	0.322	0.072	0.755	0.050	0.779	0.093	0.749	0.080						
1/17/2008	0.052	0.095	0.123	0.000	0.334	0.000	0.091	0.582	0.200	0.000	0.322	0.071	0.755	0.049	0.780	0.090	0.746	0.081						
1/18/2008																								
1/19/2008	0.052	0.094	0.121	0.000	0.333	0.000	0.090	0.448	0.191	0.000	0.322	0.069	0.755	0.049	0.779	0.091	0.744	0.081						
1/20/2008	0.052	0.094	0.122	0.000	0.334	0.000	0.090	0.465	0.189	0.000	0.322	0.069	0.756	0.048	0.779	0.093	0.746	0.081						
1/21/2008	0.052	0.093	0.122	0.000	0.335	0.000	0.090	0.427	0.189	0.000	0.323	0.068	0.756	0.049	0.778	0.093	0.748	0.081						
1/22/2008	0.054	0.101	0.121	0.000	0.334	0.000	0.090	0.400	0.188	0.000	0.322	0.067	0.755	0.049	0.779	0.091	0.745	0.081						
1/23/2008	0.055	0.103	0.120	0.000	0.334	0.000	0.090	0.408	0.182	0.000	0.322	0.064	0.755	0.049	0.779	0.092	0.744	0.082						
1/24/2008	0.056	0.104	0.119	0.000	0.334	0.000	0.089	0.369	0.174	0.000	0.321	0.061	0.756	0.047	0.778	0.093	0.745	0.082						
1/25/2008	0.055	0.101	0.117	0.000	0.334	0.000	0.088	0.307	0.166	0.000	0.321	0.059	0.756	0.047	0.778	0.093	0.746	0.082						
1/26/2008	0.054	0.099	0.115	0.000	0.334	0.000	0.087	0.278	0.160	0.000	0.321	0.059	0.756	0.048	0.778	0.093	0.747	0.082						
1/27/2008	0.054	0.099	0.114	0.000	0.334	0.000	0.086	0.254	0.155	0.000	0.320	0.058	0.755	0.048	0.778	0.094	0.747	0.082						
1/28/2008	0.052	0.095	0.112	0.000	0.334	0.000	0.085	0.214	0.150	0.000	0.320	0.057	0.755	0.048	0.778	0.094	0.746	0.082						
1/29/2008	0.051	0.092	0.110	0.000	0.334	0.000	0.084	0.207	0.146	0.000	0.319	0.056	0.755	0.047	0.779	0.091	0.744	0.083						
1/30/2008	0.050	0.090	0.108	0.000	0.334	0.000	0.083	0.189	0.142	0.000	0.319	0.054	0.755	0.047	0.779	0.090	0.745	0.082						
1/31/2008	0.051	0.091	0.106	0.000	0.334	0.000	0.082	0.182	0.137	0.000	0.319	0.053	0.755	0.047	0.779	0.090	0.746	0.082						
2/1/2008	0.049	0.089	0.103	0.000	0.334	0.000	0.082	0.177	0.134	0.000	0.319	0.053	0.755	0.047	0.779	0.089	0.745	0.082						
2/2/2008	0.048	0.087	0.101	0.000	0.334	0.000	0.081	0.167	0.130	0.000	0.319	0.053	0.754	0.050	0.779	0.090	0.746	0.082						
2/3/2008	0.047	0.085	0.100	0.000	0.335	0.000	0.081	0.161	0.128	0.000	0.319	0.053	0.755	0.049	0.779	0.090	0.746	0.082						
2/4/2008	0.047	0.084	0.098	0.000	0.335	0.000	0.080	0.156	0.125	0.000	0.319	0.053	0.755	0.049	0.778	0.091	0.744	0.083						
2/5/2008	0.046	0.082	0.096	4.751	0.335	0.000	0.079	0.146	0.121	0.000	0.319	0.053	0.754	0.050	0.777	0.090	0.743	0.084						
2/6/2008	0.045	0.081	0.094	6.010	0.335	0.000	0.079	0.146	0.118	0.000	0.319	0.053	0.754	0.050	0.778	0.088	0.743	0.084						
2/7/2008	0.044	0.079	0.092	1.207	0.335	0.000	0.078	0.136	0.115	0.000	0.319	0.054	0.750	0.048	0.777	0.089	0.744	0.084						
2/8/2008	0.042	0.076	0.090	0.645	0.333	0.000	0.076	0.130	0.112	0.000	0.319	0.055	0.725	0.043	0.777	0.090	0.745	0.083						
2/9/2008	0.041	0.075	0.089	0.477	0.306	0.000	0.076	0.124	0.110	0.000	0.319	0.057	0.710	0.037	0.777	0.090	0.745	0.083						
2/10/2008	0.041	0.074	0.087	0.387	0.282	0.000	0.077	0.129	0.110	0.000	0.320	0.059	0.729	0.036	0.776	0.090	0.746	0.084						
2/11/2008	0.039	0.071	0.086	0.318	0.250	0.000	0.077	0.129	0.108	0.000	0.320	0.059	0.708	0.036	0.777	0.091	0.747	0.084						
2/12/2008	0.039	0.071	0.084	0.284	0.235	0.000	0.076	0.119	0.106	0.000	0.320	0.061	0.709	0.032	0.775	0.091	0.745	0.084						
2/13/2008	0.059	0.126	0.090	1.362	0.258	0.000	0.100	0.015	0.138	0.000	0.339	0.062	0.727	0.036	0.775	0.090	0.744	0.084						

Table A-1. Continued.

	T1-60 (25 cm)		T1-60 (35 cm)		T1-60 (55 cm)		T1-50 (30 cm)		T1-50 (50 cm)		T1-50 (95 cm)		T1-30 (25 cm)		T1-30 (50 cm)		T1-30 (80 cm)		T1-1 (25 cm)		T1-1 (50 cm)		T1-1 (72 cm)	
Date	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w
2/14/2008	0.071	0.167	0.103	0.000	0.274	0.000	0.095	2.612	0.160	0.000	0.357	0.052	0.727	0.040	0.776	0.091	0.747	0.083						
2/15/2008	0.067	0.142	0.105	0.000	0.277	0.000	0.093	1.211	0.172	0.000	0.358	0.055	0.725	0.042	0.777	0.087	0.750	0.081						
2/16/2008	0.064	0.130	0.105	0.000	0.279	0.000	0.093	1.585	0.178	0.000	0.357	0.055	0.725	0.044	0.776	0.087	0.748	0.081						
2/17/2008	0.062	0.121	0.105	0.000	0.280	0.000	0.093	0.995	0.177	0.000	0.356	0.056	0.725	0.044	0.776	0.086	0.747	0.081						
2/18/2008	0.060	0.114	0.104	0.000	0.281	0.000	0.093	1.030	0.176	0.000	0.355	0.056	0.725	0.044	0.776	0.084	0.747	0.081						
2/19/2008	0.058	0.109	0.104	0.000	0.283	0.000	0.092	0.747	0.171	0.000	0.355	0.055	0.725	0.045	0.777	0.085	0.749	0.081						
2/20/2008	0.057	0.105	0.103	0.000	0.284	0.000	0.090	0.455	0.167	0.000	0.355	0.054	0.725	0.046	0.777	0.087	0.749	0.080						
2/21/2008	0.056	0.101	0.102	0.000	0.284	0.000	0.089	0.360	0.159	0.000	0.355	0.051	0.725	0.046	0.776	0.086	0.749	0.080						
2/22/2008	0.055	0.101	0.102	0.000	0.285	0.000	0.089	0.344	0.158	0.000	0.355	0.052	0.725	0.045	0.775	0.084	0.747	0.081						
2/23/2008	0.055	0.104	0.103	0.000	0.285	0.000	0.090	0.478	0.176	0.000	0.355	0.054	0.723	0.046	0.778	0.083	0.746	0.082						
2/24/2008	0.056	0.109	0.103	0.000	0.285	0.000	0.092	0.850	0.184	0.000	0.355	0.054	0.724	0.047	0.777	0.085	0.739	0.083						
2/25/2008	0.058	0.108	0.104	0.000	0.285	0.000	0.092	0.766	0.180	0.000	0.354	0.054	0.725	0.048	0.774	0.089	0.739	0.083						
2/26/2008	0.055	0.101	0.104	0.000	0.285	0.000	0.092	0.927	0.178	0.000	0.353	0.054	0.725	0.048	0.765	0.098	0.742	0.083						
2/27/2008	0.067	0.148	0.109	0.000	0.287	0.000	0.095	4.440	0.185	0.000	0.353	0.055	0.726	0.048	0.762	0.105	0.744	0.082						
2/28/2008	0.069	0.153	0.109	0.000	0.289	0.000	0.093	1.747	0.181	0.000	0.354	0.053	0.727	0.048	0.764	0.106	0.745	0.082						
2/29/2008	0.069	0.154	0.107	0.000	0.290	0.000	0.091	0.607	0.175	0.000	0.354	0.053	0.727	0.046	0.754	0.115	0.744	0.082						
3/1/2008	0.066	0.141	0.106	0.000	0.290	0.000	0.090	0.433	0.171	0.000	0.353	0.055	0.726	0.048	0.750	0.117	0.746	0.082						
3/2/2008	0.065	0.139	0.105	0.000	0.290	0.000	0.089	0.366	0.166	0.000	0.352	0.055	0.726	0.047	0.755	0.113	0.741	0.083						
3/3/2008	0.064	0.137	0.103	0.000	0.290	0.000	0.088	0.304	0.161	0.000	0.352	0.055	0.727	0.046	0.764	0.109	0.741	0.083						
3/4/2008	0.064	0.136	0.102	0.000	0.290	0.000	0.087	0.268	0.155	0.000	0.351	0.053	0.727	0.045	0.773	0.110	0.739	0.084						
3/5/2008	0.077	0.322	0.104	0.000	0.291	0.000	0.088	0.363	0.155	0.000	0.351	0.052	0.729	0.043	0.776	0.111	0.737	0.085						
3/6/2008	0.082	0.321	0.108	0.000	0.293	0.000	0.092	0.996	0.162	0.000	0.353	0.050	0.729	0.043	0.777	0.112	0.739	0.084						
3/7/2008	0.085	0.436	0.113	0.000	0.293	0.000	0.097	0.338	0.178	0.000	0.353	0.049	0.730	0.043	0.773	0.111	0.741	0.084						
3/8/2008	0.084	0.378	0.114	0.000	0.294	0.000	0.096	0.661	0.183	0.000	0.353	0.051	0.731	0.045	0.772	0.114	0.739	0.084						
3/9/2008	0.079	0.253	0.114	0.000	0.295	0.000	0.097	0.000	0.209	0.000	0.353	0.058	0.731	0.047	0.773	0.114	0.744	0.083						
3/10/2008	0.076	0.222	0.114	0.000	0.296	0.000	0.098	0.000	0.224	0.000	0.352	0.058	0.730	0.049	0.771	0.113	0.741	0.084						
3/11/2008	0.074	0.198	0.114	0.000	0.296	0.000	0.099	0.000	0.226	0.000	0.351	0.058	0.731	0.049	0.770	0.115	0.742	0.084						
3/12/2008	0.074	0.199	0.115	0.000	0.296	0.000	0.101	0.000	0.233	0.000	0.351	0.061	0.730	0.050	0.768	0.114	0.738	0.085						
3/13/2008	0.071	0.170	0.115	0.000	0.297	0.000	0.102	0.000	0.242	0.000	0.350	0.062	0.731	0.051	0.769	0.113	0.739	0.085						
3/14/2008	0.069	0.157	0.114	0.000	0.297	0.000	0.099	0.000	0.230	0.000	0.348	0.059	0.731	0.050	0.768	0.112	0.739	0.085						
3/15/2008	0.067	0.144	0.112	0.000	0.297	0.000	0.098	3.076	0.222	0.000	0.348	0.059	0.732	0.048	0.763	0.112	0.737	0.085						
3/16/2008	0.066	0.141	0.110	0.000	0.298	0.000	0.097	0.996	0.219	0.000	0.348	0.063	0.725	0.056	0.760	0.116	0.739	0.085						
3/17/2008	0.063	0.132	0.108	0.000	0.299	0.000	0.094	3.173	0.198	0.000	0.347	0.057	0.716	0.067	0.762	0.113	0.739	0.085						
3/18/2008	0.062	0.126	0.106	0.000	0.299	0.000	0.091	0.620	0.187	0.000	0.347	0.058	0.719	0.067	0.763	0.111	0.740	0.084						
3/19/2008	0.059	0.113	0.104	0.000	0.299	0.000	0.090	0.451	0.175	0.000	0.345	0.058	0.720	0.064	0.763	0.106	0.738	0.085						
3/20/2008	0.057	0.106	0.103	0.000	0.300	0.000	0.089	0.404	0.172	0.000	0.344	0.059	0.719	0.067	0.763	0.102	0.740	0.085	0.849	0.207	0.807	0.116	0.668	0.160
3/21/2008	0.055	0.101	0.101	0.000	0.300	0.000	0.087	0.311	0.159	0.000	0.345	0.055							0.850	0.205	0.808	0.115	0.670	0.160
3/22/2008	0.054	0.097	0.099	0.000	0.300	0.000	0.085	0.249	0.148	0.000	0.339	0.052							0.852	0.202	0.808	0.113	0.670	0.160
3/23/2008	0.075	2.567	0.113	0.000	0.302	0.000	0.100	0.084	0.207	0.000	0.341	0.057							0.855	0.197	0.809	0.111	0.673	0.158
3/24/2008	0.078	0.240	0.124	0.000	0.303	0.000	0.103	0.000	0.236	0.000	0.343	0.053							0.854	0.198	0.809	0.110	0.674	0.157
3/25/2008	0.071	0.163	0.121	0.000	0.303	0.000	0.099	0.000	0.224	0.000	0.343	0.053							0.853	0.199	0.808	0.110	0.669	0.158
3/26/2008	0.066	0.141	0.117	0.000	0.304	0.000	0.097	0.000	0.217	0.000	0.343	0.057							0.854	0.198	0.810	0.108	0.668	0.158
3/27/2008	0.068	0.143	0.114	0.000	0.304	0.000	0.095	2.600	0.205	0.000	0.342	0.058							0.856	0.194	0.810	0.106	0.669	0.157
3/28/2008	0.064	0.128	0.113	0.000	0.304	0.000	0.097	1.840	0.216	0.000	0.343	0.066							0.856	0.194	0.810	0.105	0.669	0.157
3/29/2008	0.062	0.119	0.114	0.000	0.305	0.000	0.102	0.000	0.233	0.000	0.343	0.068							0.855	0.196	0.810	0.105	0.669	0.156
3/30/2008	0.060	0.114	0.114	0.000	0.305	0.000	0.104	0.000	0.240	0.000	0.343	0.067							0.853	0.199	0.810	0.104	0.665	0.158
3/31/2008	0.063	0.125	0.117	0.000	0.307	0.000	0.105	0.000	0.242	0.000	0.343	0.064							0.852	0.201	0.811	0.101	0.661	0.159
4/1/2008	0.069	0.160	0.121	0.000	0.307	0.000	0.107	0.000	0.248	0.000	0.343	0.066							0.855	0.199	0.812	0.100	0.665	0.157
4/2/2008	0.075	0.198	0.125	0.000	0.307	0.000	0.109	0.000	0.258	0.000	0.343	0.065							0.857	0.197	0.812	0.098	0.669	0.155
4/3/2008	0.072	0.178	0.123	0.000	0.308	0.000	0.109	0.000	0.258	0.000	0.343	0.067							0.853	0.202	0.811	0.099	0.672	0.153

Table A-1. Continued.

	T1-60 (25 cm)		T1-60 (35 cm)		T1-60 (55 cm)		T1-50 (30 cm)		T1-50 (50 cm)		T1-50 (95 cm)		T1-30 (25 cm)		T1-30 (50 cm)		T1-30 (80 cm)		T1-1 (25 cm)		T1-1 (50 cm)		T1-1 (72 cm)	
Date	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w
4/4/2008	0.069	0.158	0.120	0.000	0.308	0.000	0.104	0.000	0.244	0.000	0.341	0.063							0.850	0.205	0.810	0.100	0.672	0.152
4/5/2008	0.066	0.139	0.117	0.000	0.307	0.000	0.100	0.000	0.229	0.000	0.340	0.063							0.850	0.205	0.809	0.101	0.671	0.152
4/6/2008	0.070	0.173	0.117	0.000			0.101	0.000	0.230	0.000	0.340	0.067							0.846	0.210	0.809	0.100	0.669	0.153
4/7/2008	0.096	0.511	0.136	0.000			0.112	0.000	0.269	0.000	0.341	0.063							0.843	0.214	0.808	0.100	0.666	0.154
4/8/2008	0.083	0.342	0.138	0.000			0.115	0.000	0.302	0.000	0.342	0.069							0.845	0.211	0.808	0.099	0.666	0.154
4/9/2008	0.077	0.219	0.134	0.000			0.114	0.000	0.304	0.000	0.342	0.071							0.844	0.213	0.809	0.098	0.670	0.152
4/10/2008	0.072	0.174	0.130	0.000			0.113	0.000	0.300	0.000	0.342	0.074							0.843	0.213	0.810	0.096	0.674	0.150
4/11/2008	0.069	0.153	0.127	0.000			0.111	0.000	0.293	0.000	0.341	0.074							0.839	0.218	0.811	0.094	0.675	0.149
4/12/2008	0.066	0.139	0.123	0.000			0.107	0.000	0.276	0.000	0.340	0.070							0.836	0.219	0.810	0.095	0.671	0.150
4/13/2008	0.064	0.127	0.120	0.000			0.102	0.000	0.258	0.000	0.339	0.065							0.841	0.211	0.810	0.094	0.669	0.151
4/14/2008	0.061	0.115	0.117	0.000			0.100	0.000	0.248	0.000	0.339	0.069							0.832	0.221	0.810	0.094	0.670	0.150
4/15/2008	0.057	0.104	0.113	0.000			0.097	1.387	0.236	0.000	0.339	0.068							0.826	0.223	0.808	0.095	0.671	0.150
4/16/2008	0.055	0.099	0.110	0.000			0.093	3.332	0.205	0.000	0.339	0.062							0.828	0.213	0.809	0.093	0.670	0.153
4/17/2008	0.053	0.094	0.108	0.000			0.091	0.718	0.185	0.000	0.339	0.062	0.748	0.049	0.781	0.090	0.742	0.085	0.832	0.205	0.810	0.092	0.666	0.154
4/18/2008	0.050	0.088	0.106	0.000			0.089	0.498	0.176	0.000	0.339	0.063	0.749	0.051	0.781	0.092	0.746	0.084	0.835	0.200	0.809	0.092	0.671	0.151
4/19/2008	0.049	0.086	0.104	0.000			0.088	0.394	0.168	0.000	0.338	0.062	0.750	0.050	0.780	0.090	0.744	0.085	0.832	0.202	0.812	0.088	0.669	0.152
4/20/2008	0.048	0.084	0.102	0.000			0.087	0.332	0.159	0.000	0.338	0.060	0.751	0.049	0.780	0.087	0.741	0.086	0.831	0.202	0.811	0.087	0.668	0.152
4/21/2008	0.048	0.083	0.100	0.000			0.085	0.282	0.152	0.000	0.337	0.059	0.751	0.048	0.780	0.085	0.740	0.086	0.826	0.208	0.811	0.087	0.668	0.151
4/22/2008	0.046	0.080	0.098	0.000			0.083	0.232	0.143	0.000	0.335	0.058	0.752	0.049	0.780	0.085	0.740	0.086	0.830	0.203	0.811	0.086	0.666	0.151
4/23/2008	0.044	0.077	0.095	3.618			0.081	0.199	0.135	0.000	0.330	0.057	0.752	0.049	0.780	0.084	0.741	0.086	0.831	0.201	0.811	0.085	0.668	0.150
4/24/2008	0.042	0.075	0.093	2.291			0.078	0.173	0.128	0.000	0.329	0.058	0.728	0.046	0.776	0.081	0.739	0.087	0.832	0.199	0.811	0.084	0.669	0.148
4/25/2008	0.041	0.074	0.090	0.665			0.075	0.146	0.122	0.000	0.328	0.058	0.695	0.037	0.777	0.076	0.739	0.087	0.827	0.206	0.812	0.082	0.666	0.148
4/26/2008	0.041	0.072	0.088	0.380			0.071	0.125	0.117	0.000	0.327	0.059	0.690	0.033	0.777	0.078	0.741	0.087	0.824	0.210	0.812	0.081	0.664	0.148
4/27/2008	0.040	0.072	0.096	2.939			0.067	0.108	0.112	0.000	0.326	0.059	0.688	0.030	0.777	0.073	0.740	0.087	0.822	0.212	0.812	0.081	0.666	0.147
4/28/2008	0.039	0.070	0.093	1.393			0.064	0.098	0.107	0.000	0.325	0.060	0.680	0.026	0.777	0.074	0.741	0.087	0.822	0.211	0.812	0.080	0.663	0.147
4/29/2008	0.038	0.070	0.090	0.571			0.062	0.094	0.103	0.000	0.324	0.062	0.680	0.024	0.776	0.072	0.741	0.087	0.823	0.211	0.812	0.079	0.660	0.147
4/30/2008	0.037	0.067	0.088	0.404			0.060	0.090	0.100	0.000	0.323	0.062	0.678	0.023	0.776	0.076	0.743	0.086	0.823	0.210	0.812	0.079	0.662	0.146
5/1/2008	0.036	0.066	0.086	0.273			0.057	0.084	0.095	1.239	0.315	0.061							0.825	0.206	0.812	0.079	0.665	0.145
5/2/2008	0.035	0.066	0.083	0.216			0.053	0.077	0.091	0.908	0.300	0.060							0.820	0.209	0.813	0.079	0.669	0.142
5/3/2008	0.035	0.066	0.080	0.179			0.050	0.073	0.087	0.427	0.287	0.056							0.813	0.216	0.813	0.080	0.665	0.143
5/4/2008	0.034	0.065	0.077	0.149			0.048	0.070	0.084	0.301	0.276	0.055							0.810	0.220	0.812	0.081	0.660	0.145
5/5/2008	0.033	0.064	0.074	0.126			0.046	0.068	0.081	0.235	0.264	0.053							0.810	0.219	0.811	0.082	0.662	0.145
5/6/2008	0.033	0.064	0.071	0.110			0.045	0.067	0.077	0.189	0.249	0.050							0.809	0.220	0.811	0.083	0.660	0.148
5/7/2008	0.031	0.062	0.067	0.098			0.043	0.064	0.074	0.160	0.237	0.051							0.809	0.220	0.811	0.085	0.658	0.148
5/8/2008	0.031	0.062	0.063	0.086			0.042	0.064	0.072	0.140	0.226	0.048							0.815	0.213	0.811	0.085	0.658	0.148
5/9/2008	0.030	0.061	0.060	0.081			0.041	0.063	0.069	0.126	0.218	0.049							0.816	0.213	0.811	0.086	0.658	0.149
5/10/2008	0.030	0.060	0.058	0.076			0.042	0.064	0.068	0.116	0.215	0.052							0.827	0.203	0.810	0.088	0.656	0.152
5/11/2008	0.030	0.059	0.055	0.072			0.043	0.065	0.067	0.113	0.208	0.046							0.826	0.204	0.810	0.089	0.655	0.152
5/12/2008	0.030	0.060	0.051	0.067			0.043	0.064	0.065	0.107	0.202	0.042							0.822	0.201	0.809	0.091	0.652	0.153
5/13/2008	0.029	0.059	0.047	0.063			0.041	0.063	0.064	0.103	0.196	0.041							0.823	0.199	0.809	0.093	0.657	0.150
5/14/2008	0.028	0.058	0.045	0.061			0.040	0.062	0.062	0.097	0.191	0.040							0.827	0.193	0.809	0.095	0.652	0.152
5/15/2008	0.028	0.059	0.042	0.058			0.039	0.060	0.061	0.092	0.187	0.043							0.825	0.195	0.809	0.096	0.655	0.151
5/16/2008	0.028	0.057	0.039	0.054			0.037	0.059	0.059	0.088	0.183	0.046							0.832	0.188	0.809	0.098	0.657	0.149
5/17/2008	0.027	0.056	0.036	0.051			0.036	0.058	0.058	0.086	0.180	0.049							0.833	0.189	0.809	0.102	0.655	0.149
5/18/2008	0.027	0.057	0.034	0.050			0.034	0.057	0.057	0.083	0.177	0.053							0.830	0.194	0.809	0.103	0.650	0.150
5/19/2008	0.027	0.056	0.033	0.049			0.033	0.056	0.056	0.080	0.174	0.056							0.828	0.199	0.808	0.104	0.649	0.149
5/20/2008	0.042	0.134	0.060	0.035			0.037	0.062	0.055	0.077	0.172	0.066							0.829	0.200	0.807	0.106	0.647	0.151
5/21/2008	0.068	0.137	0.096	0.471			0.066	0.098	0.076	0.176	0.179	0.051							0.828	0.205	0.809	0.103	0.652	0.151
5/22/2008	0.068	0.163	0.112	0.242			0.078	0.228	0.101	0.147	0.210	0.048							0.829	0.208	0.808	0.103	0.655	0.152
5/23/2008	0.068	0.139	0.113	0.000			0.085	0.248	0.143	0.000	0.289	0.048							0.840	0.202	0.809	0.100	0.654	0.155

Table A-1. Continued.

	T1-60 (25 cm)		T1-60 (35 cm)		T1-60 (55 cm)		T1-50 (30 cm)		T1-50 (50 cm)		T1-50 (95 cm)		T1-30 (25 cm)		T1-30 (50 cm)		T1-30 (80 cm)		T1-1 (25 cm)		T1-1 (50 cm)		T1-1 (72 cm)	
Date	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w
5/24/2008	0.070	0.150	0.108	0.000			0.083	0.212	0.138	0.000	0.291	0.047							0.843	0.200	0.811	0.094	0.652	0.156
5/25/2008	0.069	0.146	0.111	0.000			0.082	0.201	0.136	0.000	0.295	0.045							0.839	0.209	0.811	0.093	0.655	0.155
5/26/2008	0.062	0.114	0.107	0.000			0.079	0.167	0.131	0.000	0.298	0.042							0.837	0.211	0.810	0.095	0.653	0.155
5/27/2008	0.058	0.101	0.102	0.000			0.076	0.148	0.125	0.000	0.295	0.041							0.837	0.214	0.810	0.096	0.649	0.156
5/28/2008	0.055	0.094	0.098	0.000			0.074	0.136	0.120	0.000	0.292	0.040							0.835	0.217	0.810	0.098	0.649	0.156
5/29/2008	0.052	0.087	0.095	1.583			0.072	0.124	0.115	0.000	0.292	0.041	0.669	0.026	0.777	0.072	0.752	0.084	0.840	0.213	0.810	0.101	0.649	0.156
5/30/2008	0.049	0.082	0.092	1.151			0.070	0.117	0.109	0.000	0.293	0.041	0.658	0.023	0.776	0.068	0.751	0.084						
5/31/2008	0.047	0.078	0.089	0.571			0.068	0.105	0.104	0.000	0.293	0.041	0.641	0.016	0.776	0.067	0.750	0.085						
6/1/2008	0.045	0.075	0.086	0.316			0.064	0.094	0.098	0.898	0.291	0.041	0.633	0.012	0.775	0.066	0.750	0.085						
6/2/2008	0.044	0.073	0.084	0.245			0.062	0.088	0.093	3.863	0.288	0.040	0.629	0.012	0.773	0.067	0.749	0.086						
6/3/2008	0.042	0.071	0.082	0.212			0.061	0.086	0.091	0.951	0.286	0.046	0.646	0.021	0.778	0.062	0.748	0.086						
6/4/2008	0.044	0.074	0.082	0.200			0.060	0.083	0.092	1.329	0.286	0.049	0.657	0.026	0.778	0.056	0.746	0.087						
6/5/2008	0.044	0.074	0.080	0.179			0.058	0.082	0.091	0.893	0.285	0.048	0.641	0.020	0.777	0.050	0.747	0.087						
6/6/2008	0.044	0.075	0.078	0.156			0.056	0.077	0.089	0.564	0.282	0.047	0.631	0.015	0.772	0.050	0.746	0.088						
6/7/2008	0.043	0.074	0.076	0.131			0.053	0.073	0.085	0.361	0.273	0.044	0.624	0.013	0.762	0.054	0.747	0.088						
6/8/2008	0.043	0.073	0.072	0.111			0.050	0.070	0.082	0.272	0.263	0.042	0.620	0.011	0.756	0.052	0.747	0.088						
6/9/2008	0.042	0.072	0.069	0.094			0.048	0.067	0.080	0.221	0.253	0.041	0.616	0.009	0.747	0.049	0.746	0.088						
6/10/2008	0.041	0.071	0.066	0.082			0.047	0.066	0.077	0.186	0.245	0.041	0.615	0.009	0.745	0.048	0.747	0.089						
6/11/2008	0.040	0.069	0.064	0.079			0.047	0.065	0.075	0.166	0.241	0.044	0.621	0.016	0.776	0.044	0.746	0.089						
6/12/2008	0.040	0.068	0.064	0.078			0.048	0.066	0.075	0.163	0.240	0.045	0.623	0.017	0.776	0.038	0.745	0.089						
6/13/2008	0.044	0.075	0.063	0.074			0.048	0.067	0.076	0.173	0.241	0.046	0.665	0.027	0.777	0.038	0.745	0.089						
6/14/2008	0.071	0.194	0.094	0.029			0.060	0.092	0.101	0.168	0.270	0.046	0.713	0.031	0.777	0.036	0.744	0.090						
6/15/2008	0.066	0.135	0.102	0.000			0.077	0.142	0.131	0.000	0.295	0.043	0.731	0.027	0.777	0.029	0.744	0.091						
6/16/2008	0.062	0.116	0.098	0.000			0.076	0.129	0.126	0.000	0.298	0.039	0.731	0.026	0.778	0.028	0.743	0.091						
6/17/2008	0.066	0.132	0.098	0.000			0.077	0.130	0.124	0.000	0.301	0.038	0.731	0.027	0.776	0.027	0.742	0.092						
6/18/2008	0.064	0.121	0.097	0.000			0.076	0.129	0.122	0.000	0.303	0.040	0.730	0.029	0.778	0.031	0.744	0.091						
6/19/2008	0.066	0.130	0.097	0.000			0.076	0.124	0.123	0.000	0.305	0.041	0.730	0.030	0.777	0.023	0.743	0.092						
6/20/2008	0.064	0.122	0.096	1.726			0.076	0.122	0.121	0.000	0.307	0.040	0.731	0.032	0.777	0.025	0.744	0.092						
6/21/2008	0.072	0.239	0.103	0.000			0.077	0.139	0.127	0.000	0.310	0.042	0.731	0.035	0.777	0.025	0.745	0.092						
6/22/2008	0.075	0.196	0.120	0.000			0.087	0.243	0.175	0.000	0.315	0.042	0.731	0.036	0.777	0.026	0.744	0.092						
6/23/2008	0.068	0.144	0.115	0.000			0.085	0.192	0.182	0.000	0.319	0.043	0.730	0.037	0.778	0.027	0.746	0.092						
6/24/2008	0.068	0.141	0.112	0.000			0.083	0.174	0.176	0.000	0.322	0.043	0.732	0.033	0.776	0.021	0.744	0.092						
6/25/2008	0.066	0.132	0.109	0.000			0.082	0.162	0.173	0.000	0.325	0.044	0.731	0.031	0.774	0.010	0.741	0.092						
6/26/2008	0.068	0.202	0.109	0.000			0.082	0.162	0.173	0.000	0.328	0.045	0.732	0.031	0.776	0.016	0.742	0.091						
6/27/2008	0.077	0.227	0.124	0.000			0.089	0.317	0.218	0.000	0.331	0.046	0.731	0.033	0.775	0.010	0.742	0.092						
6/28/2008	0.070	0.158	0.120	0.000			0.090	0.365	0.231	0.000	0.332	0.047	0.730	0.035	0.774	0.008	0.745	0.091						
6/29/2008	0.067	0.139	0.116	0.000			0.089	0.345	0.225	0.000	0.332	0.048	0.730	0.036	0.775	0.008	0.743	0.092						
6/30/2008	0.064	0.126	0.112	0.000			0.086	0.232	0.206	0.000	0.332	0.046	0.732	0.037	0.776	0.010	0.741	0.092						
7/1/2008	0.064	0.132	0.101	0.313	0.281	0.010	0.086	0.240	0.206	0.000	0.332	0.046	0.731	0.042	0.778	0.022	0.745	0.091	0.832	0.268	0.807	0.135	0.658	0.159
7/2/2008	0.077	0.217	0.101	0.000	0.363	0.010	0.094	1.282	0.251	0.000	0.333	0.047	0.731	0.038	0.778	0.017	0.743	0.091	0.828	0.273	0.806	0.138	0.653	0.162
7/3/2008	0.084	0.109	0.140	0.000	0.371	0.008	0.111	0.000	0.318	0.000	0.334	0.048	0.732	0.039	0.778	0.017	0.742	0.091	0.826	0.277	0.806	0.140	0.653	0.161
7/4/2008	0.090	1.705	0.201	0.000	0.374	0.009	0.135	0.000	0.369	0.000	0.334	0.047	0.732	0.037	0.778	0.014	0.742	0.091	0.829	0.273	0.807	0.138	0.658	0.159
7/5/2008	0.081	0.281	0.175	0.000	0.374	0.008	0.126	0.000	0.373	0.000	0.333	0.048	0.733	0.035	0.777	0.007	0.742	0.091	0.829	0.272	0.807	0.137	0.662	0.157
7/6/2008	0.076	0.199	0.159	0.000	0.374	0.007	0.124	0.000	0.376	0.000	0.332	0.048	0.732	0.037	0.777	0.007	0.741	0.092	0.829	0.272	0.808	0.138	0.662	0.157
7/7/2008	0.072	0.168	0.149	0.000	0.373	0.007	0.120	0.000	0.380	0.000	0.331	0.049	0.733	0.038	0.777	0.005	0.742	0.092	0.832	0.268	0.808	0.137	0.662	0.157
7/8/2008	0.070	0.152	0.138	0.000	0.372	0.006	0.113	0.000	0.383	0.000	0.330	0.051	0.733	0.038	0.775	0.004	0.742	0.092	0.834	0.267	0.809	0.137	0.654	0.160
7/9/2008	0.067	0.138	0.131	0.000	0.371	0.005	0.111	0.000	0.386	0.000	0.330	0.051	0.733	0.041	0.775	0.003	0.738	0.093	0.835	0.264	0.809	0.136	0.651	0.161
7/10/2008	0.065	0.126	0.126	0.000	0.370	0.005	0.110	0.000	0.390	0.000	0.329	0.052	0.733	0.046	0.775	0.003	0.739	0.093	0.838	0.262	0.808	0.137	0.651	0.161
7/11/2008	0.063	0.119	0.123	0.000	0.368	0.005	0.109	0.000	0.395	0.000	0.330	0.057	0.734	0.050	0.777	0.005	0.743	0.092	0.838	0.262	0.808	0.137	0.653	0.160
7/12/2008	0.062	0.115	0.117	0.000	0.367	0.006	0.100	0.000	0.387	0.000	0.329	0.061	0.736	0.046	0.780	0.014	0.743	0.092	0.828	0.271	0.809	0.131	0.654	0.163

Table A-1. Continued.

	T1-60 (25 cm)		T1-60 (35 cm)		T1-60 (55 cm)		T1-50 (30 cm)		T1-50 (50 cm)		T1-50 (95 cm)		T1-30 (25 cm)		T1-30 (50 cm)		T1-30 (80 cm)		T1-1 (25 cm)		T1-1 (50 cm)		T1-1 (72 cm)	
Date	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w
7/13/2008	0.061	0.111	0.113	0.000	0.365	0.005	0.094	2.893	0.318	0.000	0.328	0.061	0.737	0.045	0.783	0.023	0.743	0.092	0.837	0.256	0.810	0.119	0.656	0.163
7/14/2008	0.066	0.134	0.115	0.000	0.364	0.004	0.093	1.252	0.283	0.000	0.328	0.063	0.736	0.041	0.780	0.014	0.742	0.093	0.849	0.237	0.810	0.117	0.656	0.163
7/15/2008	0.066	0.130	0.110	0.000	0.364	0.005	0.090	0.524	0.247	0.000	0.327	0.062	0.736	0.040	0.780	0.014	0.739	0.093	0.851	0.233	0.809	0.118	0.651	0.166
7/16/2008	0.065	0.127	0.107	0.000	0.363	0.005	0.088	0.355	0.215	0.000	0.327	0.060	0.737	0.041	0.779	0.016	0.740	0.093	0.851	0.231	0.808	0.115	0.651	0.166
7/17/2008	0.063	0.120	0.105	0.000	0.361	0.006	0.087	0.285	0.198	0.000	0.326	0.058	0.739	0.043	0.779	0.016	0.744	0.093	0.854	0.225	0.809	0.114	0.661	0.162
7/18/2008	0.065	0.127	0.105	0.000	0.360	0.006	0.087	0.297	0.199	0.000	0.327	0.062	0.739	0.040	0.778	0.011	0.744	0.093	0.856	0.222	0.809	0.112	0.651	0.165
7/19/2008	0.066	0.133	0.103	0.000	0.359	0.006	0.086	0.251	0.191	0.000	0.326	0.062	0.739	0.042	0.778	0.011	0.745	0.092	0.857	0.221	0.810	0.114	0.649	0.166
7/20/2008	0.064	0.123	0.100	0.000	0.359	0.002	0.084	0.218	0.177	0.000	0.326	0.060	0.740	0.041	0.778	0.011	0.744	0.093	0.858	0.220	0.810	0.114	0.647	0.167
7/21/2008	0.061	0.114	0.097	0.110	0.357	0.002	0.082	0.183	0.162	0.000	0.325	0.058	0.736	0.044	0.779	0.014	0.746	0.093	0.855	0.223	0.810	0.113	0.650	0.166
7/22/2008	0.059	0.106	0.095	2.436	0.357	0.002	0.080	0.162	0.150	0.000	0.325	0.056	0.713	0.044	0.780	0.014	0.746	0.095	0.851	0.224	0.810	0.112	0.652	0.164
7/23/2008	0.058	0.102	0.093	1.949	0.346	0.004	0.078	0.154	0.142	0.000	0.325	0.056	0.699	0.043	0.782	0.020	0.747	0.094	0.852	0.217	0.810	0.113	0.653	0.164
7/24/2008	0.057	0.100	0.094	5.428	0.299	0.003	0.078	0.154	0.162	0.000	0.324	0.049	0.727	0.043	0.780	0.017	0.749	0.094	0.857	0.209	0.811	0.112	0.661	0.162
7/25/2008	0.056	0.097	0.095	5.965	0.298	0.002	0.083	0.193	0.185	0.000	0.327	0.049	0.727	0.044	0.779	0.010	0.748	0.094	0.854	0.216	0.811	0.113	0.658	0.162
7/26/2008	0.055	0.094	0.094	3.525	0.295	0.001	0.082	0.188	0.176	0.000	0.326	0.051	0.729	0.042	0.777	0.007	0.749	0.093	0.854	0.218	0.814	0.112	0.655	0.163
7/27/2008	0.053	0.091	0.093	4.132	0.290	0.001	0.081	0.178	0.170	0.000	0.326	0.051	0.728	0.048	0.779	0.019	0.748	0.092	0.852	0.222	0.814	0.112	0.657	0.162
7/28/2008	0.055	0.095	0.095	2.772	0.291	0.001	0.082	0.189	0.177	0.000	0.325	0.051	0.727	0.057	0.785	0.053	0.750	0.092	0.854	0.222	0.812	0.115	0.655	0.162
7/29/2008	0.058	0.103	0.095	2.555	0.292	0.001	0.083	0.207	0.183	0.000	0.326	0.051	0.728	0.057	0.784	0.054	0.751	0.091	0.856	0.220	0.811	0.116	0.655	0.162
7/30/2008	0.058	0.102	0.094	2.115	0.289	0.002	0.082	0.190	0.171	0.000	0.325	0.052	0.728	0.057	0.784	0.055	0.750	0.091	0.854	0.222	0.812	0.114	0.656	0.162
7/31/2008	0.057	0.099	0.092	1.418	0.283	0.003	0.080	0.168	0.163	0.000	0.324	0.050	0.729	0.055	0.784	0.057	0.751	0.090	0.852	0.225	0.811	0.116	0.659	0.161
8/1/2008	0.056	0.096	0.091	0.816	0.279	0.003	0.079	0.158	0.158	0.000	0.324	0.050	0.729	0.053	0.784	0.052	0.749	0.091	0.850	0.227	0.810	0.117	0.662	0.159
8/2/2008	0.057	0.098	0.090	0.618	0.273	0.005	0.079	0.153	0.154	0.000	0.324	0.050	0.729	0.051	0.783	0.048	0.750	0.090	0.849	0.227	0.811	0.116	0.657	0.161
8/3/2008	0.056	0.096	0.089	0.502	0.267	0.009	0.078	0.146	0.153	0.000	0.323	0.049	0.729	0.053	0.784	0.051	0.750	0.090	0.848	0.230	0.813	0.113	0.659	0.159
8/4/2008	0.056	0.096	0.088	0.490	0.264	0.011	0.078	0.147	0.161	0.000	0.324	0.048	0.729	0.054	0.784	0.050	0.750	0.090	0.848	0.232	0.812	0.114	0.658	0.159
8/5/2008	0.074	0.175	0.092	1.319	0.268	0.009	0.081	0.176	0.178	0.000	0.325	0.048	0.729	0.055	0.784	0.043	0.750	0.090	0.849	0.231	0.813	0.112	0.655	0.161
8/6/2008	0.071	0.154	0.093	3.067	0.269	0.006	0.083	0.192	0.177	0.000	0.325	0.050	0.729	0.055	0.783	0.038	0.751	0.090	0.848	0.235	0.812	0.113	0.651	0.162
8/7/2008	0.068	0.133	0.092	1.725	0.268	0.004	0.082	0.186	0.174	0.000	0.324	0.051	0.728	0.057	0.782	0.032	0.748	0.090	0.845	0.240	0.811	0.114	0.652	0.161
8/8/2008	0.065	0.121	0.090	0.732	0.264	0.004	0.081	0.177	0.168	0.000	0.324	0.051	0.729	0.059	0.783	0.038	0.749	0.090	0.845	0.242	0.811	0.113	0.654	0.160
8/9/2008	0.062	0.110	0.089	0.554	0.260	0.003	0.081	0.174	0.163	0.000	0.323	0.051	0.729	0.053	0.782	0.034	0.747	0.090	0.846	0.241	0.812	0.110	0.656	0.159
8/10/2008	0.060	0.103	0.088	0.442	0.256	0.002	0.081	0.173	0.169	0.000	0.324	0.053	0.730	0.053	0.782	0.032	0.749	0.090	0.854	0.230	0.813	0.109	0.657	0.158
8/11/2008	0.059	0.102	0.087	0.416	0.252	0.002	0.080	0.165	0.158	0.000	0.323	0.054	0.731	0.050	0.782	0.032	0.750	0.090	0.853	0.229	0.812	0.107	0.654	0.161
8/12/2008	0.059	0.101	0.085	0.315	0.245	0.001	0.079	0.153	0.147	0.000	0.320	0.051	0.731	0.051	0.782	0.036	0.750	0.090	0.856	0.224	0.811	0.104	0.655	0.160
8/13/2008	0.060	0.103	0.084	0.280	0.240	0.000	0.077	0.141	0.146	0.000	0.320	0.051	0.732	0.048	0.781	0.031	0.751	0.090	0.858	0.219	0.812	0.103	0.657	0.158
8/14/2008	0.061	0.105	0.082	0.238	0.233	0.000	0.076	0.132	0.141	0.000	0.319	0.051	0.732	0.049	0.781	0.027	0.748	0.090	0.859	0.218	0.813	0.101	0.655	0.158
8/15/2008	0.059	0.100	0.081	0.214	0.226	0.000	0.074	0.125	0.140	0.000	0.318	0.051	0.732	0.049	0.781	0.029	0.751	0.089	0.859	0.219	0.813	0.100	0.655	0.157
8/16/2008	0.057	0.095	0.079	0.190	0.219	0.000	0.073	0.120	0.138	0.000	0.319	0.052	0.732	0.049	0.781	0.029	0.751	0.089	0.858	0.220	0.813	0.099	0.658	0.154
8/17/2008	0.055	0.090	0.078	0.178	0.213	0.000	0.073	0.117	0.144	0.000	0.321	0.053	0.733	0.049	0.781	0.024	0.751	0.089	0.857	0.222	0.812	0.098	0.659	0.154
8/18/2008	0.059	0.108	0.078	0.177	0.206	0.000	0.074	0.123	0.143	0.000	0.321	0.055	0.734	0.046	0.783	0.031	0.749	0.089	0.853	0.226	0.811	0.099	0.657	0.154
8/19/2008	0.127	0.000	0.303	0.047	0.306	0.005	0.278	0.060	0.283	0.000	0.337	0.053	0.733	0.045	0.781	0.026	0.750	0.088	0.857	0.222	0.812	0.096	0.659	0.154
8/20/2008	0.129	0.000	0.482	0.000	0.374	0.010	0.540	0.003	0.358	0.003	0.341	0.051	0.735	0.046	0.781	0.024	0.751	0.088	0.861	0.219	0.813	0.094	0.656	0.155
8/21/2008	0.122	0.000	0.490	0.000	0.382	0.011	0.557	0.003	0.365	0.002	0.340	0.050	0.737	0.044	0.780	0.016	0.752	0.087	0.859	0.222	0.815	0.092	0.663	0.151
8/22/2008	0.100	2.022	0.496	0.000	0.386	0.013	0.397	0.001	0.370	0.001	0.338	0.052	0.737	0.046	0.779	0.016	0.754	0.087	0.856	0.228	0.814	0.093	0.657	0.152
8/23/2008	0.088	0.657	0.364	0.000	0.391	0.011	0.231	0.000	0.374	0.001	0.336	0.048	0.738	0.047	0.779	0.014	0.755	0.086	0.862	0.223	0.812	0.093	0.656	0.152
8/24/2008	0.082	0.290	0.278	0.000	0.395	0.011	0.190	0.000	0.378	0.000	0.335	0.048	0.738	0.047	0.778	0.014	0.755	0.086	0.861	0.228	0.812	0.093	0.651	0.153
8/25/2008	0.078	0.221	0.240	0.000	0.398	0.010	0.161	0.000	0.382	0.002	0.335	0.048	0.739	0.045	0.778	0.011	0.751	0.086	0.853	0.240	0.811	0.094	0.647	0.154
8/26/2008	0.075	0.194	0.219	0.000	0.400	0.007	0.157	0.000	0.388	0.004	0.334	0.048	0.739	0.045	0.774	0.007	0.750	0.086	0.859	0.235	0.811	0.093	0.648	0.153
8/27/2008	0.080	1.622	0.219	0.000	0.400	0.006	0.174	0.000	0.394	0.004	0.335	0.050	0.739	0.047	0.776	0.007	0.752	0.086	0.863	0.233	0.811	0.093	0.649	0.152
8/28/2008	0.087	0.479	0.234	0.000	0.401	0.006	0.183	0.000	0.397	0.003	0.335	0.048	0.741	0.044	0.775	0.006	0.752	0.086	0.861	0.238	0.812	0.091	0.657	0.148

Table A-2. Mean daily soil moisture (θ) and porewater salinity (σ_w) for measurement locations on Transect 7.

	T7-145 (20 cm)		T7-145 (40 cm)		T7-145 (67 cm)		T7-90 (23 cm)		T7-90 (40 cm)		T7-90 (66 cm)		T7-25 (23 cm)		T7-25 (46 cm)		T7-25 (66 cm)		T7-2 (16 cm)		T7-2 (32 cm)		T7-2 (48 cm)	
Date	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w
1/27/2005	0.902	0.030	0.882	0.007	0.796	0.000	0.812	0.094	0.916	0.126	0.805	0.116												
1/28/2005	0.902	0.031	0.882	0.008	0.797	0.000	0.812	0.094	0.912	0.126	0.807	0.115												
1/29/2005	0.901	0.031	0.881	0.007	0.797	0.000	0.811	0.094	0.904	0.125	0.806	0.115												
1/30/2005	0.898	0.032	0.881	0.007	0.797	0.000	0.810	0.094	0.896	0.124	0.806	0.114												
1/31/2005	0.900	0.032	0.882	0.007	0.797	0.000	0.808	0.094	0.891	0.122	0.806	0.114												
2/1/2005	0.900	0.032	0.882	0.007	0.797	0.000	0.808	0.093	0.884	0.121	0.806	0.114												
2/2/2005	0.900	0.032	0.881	0.007	0.797	0.000	0.808	0.092	0.881	0.120	0.806	0.113												
2/3/2005	0.896	0.033	0.881	0.007	0.797	0.000	0.807	0.092	0.878	0.118	0.806	0.113												
2/4/2005	0.898	0.033	0.881	0.006	0.797	0.000	0.805	0.093	0.871	0.118	0.805	0.113												
2/5/2005	0.897	0.033	0.879	0.006	0.796	0.000	0.805	0.092	0.867	0.117	0.806	0.113												
2/6/2005	0.896	0.033	0.879	0.005	0.796	0.000	0.806	0.091	0.867	0.116	0.805	0.113												
2/7/2005	0.895	0.034	0.878	0.005	0.796	0.000	0.803	0.091	0.865	0.116	0.805	0.113												
2/8/2005	0.892	0.038	0.878	0.005	0.796	0.000	0.804	0.090	0.867	0.116	0.806	0.113												
2/9/2005	0.887	0.043	0.877	0.004	0.796	0.000	0.803	0.090	0.868	0.115	0.806	0.113												
2/10/2005	0.883	0.049	0.875	0.005	0.796	0.000	0.802	0.090	0.867	0.114	0.806	0.113												
2/11/2005	0.882	0.055	0.875	0.006	0.796	0.000	0.802	0.089	0.865	0.114	0.805	0.113												
2/12/2005	0.883	0.057	0.875	0.007	0.796	0.000	0.802	0.089	0.865	0.114	0.806	0.112												
2/13/2005	0.884	0.059	0.877	0.007	0.796	0.000	0.803	0.089	0.867	0.113	0.805	0.112												
2/14/2005	0.886	0.059	0.876	0.008	0.796	0.000	0.804	0.089	0.868	0.112	0.806	0.112												
2/15/2005	0.881	0.061	0.876	0.009	0.797	0.000	0.803	0.090	0.867	0.112	0.806	0.112												
2/16/2005	0.880	0.060	0.875	0.010	0.797	0.000	0.800	0.092	0.866	0.111	0.805	0.112												
2/17/2005	0.877	0.058	0.874	0.009	0.797	0.000	0.799	0.092	0.866	0.111	0.805	0.111												
2/18/2005	0.874	0.059	0.873	0.009	0.797	0.000	0.799	0.094	0.868	0.111	0.806	0.111												
2/19/2005	0.875	0.059	0.872	0.009	0.797	0.000	0.798	0.095	0.865	0.111	0.806	0.111												
2/20/2005	0.874	0.063	0.871	0.010	0.797	0.000	0.798	0.096	0.866	0.111	0.806	0.112												
2/21/2005	0.873	0.063	0.870	0.010	0.797	0.000	0.797	0.097	0.865	0.111	0.805	0.112												
2/22/2005	0.872	0.062	0.869	0.010	0.797	0.000	0.797	0.097	0.866	0.110	0.805	0.112												
2/23/2005	0.872	0.061	0.868	0.011	0.797	0.000	0.795	0.098	0.866	0.110	0.804	0.112												
2/24/2005	0.871	0.059	0.868	0.010	0.797	0.000	0.795	0.099	0.864	0.111	0.805	0.112												
2/25/2005	0.871	0.059	0.867	0.010	0.797	0.000	0.794	0.100	0.865	0.111	0.806	0.112												
2/26/2005	0.870	0.064	0.865	0.011	0.797	0.000	0.795	0.101	0.864	0.110	0.806	0.112												
2/27/2005	0.869	0.065	0.866	0.011	0.796	0.000	0.793	0.102	0.865	0.110	0.807	0.112												
2/28/2005	0.868	0.065	0.865	0.012	0.796	0.000	0.791	0.104	0.863	0.110	0.806	0.112												
3/1/2005	0.867	0.063	0.864	0.013	0.797	0.000	0.793	0.104	0.864	0.110	0.804	0.113												
3/2/2005	0.872	0.061	0.864	0.014	0.797	0.000	0.792	0.105	0.864	0.110	0.805	0.114												
3/3/2005	0.878	0.061	0.865	0.015	0.796	0.000	0.793	0.105	0.864	0.109	0.804	0.114												
3/4/2005	0.882	0.061	0.866	0.016	0.796	0.000	0.794	0.106	0.865	0.109	0.805	0.114												
3/5/2005	0.882	0.060	0.867	0.017	0.796	0.000	0.794	0.106	0.867	0.109	0.804	0.114												
3/6/2005	0.883	0.060	0.866	0.017	0.797	0.000	0.795	0.107	0.865	0.108	0.805	0.114												
3/7/2005	0.884	0.060	0.867	0.018	0.797	0.000	0.795	0.108	0.864	0.109	0.806	0.113												
3/8/2005	0.884	0.059	0.866	0.018	0.796	0.000	0.794	0.110	0.865	0.108	0.806	0.113												
3/9/2005	0.887	0.057	0.867	0.019	0.796	0.000	0.796	0.111	0.866	0.108	0.805	0.113												
3/10/2005	0.890	0.055	0.866	0.019	0.796	0.000	0.796	0.111	0.866	0.108	0.805	0.113												
3/11/2005	0.892	0.050	0.866	0.020	0.797	0.000	0.796	0.112	0.865	0.108	0.805	0.113												
3/12/2005	0.891	0.045	0.867	0.021	0.797	0.000	0.797	0.113	0.867	0.107	0.804	0.113												
3/13/2005	0.892	0.047	0.867	0.021	0.797	0.000	0.797	0.114	0.863	0.108	0.806	0.111												
3/14/2005	0.889	0.049	0.867	0.022	0.797	0.000	0.797	0.114	0.867	0.107	0.806	0.111												
3/15/2005	0.889	0.048	0.866	0.023	0.797	0.000	0.797	0.115	0.865	0.107	0.805	0.111												
3/16/2005	0.886	0.046	0.864	0.023	0.797	0.000	0.795	0.116	0.863	0.107	0.804	0.112												
3/17/2005	0.886	0.045	0.864	0.023	0.796	0.000	0.796	0.118	0.863	0.109	0.805	0.112												

Table A-2. Continued.

	T7-145 (20 cm)		T7-145 (40 cm)		T7-145 (67 cm)		T7-90 (23 cm)		T7-90 (40 cm)		T7-90 (66 cm)		T7-25 (23 cm)		T7-25 (46 cm)		T7-25 (66 cm)		T7-2 (16 cm)		T7-2 (32 cm)		T7-2 (48 cm)	
Date	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w
3/18/2005	0.890	0.043	0.864	0.024	0.796	0.000	0.797	0.118	0.863	0.109	0.806	0.111												
3/19/2005	0.892	0.040	0.864	0.023	0.796	0.000	0.798	0.118	0.861	0.109	0.805	0.112												
3/20/2005	0.894	0.038	0.864	0.023	0.796	0.000	0.799	0.117	0.861	0.108	0.805	0.111												
3/21/2005	0.894	0.038	0.865	0.023	0.796	0.000	0.799	0.119	0.864	0.109	0.805	0.111												
3/22/2005	0.893	0.037	0.865	0.023	0.796	0.000	0.800	0.118	0.863	0.109	0.806	0.110												
3/23/2005	0.891	0.034	0.864	0.023	0.796	0.000	0.799	0.119	0.861	0.108	0.805	0.110												
3/24/2005	0.890	0.033	0.863	0.022	0.796	0.000	0.797	0.120	0.863	0.109	0.805	0.110												
3/25/2005	0.891	0.033	0.863	0.021	0.796	0.000	0.798	0.120	0.861	0.109	0.805	0.110												
3/26/2005	0.891	0.031	0.863	0.021	0.796	0.000	0.799	0.120	0.862	0.109	0.805	0.109												
3/27/2005	0.889	0.030	0.861	0.020	0.796	0.000	0.800	0.120	0.861	0.110	0.802	0.110												
3/28/2005	0.888	0.029	0.861	0.020	0.796	0.000	0.798	0.121	0.859	0.110	0.803	0.110												
3/29/2005	0.891	0.028	0.861	0.019	0.795	0.000	0.799	0.121	0.859	0.111	0.804	0.110												
3/30/2005	0.893	0.028	0.861	0.019	0.795	0.000	0.799	0.121	0.857	0.111	0.803	0.110												
3/31/2005	0.893	0.028	0.862	0.018	0.796	0.000	0.801	0.120	0.859	0.111	0.804	0.109												
4/1/2005	0.891	0.027	0.862	0.017	0.796	0.000	0.802	0.120	0.858	0.111	0.803	0.108												
4/2/2005	0.892	0.027	0.861	0.017	0.796	0.000	0.802	0.120	0.860	0.111	0.804	0.108												
4/3/2005	0.894	0.027	0.861	0.016	0.796	0.000	0.803	0.120	0.860	0.111	0.803	0.109												
4/4/2005	0.897	0.027	0.863	0.015	0.796	0.000	0.804	0.119	0.858	0.111	0.803	0.109												
4/5/2005	0.897	0.027	0.864	0.015	0.796	0.000	0.805	0.119	0.859	0.110	0.804	0.108												
4/6/2005	0.895	0.027	0.864	0.014	0.795	0.000	0.806	0.118	0.858	0.110	0.804	0.108												
4/7/2005	0.894	0.027	0.864	0.014	0.795	0.000	0.805	0.119	0.859	0.110	0.804	0.107												
4/8/2005	0.895	0.028	0.865	0.013	0.795	0.000	0.804	0.119	0.859	0.111	0.804	0.107												
4/9/2005	0.894	0.027	0.863	0.012	0.796	0.000	0.804	0.119	0.860	0.111	0.804	0.107												
4/10/2005	0.895	0.027	0.864	0.012	0.796	0.000	0.804	0.118	0.860	0.110	0.804	0.106												
4/11/2005	0.895	0.027	0.863	0.011	0.795	0.000	0.805	0.117	0.860	0.110	0.804	0.106												
4/12/2005	0.895	0.027	0.863	0.011	0.795	0.000	0.804	0.117	0.858	0.110	0.804	0.106												
4/13/2005	0.893	0.027	0.863	0.011	0.795	0.000	0.804	0.117	0.857	0.110	0.804	0.105												
4/14/2005	0.895	0.027	0.863	0.010	0.796	0.000	0.805	0.116	0.858	0.110	0.804	0.105												
4/15/2005	0.895	0.028	0.864	0.010	0.795	0.000	0.804	0.116	0.860	0.110	0.805	0.104												
4/16/2005	0.896	0.028	0.865	0.009	0.795	0.000	0.805	0.115	0.861	0.110	0.804	0.104												
4/17/2005	0.897	0.029	0.865	0.009	0.795	0.000	0.807	0.114	0.860	0.110	0.805	0.104												
4/18/2005	0.897	0.029	0.866	0.008	0.795	0.000	0.806	0.113	0.859	0.110	0.804	0.104												
4/19/2005	0.897	0.029	0.867	0.008	0.796	0.000	0.806	0.112	0.858	0.109	0.804	0.105												
4/20/2005	0.897	0.030	0.866	0.008	0.796	0.000	0.806	0.112	0.858	0.109	0.804	0.104												
4/21/2005	0.897	0.031	0.867	0.009	0.796	0.000	0.806	0.111	0.858	0.109	0.805	0.104												
4/22/2005	0.898	0.032	0.867	0.009	0.796	0.000	0.806	0.111	0.858	0.109	0.806	0.103												
4/23/2005	0.896	0.033	0.867	0.009	0.795	0.000	0.807	0.110	0.861	0.108	0.806	0.102												
4/24/2005	0.895	0.033	0.868	0.009	0.795	0.000	0.807	0.109	0.860	0.109	0.806	0.102												
4/25/2005	0.899	0.033	0.868	0.009	0.796	0.000	0.807	0.109	0.860	0.108	0.806	0.102												
4/26/2005	0.898	0.034	0.868	0.010	0.795	0.000	0.807	0.108	0.859	0.108	0.806	0.101												
4/27/2005	0.897	0.034	0.868	0.010	0.796	0.000	0.808	0.108	0.860	0.107	0.806	0.101												
4/28/2005	0.895	0.034	0.869	0.010	0.796	0.000	0.806	0.108	0.858	0.107	0.806	0.100												
4/29/2005	0.896	0.034	0.868	0.010	0.796	0.000	0.806	0.107	0.859	0.106	0.806	0.099												
4/30/2005	0.895	0.035	0.868	0.010	0.795	0.000	0.806	0.106	0.858	0.106	0.806	0.099												
5/1/2005	0.893	0.036	0.868	0.010	0.796	0.000	0.805	0.106	0.859	0.106	0.804	0.099												
5/2/2005	0.892	0.036	0.868	0.010	0.795	0.000	0.805	0.106	0.857	0.106	0.804	0.100												
5/3/2005	0.893	0.038	0.867	0.010	0.795	0.000	0.805	0.106	0.857	0.106	0.804	0.100												
5/4/2005	0.893	0.038	0.867	0.010	0.795	0.000	0.804	0.105	0.860	0.105	0.804	0.099												
5/5/2005	0.894	0.037	0.867	0.010	0.794	0.000	0.806	0.104	0.856	0.106	0.805	0.099												
5/6/2005	0.894	0.035	0.866	0.010	0.795	0.000	0.807	0.103	0.857	0.106	0.805	0.099	0.759	0.107	0.796	0.115	0.806	0.088	0.758	0.118	0.755	0.095	0.751	0.126

Table A-2. Continued.

	T7-145 (20 cm)		T7-145 (40 cm)		T7-145 (67 cm)		T7-90 (23 cm)		T7-90 (40 cm)		T7-90 (66 cm)		T7-25 (23 cm)		T7-25 (46 cm)		T7-25 (66 cm)		T7-2 (16 cm)		T7-2 (32 cm)		T7-2 (48 cm)	
Date	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w
5/7/2005	0.894	0.034	0.867	0.010	0.795	0.000	0.806	0.103	0.861	0.105	0.805	0.098	0.759	0.107	0.795	0.115	0.807	0.087	0.758	0.118	0.755	0.095	0.751	0.126
5/8/2005	0.896	0.034	0.868	0.010	0.795	0.000	0.808	0.102	0.861	0.105	0.805	0.098	0.759	0.107	0.795	0.115	0.807	0.087	0.757	0.118	0.755	0.096	0.751	0.125
5/9/2005	0.896	0.034	0.869	0.011	0.795	0.000	0.807	0.102	0.860	0.104	0.805	0.098	0.758	0.107	0.796	0.114	0.806	0.087	0.757	0.117	0.754	0.096	0.751	0.125
5/10/2005	0.896	0.034	0.869	0.011	0.795	0.000	0.806	0.102	0.860	0.103	0.805	0.098	0.758	0.108	0.795	0.114	0.806	0.087	0.757	0.117	0.754	0.096	0.751	0.124
5/11/2005	0.896	0.035	0.869	0.011	0.795	0.000	0.806	0.102	0.859	0.103	0.805	0.098	0.758	0.108	0.795	0.113	0.806	0.086	0.757	0.116	0.754	0.095	0.751	0.124
5/12/2005	0.896	0.035	0.869	0.011	0.795	0.000	0.806	0.101	0.860	0.103	0.805	0.097	0.758	0.108	0.794	0.112	0.808	0.084	0.757	0.117	0.754	0.094	0.751	0.124
5/13/2005	0.895	0.035	0.870	0.011	0.795	0.000	0.807	0.101	0.861	0.102	0.805	0.097	0.758	0.107	0.794	0.112	0.808	0.083	0.757	0.116	0.754	0.094	0.751	0.123
5/14/2005	0.895	0.036	0.869	0.012	0.795	0.000	0.807	0.101	0.860	0.102	0.805	0.097	0.758	0.107	0.793	0.111	0.808	0.083	0.757	0.116	0.755	0.093	0.751	0.123
5/15/2005	0.894	0.037	0.870	0.012	0.795	0.000	0.805	0.102	0.859	0.102	0.805	0.097	0.758	0.107	0.793	0.110	0.808	0.082	0.757	0.116	0.755	0.093	0.751	0.122
5/16/2005	0.894	0.037	0.870	0.012	0.795	0.000	0.805	0.101	0.861	0.102	0.806	0.097	0.758	0.106	0.794	0.109	0.808	0.081	0.757	0.116	0.755	0.093	0.751	0.121
5/17/2005	0.891	0.038	0.870	0.011	0.795	0.000	0.806	0.101	0.860	0.101	0.805	0.097	0.758	0.106	0.794	0.108	0.808	0.080	0.757	0.115	0.755	0.093	0.751	0.121
5/18/2005	0.891	0.038	0.870	0.010	0.795	0.000	0.805	0.101	0.858	0.102	0.804	0.098	0.758	0.105	0.794	0.108	0.807	0.079	0.757	0.115	0.755	0.093	0.751	0.120
5/19/2005	0.890	0.038	0.870	0.009	0.795	0.000	0.806	0.100	0.861	0.102	0.803	0.099	0.758	0.105	0.795	0.107	0.807	0.078	0.757	0.115	0.755	0.093	0.751	0.120
5/20/2005	0.892	0.039	0.869	0.010	0.794	0.000	0.807	0.100	0.859	0.102	0.803	0.100	0.759	0.104	0.795	0.107	0.807	0.078	0.757	0.115	0.755	0.093	0.751	0.119
5/21/2005	0.893	0.040	0.870	0.010	0.794	0.000	0.805	0.101	0.859	0.102	0.804	0.099	0.759	0.103	0.796	0.106	0.807	0.077	0.757	0.114			0.751	0.118
5/22/2005	0.893	0.040	0.870	0.011	0.794	0.000	0.804	0.101	0.859	0.101	0.804	0.098	0.759	0.103	0.797	0.105	0.806	0.077	0.757	0.114			0.751	0.117
5/23/2005	0.891	0.040	0.869	0.012	0.794	0.000	0.804	0.100	0.859	0.101	0.803	0.098	0.759	0.102	0.797	0.104	0.806	0.076	0.757	0.114			0.751	0.117
5/24/2005	0.891	0.039	0.870	0.012	0.794	0.000	0.803	0.099	0.856	0.101	0.803	0.098	0.759	0.102	0.798	0.103	0.807	0.077	0.757	0.114			0.751	0.116
5/25/2005	0.890	0.039	0.870	0.012	0.794	0.000	0.803	0.099	0.857	0.101	0.803	0.097	0.759	0.102	0.799	0.102	0.807	0.076	0.757	0.114			0.751	0.116
5/26/2005	0.890	0.039	0.870	0.013	0.794	0.000	0.805	0.098	0.857	0.101	0.802	0.097	0.759	0.102	0.796	0.103	0.806	0.076	0.757	0.114			0.751	0.116
5/27/2005	0.892	0.037	0.870	0.013	0.794	0.000	0.804	0.097	0.859	0.101	0.802	0.097	0.759	0.101	0.797	0.102	0.806	0.076	0.757	0.114			0.751	0.115
5/28/2005	0.890	0.036	0.869	0.013	0.793	0.000	0.802	0.097	0.856	0.101	0.802	0.096	0.759	0.101	0.797	0.101	0.806	0.076	0.757	0.113			0.751	0.115
5/29/2005	0.890	0.037	0.870	0.013	0.793	0.000	0.801	0.097	0.855	0.100	0.802	0.096	0.758	0.101	0.797	0.100	0.806	0.076	0.757	0.113			0.751	0.115
5/30/2005	0.889	0.038	0.869	0.014	0.793	0.000	0.799	0.097	0.855	0.100	0.803	0.095	0.758	0.102	0.797	0.100	0.806	0.076	0.757	0.113			0.751	0.115
5/31/2005	0.890	0.039	0.868	0.013	0.793	0.000	0.799	0.095	0.856	0.100	0.802	0.095	0.758	0.101	0.796	0.100	0.803	0.077	0.757	0.113			0.751	0.114
6/1/2005	0.889	0.039	0.868	0.013	0.793	0.000	0.798	0.095	0.857	0.100	0.802	0.095	0.758	0.101	0.796	0.100	0.805	0.076	0.757	0.113			0.751	0.114
6/2/2005	0.891	0.040	0.867	0.013	0.793	0.000	0.798	0.093	0.857	0.099	0.803	0.094	0.758	0.100	0.796	0.099	0.806	0.076	0.757	0.113			0.751	0.113
6/3/2005	0.892	0.039	0.867	0.013	0.792	0.000	0.798	0.092	0.860	0.099	0.802	0.093	0.758	0.099	0.797	0.099	0.806	0.075	0.757	0.113			0.751	0.113
6/4/2005	0.893	0.038	0.868	0.013	0.793	0.000	0.798	0.091	0.859	0.099	0.802	0.093	0.758	0.099	0.796	0.098	0.806	0.075	0.756	0.113			0.751	0.113
6/5/2005	0.892	0.037	0.868	0.013	0.793	0.000	0.795	0.090	0.856	0.098	0.803	0.092	0.758	0.098	0.796	0.097	0.807	0.075	0.757	0.112			0.751	0.114
6/6/2005	0.891	0.036	0.868	0.013	0.793	0.000	0.795	0.089	0.857	0.098	0.803	0.092	0.758	0.097	0.796	0.097	0.806	0.075	0.757	0.111			0.751	0.113
6/7/2005	0.893	0.036	0.867	0.013	0.793	0.000	0.792	0.089	0.857	0.098	0.803	0.092	0.758	0.097	0.797	0.096	0.807	0.074	0.757	0.111			0.751	0.112
6/8/2005	0.891	0.035	0.867	0.012	0.793	0.000	0.791	0.088	0.855	0.098	0.802	0.092	0.758	0.096	0.796	0.096	0.806	0.074	0.757	0.111			0.751	0.112
6/9/2005	0.889	0.033	0.867	0.012	0.793	0.000	0.788	0.087	0.857	0.098	0.802	0.092	0.759	0.096	0.795	0.096	0.806	0.074	0.757	0.111			0.751	0.111
6/10/2005	0.888	0.033	0.867	0.012	0.793	0.000	0.788	0.086	0.857	0.098	0.800	0.093	0.759	0.095	0.795	0.095	0.804	0.074	0.757	0.110			0.751	0.111
6/11/2005	0.888	0.032	0.868	0.011	0.793	0.000	0.787	0.085	0.857	0.097	0.801	0.094	0.759	0.094	0.796	0.095	0.805	0.073	0.757	0.110			0.751	0.110
6/12/2005	0.889	0.032	0.867	0.011	0.793	0.000	0.787	0.085	0.856	0.097	0.802	0.094	0.759	0.094	0.796	0.094	0.806	0.073	0.756	0.110			0.751	0.110
6/13/2005	0.888	0.029	0.867	0.012	0.793	0.000	0.788	0.084	0.857	0.097	0.802	0.094	0.759	0.093	0.797	0.094	0.805	0.073	0.756	0.110			0.751	0.109
6/14/2005	0.886	0.027	0.867	0.012	0.793	0.000	0.787	0.084	0.856	0.097	0.803	0.094	0.759	0.093	0.796	0.094	0.805	0.073	0.756	0.110			0.751	0.109
6/15/2005	0.886	0.026	0.867	0.011	0.793	0.000	0.785	0.084	0.854	0.098	0.801	0.096	0.759	0.093	0.796	0.093	0.805	0.073	0.756	0.109			0.751	0.108
6/16/2005	0.886	0.025	0.867	0.011	0.792	0.000	0.785	0.084	0.855	0.098	0.801	0.098	0.758	0.094	0.796	0.093	0.805	0.073	0.756	0.109			0.751	0.108
6/17/2005	0.886	0.025	0.868	0.010	0.792	0.000	0.784	0.084	0.855	0.098	0.801	0.099	0.758	0.093	0.796	0.093	0.805	0.072	0.756	0.109			0.751	0.107
6/18/2005	0.885	0.025	0.868	0.009	0.792	0.000	0.783	0.084	0.855	0.098	0.800	0.099	0.759	0.093	0.795	0.093	0.805	0.071	0.756	0.109			0.751	0.106
6/19/2005	0.884	0.025	0.868	0.009	0.792	0.000	0.783	0.084	0.857	0.098	0.798	0.100	0.759	0.093	0.796	0.093	0.805	0.070	0.756	0.109			0.751	0.105
6/20/2005	0.885	0.025	0.868	0.009	0.793	0.000	0.783	0.083	0.859	0.098	0.798	0.099	0.759	0.092	0.796	0.092	0.805	0.069	0.756	0.109			0.751	0.105
6/21/2005	0.886	0.025	0.868	0.008	0.793	0.000	0.783	0.083	0.855	0.098	0.799	0.099	0.759	0.092	0.796	0.092	0.806	0.068	0.756	0.109			0.751	0.104
6/22/2005	0.885	0.025	0.869	0.008	0.793	0.000	0.783	0.083	0.857	0.098	0.796	0.098	0.759	0.091	0.796	0.092	0.807	0.068	0.756	0.109			0.751	0.103
6/23/2005	0.885	0.025	0.869	0.007	0.792	0.000	0.784	0.082	0.857	0.098	0.796	0.098	0.759	0.091	0.796	0.091	0.808	0.067	0.756	0.108			0.751	0.102
6/24/2005	0.886	0.025	0.869	0.007	0.792	0.000	0.782	0.083	0.856	0.098	0.796	0.098	0.759	0.091	0.797	0.090	0.809	0.066	0.757	0.108			0.751	0.101
6/25/2005	0.884	0.025	0.869	0.006	0.792	0.000	0.781	0.083	0.855	0.098	0.795	0.098	0.759	0.090	0.796	0.090	0.808	0.066	0.757	0.107			0.751	0.101

Table A-2. Continued.

	T7-145 (20 cm)		T7-145 (40 cm)		T7-145 (67 cm)		T7-90 (23 cm)		T7-90 (40 cm)		T7-90 (66 cm)		T7-25 (23 cm)		T7-25 (46 cm)		T7-25 (66 cm)		T7-2 (16 cm)		T7-2 (32 cm)		T7-2 (48 cm)	
Date	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w
6/26/2005	0.882	0.025	0.869	0.006	0.792	0.000	0.781	0.082	0.857	0.098	0.794	0.099	0.759	0.090	0.796	0.090	0.807	0.066	0.757	0.107			0.751	0.100
6/27/2005	0.883	0.025	0.870	0.006	0.792	0.000	0.780	0.083	0.857	0.098	0.793	0.100	0.759	0.089	0.796	0.090	0.807	0.066	0.757	0.107			0.751	0.099
6/28/2005	0.881	0.025	0.870	0.006	0.791	0.000	0.779	0.083	0.854	0.098	0.796	0.100	0.759	0.089	0.796	0.090	0.805	0.066	0.757	0.107			0.751	0.099
6/29/2005	0.881	0.025	0.870	0.006	0.792	0.000	0.780	0.082	0.859	0.098	0.796	0.101	0.759	0.089	0.796	0.089	0.806	0.065	0.757	0.107			0.751	0.098
6/30/2005	0.882	0.025	0.870	0.005	0.792	0.000	0.779	0.082	0.857	0.099	0.794	0.101	0.759	0.088	0.797	0.089	0.808	0.064	0.757	0.106			0.751	0.098
7/1/2005	0.880	0.025	0.870	0.005	0.792	0.000	0.780	0.081	0.856	0.099	0.794	0.102	0.759	0.088	0.797	0.089	0.808	0.064	0.757	0.106			0.751	0.097
7/2/2005	0.879	0.024	0.870	0.005	0.792	0.000	0.778	0.082	0.852	0.099	0.794	0.102	0.759	0.088	0.796	0.089	0.807	0.064	0.756	0.107			0.751	0.096
7/3/2005	0.877	0.023	0.870	0.005	0.792	0.000	0.779	0.081	0.854	0.099	0.794	0.102	0.759	0.087	0.796	0.089	0.806	0.064	0.756	0.106			0.751	0.095
7/4/2005	0.877	0.022	0.869	0.006	0.792	0.000	0.779	0.081	0.855	0.099	0.791	0.103	0.759	0.087	0.797	0.088	0.806	0.063	0.756	0.106			0.751	0.095
7/5/2005	0.877	0.021	0.868	0.006	0.792	0.000	0.776	0.082	0.853	0.099	0.791	0.102	0.759	0.087	0.797	0.087	0.807	0.063	0.756	0.105			0.751	0.095
7/6/2005	0.876	0.019	0.868	0.005	0.792	0.000	0.776	0.082	0.856	0.099	0.791	0.102	0.759	0.087	0.797	0.087	0.807	0.062	0.756	0.105			0.751	0.094
7/7/2005	0.874	0.017	0.868	0.005	0.792	0.000	0.775	0.081	0.853	0.099	0.791	0.101	0.759	0.087	0.798	0.087	0.806	0.061	0.757	0.105			0.751	0.093
7/8/2005	0.874	0.016	0.868	0.004	0.792	0.000	0.774	0.081	0.850	0.099	0.791	0.101	0.759	0.087	0.798	0.086	0.806	0.061	0.757	0.105			0.751	0.093
7/9/2005	0.875	0.016	0.868	0.004	0.792	0.000	0.774	0.081	0.851	0.100	0.791	0.100	0.759	0.087	0.798	0.086	0.807	0.060	0.757	0.104			0.751	0.092
7/10/2005	0.875	0.016	0.868	0.004	0.792	0.000	0.774	0.080	0.852	0.100	0.789	0.101	0.759	0.086	0.797	0.086	0.808	0.060	0.756	0.105			0.751	0.092
7/11/2005	0.873	0.014	0.868	0.003	0.791	0.000	0.773	0.080	0.852	0.099	0.790	0.100	0.759	0.086	0.796	0.086	0.807	0.059	0.756	0.105			0.751	0.091
7/12/2005	0.874	0.013	0.869	0.002	0.791	0.000	0.772	0.081	0.852	0.099	0.789	0.100	0.759	0.085	0.796	0.085	0.806	0.059	0.756	0.105			0.751	0.091
7/13/2005	0.874	0.012	0.867	0.002	0.791	0.000	0.772	0.080	0.853	0.099	0.787	0.100	0.759	0.085	0.796	0.085	0.807	0.059	0.756	0.104			0.751	0.090
7/14/2005	0.875	0.012	0.868	0.001	0.792	0.000	0.771	0.081	0.853	0.100	0.787	0.101	0.759	0.085	0.797	0.085	0.808	0.059	0.756	0.104			0.751	0.089
7/15/2005	0.877	0.012	0.868	0.001	0.791	0.000	0.772	0.079	0.853	0.099	0.786	0.101	0.759	0.085	0.797	0.085	0.809	0.059	0.756	0.104			0.751	0.089
7/16/2005	0.878	0.012	0.868	0.000	0.792	0.000	0.770	0.080	0.851	0.100	0.784	0.101	0.759	0.085	0.797	0.084	0.808	0.058	0.756	0.104			0.751	0.088
7/17/2005	0.878	0.012	0.868	0.000	0.792	0.000	0.769	0.080	0.853	0.100	0.784	0.101	0.759	0.084	0.797	0.084	0.808	0.058	0.756	0.103			0.751	0.087
7/18/2005	0.878	0.012	0.868	0.000	0.792	0.000	0.769	0.080	0.851	0.100	0.783	0.101	0.759	0.084	0.798	0.083	0.808	0.057	0.756	0.103			0.751	0.087
7/19/2005	0.877	0.013	0.868	0.000	0.792	0.000	0.769	0.079	0.850	0.100	0.782	0.100	0.759	0.084	0.798	0.083	0.808	0.056	0.756	0.103			0.751	0.086
7/20/2005	0.877	0.013	0.868	0.000	0.792	0.000	0.768	0.080	0.853	0.100	0.781	0.099	0.759	0.083	0.798	0.082	0.807	0.056	0.756	0.103			0.751	0.086
7/21/2005	0.877	0.014	0.868	0.000	0.792	0.000	0.768	0.080	0.852	0.100	0.781	0.098	0.759	0.083	0.798	0.082	0.807	0.055	0.756	0.103			0.751	0.085
7/22/2005	0.876	0.014	0.868	0.000	0.791	0.000	0.768	0.079	0.850	0.100	0.779	0.097	0.759	0.082	0.798	0.082	0.808	0.055	0.756	0.102			0.751	0.085
7/23/2005	0.876	0.015	0.869	0.000	0.791	0.000	0.767	0.079	0.851	0.099	0.779	0.096	0.760	0.081	0.797	0.081	0.808	0.054	0.756	0.102			0.751	0.084
7/24/2005	0.877	0.015	0.868	0.000	0.791	0.000	0.767	0.080	0.850	0.100	0.779	0.096	0.759	0.082	0.798	0.081	0.808	0.054	0.756	0.102			0.751	0.084
7/25/2005	0.877	0.015	0.868	0.000	0.791	0.000	0.768	0.079	0.852	0.100	0.779	0.095	0.759	0.081	0.798	0.080	0.809	0.053	0.756	0.102			0.751	0.083
7/26/2005	0.877	0.016	0.868	0.000	0.791	0.000	0.769	0.079	0.850	0.099	0.779	0.095	0.759	0.081	0.798	0.080	0.810	0.053	0.757	0.102			0.751	0.083
7/27/2005	0.877	0.016	0.868	0.000	0.791	0.000	0.769	0.079	0.851	0.100	0.777	0.095	0.759	0.080	0.798	0.080	0.810	0.052	0.756	0.101			0.751	0.081
7/28/2005	0.876	0.017	0.868	0.000	0.791	0.000	0.769	0.079	0.853	0.099	0.777	0.094	0.759	0.080	0.797	0.079	0.809	0.052	0.757	0.100			0.751	0.081
7/29/2005	0.876	0.017	0.868	0.000	0.791	0.000	0.769	0.078	0.850	0.099	0.777	0.093	0.759	0.080	0.797	0.079	0.809	0.051	0.756	0.100			0.751	0.080
7/30/2005	0.876	0.017	0.868	0.000	0.791	0.000	0.769	0.078	0.852	0.099	0.776	0.093	0.759	0.080	0.797	0.078	0.809	0.052	0.756	0.100			0.751	0.079
7/31/2005	0.877	0.017	0.868	0.000	0.791	0.000	0.768	0.079	0.854	0.099	0.776	0.094	0.759	0.079	0.798	0.078	0.809	0.052	0.756	0.100			0.751	0.079
8/1/2005	0.878	0.018	0.868	0.000	0.791	0.000	0.769	0.079	0.853	0.099	0.776	0.093	0.759	0.078	0.799	0.078	0.810	0.051	0.756	0.100			0.751	0.078
8/2/2005	0.879	0.018	0.869	0.000	0.791	0.000	0.768	0.079	0.851	0.099	0.777	0.093	0.760	0.077	0.800	0.077	0.810	0.051	0.756	0.100			0.751	0.078
8/3/2005	0.880	0.017	0.869	0.000	0.791	0.000	0.768	0.079	0.855	0.098	0.776	0.093	0.760	0.077	0.799	0.077	0.811	0.050	0.756	0.099			0.751	0.077
8/4/2005	0.880	0.016	0.869	0.000	0.791	0.000	0.768	0.079	0.855	0.098	0.776	0.092	0.760	0.077	0.798	0.077	0.811	0.050	0.756	0.099			0.751	0.077
8/5/2005	0.882	0.017	0.869	0.000	0.791	0.000	0.769	0.078	0.855	0.098	0.776	0.092	0.759	0.077	0.798	0.077	0.813	0.049	0.756	0.099			0.751	0.077
8/6/2005	0.882	0.016	0.869	0.000	0.791	0.000	0.769	0.078	0.854	0.098	0.775	0.092	0.760	0.076	0.798	0.076	0.811	0.049	0.756	0.098			0.751	0.076
8/7/2005	0.882	0.015	0.870	0.000	0.791	0.000	0.769	0.078	0.853	0.099	0.774	0.091	0.760	0.075	0.799	0.076	0.811	0.049	0.756	0.098			0.751	0.076
8/8/2005	0.882	0.016	0.870	0.000	0.791	0.000	0.769	0.078	0.853	0.098	0.774	0.091	0.760	0.075	0.799	0.076	0.811	0.049	0.756	0.098			0.751	0.075
8/9/2005	0.879	0.016	0.870	0.000	0.791	0.000	0.769	0.078	0.852	0.099	0.774	0.092	0.760	0.075	0.799	0.075	0.812	0.048	0.757	0.098			0.751	0.075
8/10/2005	0.879	0.016	0.869	0.000	0.791	0.000	0.769	0.077	0.855	0.097	0.774	0.091	0.760	0.075	0.799	0.075	0.812	0.048	0.757	0.097			0.751	0.075
8/11/2005	0.881	0.016	0.868	0.000	0.791	0.000	0.768	0.074	0.858	0.096	0.776	0.090	0.760	0.074	0.778	0.064	0.813	0.047	0.757	0.097			0.751	0.074
8/12/2005	0.880	0.015	0.869	0.000	0.791	0.000	0.766	0.074	0.859	0.096	0.775	0.090	0.760	0.074	0.765	0.057	0.813	0.047	0.757	0.097			0.751	0.074
8/13/2005	0.880	0.014	0.869	0.000	0.791	0.000	0.766	0.074	0.859	0.096	0.775	0.090	0.760	0.074	0.767	0.058	0.813	0.047	0.756	0.097			0.751	0.073
8/14/2005	0.880	0.014	0.869	0.000	0.791	0.000	0.768	0.075	0.859	0.096	0.776	0.089	0.760	0.074	0.769	0.058	0.812	0.047	0.756	0.096			0.751	0.073

Table A-2. Continued.

	T7-145 (20 cm)		T7-145 (40 cm)		T7-145 (67 cm)		T7-90 (23 cm)		T7-90 (40 cm)		T7-90 (66 cm)		T7-25 (23 cm)		T7-25 (46 cm)		T7-25 (66 cm)		T7-2 (16 cm)		T7-2 (32 cm)		T7-2 (48 cm)	
Date	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w
8/15/2005	0.880	0.014	0.869	0.000	0.791	0.000	0.768	0.075	0.857	0.096	0.774	0.089	0.760	0.073	0.771	0.059	0.813	0.047	0.756	0.096			0.751	0.073
8/16/2005							0.768	0.075	0.856	0.096	0.774	0.088	0.760	0.073	0.772	0.060	0.813	0.047	0.756	0.096			0.751	0.072
8/17/2005							0.769	0.076	0.857	0.096	0.775	0.088	0.760	0.072	0.774	0.060	0.812	0.047	0.757	0.095			0.751	0.071
8/18/2005							0.769	0.077	0.857	0.096	0.774	0.088	0.760	0.072	0.775	0.061	0.813	0.047	0.756	0.095			0.751	0.072
8/19/2005							0.769	0.077	0.858	0.096	0.776	0.088	0.760	0.072	0.778	0.063	0.813	0.047	0.757	0.095			0.751	0.071
8/20/2005							0.769	0.077	0.857	0.096	0.779	0.089	0.761	0.071	0.780	0.064	0.812	0.047	0.757	0.095			0.751	0.070
8/21/2005							0.769	0.077	0.856	0.096	0.777	0.089	0.761	0.071	0.783	0.064	0.812	0.047	0.757	0.094			0.751	0.070
8/22/2005							0.770	0.077	0.856	0.096	0.779	0.089	0.760	0.071	0.784	0.065	0.812	0.047	0.757	0.094			0.751	0.070
8/23/2005							0.769	0.077	0.855	0.096	0.778	0.088	0.760	0.071	0.786	0.065	0.812	0.047	0.757	0.094			0.751	0.070
8/24/2005							0.769	0.077	0.856	0.096	0.776	0.088	0.760	0.070	0.787	0.065	0.811	0.047	0.757	0.094			0.751	0.069
8/25/2005							0.770	0.077	0.858	0.096	0.775	0.087	0.760	0.070	0.788	0.066	0.811	0.047	0.757	0.093			0.751	0.069
8/26/2005							0.771	0.077	0.855	0.096	0.775	0.087	0.761	0.069	0.789	0.066	0.813	0.047	0.757	0.093			0.751	0.069
8/27/2005							0.770	0.077	0.855	0.097	0.773	0.089	0.761	0.069	0.790	0.066	0.813	0.048	0.757	0.093			0.751	0.068
8/28/2005							0.770	0.079	0.852	0.097	0.773	0.091	0.761	0.068	0.789	0.067	0.812	0.048	0.756	0.093			0.751	0.068
8/29/2005							0.770	0.078	0.853	0.096	0.774	0.090	0.761	0.068	0.791	0.067	0.811	0.048	0.757	0.092			0.751	0.067
8/30/2005							0.770	0.078	0.853	0.097	0.774	0.091	0.760	0.068	0.792	0.067	0.812	0.048	0.757	0.092			0.751	0.067
8/31/2005							0.769	0.079	0.853	0.098	0.775	0.092	0.760	0.068	0.793	0.067	0.811	0.049	0.757	0.092			0.751	0.067
9/1/2005							0.769	0.079	0.852	0.097	0.778	0.093	0.760	0.068	0.793	0.068	0.811	0.049	0.757	0.091			0.751	0.067
9/2/2005							0.769	0.079	0.854	0.098	0.778	0.092	0.760	0.068	0.796	0.067	0.812	0.049	0.757	0.091			0.751	0.067
9/3/2005							0.769	0.079	0.853	0.098	0.778	0.092	0.760	0.068	0.797	0.067	0.812	0.049	0.757	0.091			0.751	0.067
9/4/2005							0.770	0.079	0.851	0.098	0.777	0.093	0.761	0.067	0.797	0.067	0.812	0.049	0.757	0.091			0.751	0.067
9/5/2005							0.770	0.079	0.854	0.098	0.778	0.094	0.761	0.067	0.798	0.067	0.812	0.050	0.757	0.091			0.751	0.066
9/6/2005							0.770	0.079	0.856	0.098	0.778	0.097	0.761	0.067	0.798	0.068	0.813	0.050	0.757	0.091			0.752	0.066
9/7/2005							0.770	0.078	0.855	0.098	0.777	0.099	0.761	0.067	0.799	0.068	0.814	0.050	0.757	0.091			0.752	0.066
9/8/2005							0.771	0.079	0.854	0.099	0.777	0.101	0.761	0.067	0.798	0.068	0.813	0.051	0.757	0.091			0.752	0.066
9/9/2005							0.771	0.079	0.853	0.099	0.778	0.104	0.761	0.067	0.800	0.068	0.813	0.051	0.757	0.091			0.752	0.066
9/10/2005							0.770	0.080	0.854	0.099	0.778	0.105	0.761	0.066	0.800	0.068	0.812	0.052	0.757	0.091			0.752	0.066
9/11/2005							0.770	0.079	0.853	0.100	0.778	0.105	0.761	0.066	0.799	0.068	0.812	0.052	0.757	0.090			0.752	0.066
9/12/2005							0.770	0.080	0.852	0.100	0.778	0.106	0.761	0.067	0.799	0.068	0.811	0.053	0.757	0.090			0.752	0.066
9/13/2005	0.900	0.019	0.882	0.000	0.793	0.000	0.770	0.080	0.853	0.101	0.779	0.107	0.761	0.066	0.798	0.068	0.811	0.054	0.757	0.089			0.751	0.065
9/14/2005	0.899	0.019	0.882	0.000	0.790	0.000	0.770	0.081	0.853	0.102	0.780	0.107	0.761	0.066	0.799	0.068	0.811	0.054	0.757	0.089			0.752	0.065
9/15/2005							0.770	0.081	0.851	0.102	0.779	0.108	0.761	0.066	0.799	0.068	0.810	0.055	0.757	0.089			0.752	0.065
9/16/2005							0.770	0.082	0.852	0.102	0.779	0.108	0.761	0.066	0.800	0.068	0.810	0.055	0.757	0.089			0.752	0.065
9/17/2005							0.769	0.082	0.852	0.103	0.778	0.108	0.761	0.066	0.800	0.068	0.810	0.056	0.757	0.089			0.752	0.065
9/18/2005							0.770	0.082	0.852	0.103	0.778	0.108	0.761	0.066	0.799	0.068	0.809	0.057	0.757	0.089			0.752	0.065
9/19/2005							0.770	0.083	0.853	0.103	0.778	0.108	0.761	0.066	0.800	0.068	0.809	0.057	0.757	0.089			0.752	0.065
9/20/2005							0.770	0.083	0.852	0.103	0.778	0.108	0.761	0.066	0.799	0.068	0.809	0.058	0.757	0.088			0.752	0.065
9/21/2005							0.769	0.084	0.853	0.103	0.778	0.108	0.761	0.066	0.799	0.067	0.809	0.058	0.758	0.088			0.752	0.065
9/22/2005							0.769	0.084	0.851	0.105	0.779	0.108	0.761	0.066	0.799	0.067	0.809	0.059	0.757	0.088			0.752	0.065
9/23/2005							0.769	0.084	0.851	0.104	0.777	0.108	0.761	0.066	0.799	0.067	0.809	0.059	0.757	0.088			0.752	0.065
9/24/2005							0.769	0.084	0.851	0.104	0.777	0.108	0.761	0.066	0.798	0.067	0.809	0.060	0.758	0.087			0.752	0.065
9/25/2005							0.769	0.085	0.851	0.105	0.776	0.108	0.761	0.066	0.798	0.067	0.809	0.060	0.757	0.087			0.752	0.064
9/26/2005							0.769	0.085	0.850	0.105	0.776	0.108	0.760	0.066	0.798	0.067	0.809	0.059	0.757	0.087			0.752	0.064
9/27/2005							0.769	0.085	0.850	0.105	0.776	0.108	0.760	0.066	0.799	0.067	0.809	0.060	0.757	0.087			0.752	0.064
9/28/2005							0.770	0.086	0.854	0.106	0.777	0.108	0.761	0.065	0.799	0.068	0.810	0.060	0.757	0.087			0.752	0.064
9/29/2005							0.770	0.086	0.854	0.106	0.776	0.108	0.761	0.065	0.799	0.067	0.809	0.060	0.757	0.087			0.752	0.064
9/30/2005							0.770	0.086	0.850	0.106	0.777	0.108	0.761	0.065	0.800	0.068	0.809	0.060	0.757	0.087			0.752	0.064
10/1/2005							0.770	0.087	0.850	0.106	0.776	0.108	0.761	0.065	0.801	0.068	0.810	0.060	0.757	0.087			0.752	0.064
10/2/2005							0.770	0.087	0.849	0.106	0.776	0.108	0.761	0.065	0.801	0.068	0.808	0.061	0.757	0.086			0.752	0.064
10/3/2005							0.770	0.088	0.850	0.107	0.776	0.108	0.761	0.065	0.801	0.068	0.809	0.061	0.757	0.086			0.752	0.064

Table A-2. Continued.

	T7-145 (20 cm)		T7-145 (40 cm)		T7-145 (67 cm)		T7-90 (23 cm)		T7-90 (40 cm)		T7-90 (66 cm)		T7-25 (23 cm)		T7-25 (46 cm)		T7-25 (66 cm)		T7-2 (16 cm)		T7-2 (32 cm)		T7-2 (48 cm)	
Date	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w
10/4/2005	0.893	0.021					0.770	0.088	0.850	0.107	0.777	0.108	0.761	0.065	0.802	0.068	0.808	0.061	0.758	0.086			0.752	0.064
10/5/2005	0.902	0.024					0.770	0.088	0.851	0.107	0.777	0.107	0.761	0.064	0.801	0.068	0.809	0.061	0.758	0.086			0.752	0.064
10/6/2005													0.761	0.037	0.800	0.065	0.805	0.056						
10/7/2005													0.762	0.040	0.800	0.067	0.809	0.061						
10/8/2005													0.762	0.042	0.802	0.067	0.810	0.063						
10/9/2005													0.762	0.045	0.806	0.066	0.810	0.064						
10/10/2005													0.762	0.048	0.803	0.068	0.809	0.065						
10/11/2005													0.762	0.049	0.800	0.069	0.809	0.066						
10/12/2005													0.763	0.051	0.801	0.069	0.809	0.067						
10/13/2005													0.763	0.053	0.801	0.069	0.809	0.066						
10/14/2005													0.764	0.055	0.803	0.069	0.809	0.066						
10/15/2005													0.764	0.056	0.805	0.069	0.810	0.067						
10/16/2005													0.764	0.056	0.805	0.069	0.810	0.067						
10/17/2005													0.764	0.057	0.804	0.070	0.809	0.066						
10/18/2005													0.765	0.058	0.804	0.070	0.809	0.067						
10/19/2005													0.765	0.059	0.804	0.070	0.808	0.066						
10/20/2005													0.765	0.059	0.803	0.070	0.808	0.066						
10/21/2005													0.765	0.060	0.803	0.070	0.807	0.066						
10/22/2005													0.765	0.061	0.803	0.070	0.807	0.067						
10/23/2005													0.765	0.061	0.803	0.069	0.807	0.068						
10/24/2005													0.765	0.061	0.803	0.070	0.808	0.068						
10/25/2005													0.765	0.061	0.803	0.070	0.808	0.066						
10/26/2005													0.765	0.062	0.803	0.069	0.806	0.064						
10/27/2005													0.765	0.063	0.802	0.069	0.804	0.062						
10/28/2005													0.764	0.063	0.801	0.069	0.803	0.062						
10/29/2005													0.764	0.063	0.801	0.068	0.803	0.061						
10/30/2005													0.764	0.063	0.799	0.068	0.803	0.061						
10/31/2005													0.763	0.063	0.798	0.068	0.803	0.061						
11/1/2005													0.763	0.063	0.798	0.068	0.803	0.061						
11/2/2005													0.763	0.063	0.798	0.068	0.802	0.060						
11/3/2005													0.763	0.063	0.798	0.067	0.802	0.061						
11/4/2005													0.763	0.063	0.798	0.067	0.802	0.060						
11/5/2005													0.762	0.063	0.798	0.068	0.802	0.060						
11/6/2005													0.762	0.062	0.797	0.068	0.801	0.060						
11/7/2005													0.762	0.063	0.798	0.067	0.800	0.059						
11/8/2005													0.762	0.062	0.798	0.067	0.801	0.060						
11/9/2005													0.762	0.062	0.798	0.067	0.800	0.060						
11/10/2005													0.762	0.062	0.799	0.067	0.800	0.060						
11/11/2005													0.762	0.062	0.799	0.067	0.799	0.059						
11/12/2005													0.762	0.063	0.799	0.067	0.799	0.060						
11/13/2005													0.762	0.063	0.799	0.067	0.799	0.059						
11/14/2005													0.762	0.063	0.799	0.067	0.798	0.059						
11/15/2005													0.762	0.063	0.799	0.066	0.798	0.059						
11/16/2005													0.761	0.063	0.798	0.066	0.797	0.059						
11/17/2005													0.761	0.063	0.798	0.066	0.797	0.059						
11/18/2005													0.761	0.063	0.798	0.066	0.796	0.059						
11/19/2005													0.761	0.063	0.798	0.066	0.796	0.058						
11/20/2005													0.761	0.063	0.798	0.066	0.795	0.057						
11/21/2005													0.761	0.063	0.798	0.066	0.795	0.057						
11/22/2005													0.761	0.063	0.798	0.066	0.795	0.057						

Table A-2. Continued.

	T7-145 (20 cm)		T7-145 (40 cm)		T7-145 (67 cm)		T7-90 (23 cm)		T7-90 (40 cm)		T7-90 (66 cm)		T7-25 (23 cm)		T7-25 (46 cm)		T7-25 (66 cm)		T7-2 (16 cm)		T7-2 (32 cm)		T7-2 (48 cm)	
Date	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w
11/23/2005													0.761	0.063	0.798	0.066	0.794	0.056						
11/24/2005													0.760	0.063	0.799	0.065	0.791	0.053						
11/25/2005													0.760	0.063	0.797	0.065	0.789	0.049						
11/26/2005													0.760	0.062	0.796	0.064	0.786	0.046						
11/27/2005													0.759	0.062	0.795	0.063	0.785	0.045						
11/28/2005													0.759	0.062	0.794	0.063	0.785	0.045						
11/29/2005													0.759	0.061	0.793	0.063	0.785	0.046						
11/30/2005													0.758	0.061	0.793	0.063	0.785	0.047						
12/1/2005							0.819	0.100					0.758	0.060	0.794	0.062	0.785	0.048	0.809	0.061				
12/2/2005							0.817	0.102					0.758	0.060	0.794	0.062	0.784	0.047	0.805	0.064				
12/3/2005							0.817	0.102											0.798	0.063				
12/4/2005							0.815	0.101											0.791	0.061				
12/5/2005							0.812	0.100											0.786	0.059				
12/6/2005							0.808	0.099											0.781	0.056				
12/7/2005							0.804	0.098											0.778	0.054				
12/8/2005							0.801	0.097											0.776	0.052				
12/9/2005							0.796	0.096											0.773	0.051				
12/10/2005							0.792	0.095											0.772	0.050				
12/11/2005							0.789	0.094											0.770	0.048				
12/12/2005							0.787	0.093											0.769	0.046				
12/13/2005	0.886	0.007	0.862	0.000			0.787	0.093	0.895	0.114	0.811	0.087	0.756	0.061	0.794	0.039	0.779	0.060	0.807	0.050			0.751	0.054
12/14/2005	0.884	0.006	0.862	0.000			0.787	0.095	0.893	0.114	0.810	0.088	0.756	0.061	0.794	0.041	0.779	0.061	0.885	0.059			0.751	0.055
12/15/2005	0.878	0.005	0.863	0.000			0.786	0.095	0.889	0.114	0.808	0.088	0.756	0.061	0.792	0.042	0.778	0.062	0.877	0.060			0.751	0.055
12/16/2005	0.873	0.004	0.864	0.000			0.783	0.095	0.884	0.114	0.806	0.089	0.756	0.063	0.791	0.042	0.776	0.062	0.871	0.060			0.750	0.054
12/17/2005	0.867	0.002	0.862	0.000			0.780	0.093	0.884	0.113	0.805	0.088	0.756	0.065	0.788	0.042	0.775	0.062	0.869	0.059			0.750	0.053
12/18/2005	0.860	0.001	0.861	0.000			0.775	0.091	0.876	0.112	0.803	0.087	0.755	0.068	0.787	0.041	0.773	0.063	0.863	0.058			0.750	0.052
12/19/2005	0.851	0.000	0.861	0.000			0.768	0.087	0.874	0.111	0.802	0.087	0.755	0.070	0.783	0.040	0.771	0.065	0.859	0.057			0.749	0.051
12/20/2005	0.843	0.000	0.859	0.000			0.761	0.082	0.869	0.111	0.801	0.087	0.754	0.071	0.779	0.038	0.771	0.066	0.856	0.056			0.749	0.050
12/21/2005	0.837	0.000	0.857	0.000			0.756	0.076	0.865	0.109	0.799	0.086	0.753	0.072	0.777	0.037	0.770	0.066	0.851	0.056			0.749	0.049
12/22/2005	0.834	0.000	0.857	0.000			0.753	0.072	0.858	0.109	0.797	0.085	0.753	0.071	0.775	0.036	0.770	0.066	0.846	0.054			0.749	0.048
12/23/2005	0.832	0.000	0.858	0.000			0.752	0.069	0.853	0.107	0.795	0.086	0.752	0.071	0.773	0.035	0.769	0.066	0.844	0.054			0.749	0.048
12/24/2005	0.830	0.000	0.857	0.000			0.750	0.066	0.849	0.106	0.792	0.085	0.752	0.071	0.774	0.036	0.769	0.065	0.840	0.053			0.749	0.046
12/25/2005	0.827	0.000	0.859	0.000			0.750	0.063	0.847	0.105	0.790	0.084	0.751	0.073	0.774	0.036	0.768	0.064	0.836	0.052			0.749	0.046
12/26/2005	0.826	0.000	0.859	0.000			0.749	0.061	0.845	0.104	0.789	0.083	0.751	0.074	0.773	0.036	0.768	0.064	0.833	0.052			0.749	0.045
12/27/2005	0.827	0.000	0.860	0.000			0.749	0.061	0.843	0.103	0.788	0.083	0.751	0.072	0.774	0.035	0.768	0.063	0.831	0.051			0.749	0.044
12/28/2005	0.827	0.000	0.862	0.000			0.750	0.061	0.839	0.103	0.786	0.083	0.751	0.069	0.774	0.035	0.768	0.063	0.828	0.051			0.749	0.044
12/29/2005	0.825	0.000	0.864	0.000			0.750	0.061	0.836	0.102	0.785	0.083	0.751	0.068	0.774	0.034	0.768	0.062	0.827	0.050			0.749	0.043
12/30/2005	0.825	0.000	0.865	0.000			0.750	0.062	0.838	0.101	0.783	0.082	0.751	0.069	0.774	0.034	0.767	0.061	0.826	0.050			0.749	0.042
12/31/2005	0.823	0.000	0.865	0.000			0.750	0.061	0.835	0.100	0.782	0.082	0.751	0.068	0.774	0.034	0.767	0.061	0.825	0.050			0.749	0.042
1/1/2006	0.821	0.000	0.866	0.000	0.797	0.000	0.750	0.061	0.829	0.099	0.781	0.082	0.751	0.069	0.774	0.034	0.766	0.059	0.824	0.050			0.749	0.041
1/2/2006	0.819	0.000	0.866	0.000	0.797	0.000	0.750	0.060	0.829	0.099	0.780	0.081	0.751	0.072	0.775	0.033	0.766	0.059	0.821	0.049			0.749	0.041
1/3/2006	0.814	0.000	0.867	0.000	0.797	0.000	0.750	0.059	0.827	0.098	0.780	0.080	0.751	0.075	0.775	0.033	0.766	0.059	0.818	0.049			0.749	0.040
1/4/2006	0.813	0.000	0.866	0.000	0.796	0.000	0.750	0.059	0.827	0.098	0.779	0.081	0.751	0.075	0.775	0.033	0.766	0.059	0.818	0.049			0.749	0.040
1/5/2006	0.811	0.000	0.866	0.000	0.796	0.000	0.750	0.058	0.826	0.098	0.779	0.081	0.751	0.075	0.775	0.033	0.766	0.059	0.815	0.049			0.749	0.039
1/6/2006	0.808	0.000	0.867	0.000	0.797	0.000	0.750	0.058	0.822	0.097	0.779	0.080	0.751	0.074	0.775	0.034	0.766	0.059	0.813	0.049			0.749	0.038
1/7/2006	0.810	0.000	0.866	0.000	0.797	0.000	0.750	0.057	0.821	0.096	0.779	0.080	0.751	0.071	0.775	0.033	0.766	0.058	0.813	0.049			0.749	0.038
1/8/2006	0.811	0.000	0.866	0.000	0.797	0.000	0.750	0.055	0.821	0.095	0.778	0.080	0.750	0.067	0.775	0.034	0.766	0.058	0.813	0.049			0.749	0.038
1/9/2006	0.811	0.000	0.868	0.000	0.798	0.000	0.750	0.055	0.821	0.095	0.777	0.080	0.750	0.064	0.775	0.034	0.766	0.058	0.812	0.049			0.749	0.038
1/10/2006	0.810	0.000	0.871	0.000	0.799	0.000	0.750	0.054	0.822	0.094	0.777	0.079	0.750	0.065	0.775	0.033	0.766	0.056	0.810	0.049			0.749	0.037
1/11/2006	0.808	0.000	0.869	0.000	0.799	0.000	0.750	0.054	0.821	0.094	0.776	0.079	0.751	0.068	0.775	0.033	0.765	0.056	0.807	0.049			0.749	0.037

Table A-2. Continued.

	T7-145 (20 cm)		T7-145 (40 cm)		T7-145 (67 cm)		T7-90 (23 cm)		T7-90 (40 cm)		T7-90 (66 cm)		T7-25 (23 cm)		T7-25 (46 cm)		T7-25 (66 cm)		T7-2 (16 cm)		T7-2 (32 cm)		T7-2 (48 cm)	
Date	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w
1/12/2006	0.806	0.000	0.868	0.000	0.799	0.000	0.750	0.054	0.817	0.094	0.776	0.079	0.751	0.070	0.775	0.033	0.765	0.056	0.805	0.049	0.751	0.020	0.749	0.036
1/13/2006	0.803	0.000	0.868	0.000	0.800	0.000	0.750	0.055	0.817	0.093	0.776	0.079	0.751	0.072	0.775	0.033	0.765	0.056	0.801	0.047	0.751	0.021	0.749	0.036
1/14/2006	0.800	0.000	0.867	0.000	0.798	0.000	0.750	0.055	0.816	0.093	0.777	0.079	0.751	0.074	0.775	0.033	0.765	0.055	0.792	0.046	0.750	0.020	0.749	0.036
1/15/2006	0.801	0.000	0.867	0.000	0.798	0.000	0.750	0.054	0.817	0.093	0.777	0.079	0.751	0.070	0.776	0.033	0.766	0.055	0.793	0.046	0.751	0.020	0.749	0.035
1/16/2006	0.802	0.000	0.867	0.000	0.798	0.000	0.750	0.053	0.819	0.093	0.777	0.078	0.751	0.066	0.776	0.034	0.766	0.055	0.793	0.046	0.751	0.020	0.749	0.035
1/17/2006	0.802	0.000	0.869	0.000	0.799	0.000	0.750	0.052	0.819	0.093	0.776	0.078	0.751	0.066	0.776	0.033	0.766	0.054	0.784	0.042	0.751	0.020	0.749	0.035
1/18/2006	0.802	0.000	0.870	0.000	0.800	0.000	0.750	0.053	0.821	0.092	0.777	0.078	0.751	0.068	0.776	0.034	0.766	0.053	0.782	0.041	0.750	0.019	0.749	0.034
1/19/2006	0.801	0.000	0.869	0.000	0.799	0.000	0.751	0.054	0.821	0.092	0.777	0.078	0.751	0.068	0.776	0.034	0.765	0.053	0.780	0.041	0.750	0.020	0.749	0.034
1/20/2006	0.799	0.000	0.869	0.000	0.800	0.000	0.751	0.052	0.820	0.092	0.776	0.078	0.751	0.069	0.776	0.034	0.765	0.053	0.781	0.041	0.750	0.019	0.749	0.034
1/21/2006	0.795	0.000	0.869	0.000	0.800	0.000	0.750	0.052	0.820	0.092	0.775	0.078	0.751	0.073	0.776	0.034	0.765	0.053	0.779	0.041	0.750	0.020	0.749	0.034
1/22/2006	0.793	0.000	0.868	0.000	0.801	0.000	0.750	0.051	0.819	0.091	0.776	0.078	0.751	0.076	0.776	0.034	0.766	0.053	0.777	0.041	0.750	0.020	0.749	0.034
1/23/2006	0.791	0.000	0.868	0.000	0.801	0.000	0.750	0.052	0.817	0.092	0.776	0.078	0.751	0.077	0.776	0.034	0.766	0.054	0.776	0.040	0.750	0.020	0.749	0.033
1/24/2006	0.789	0.000	0.865	0.000	0.800	0.000	0.750	0.052	0.817	0.091	0.776	0.078	0.752	0.078	0.776	0.035	0.766	0.054	0.775	0.040	0.750	0.021	0.749	0.034
1/25/2006	0.789	0.000	0.866	0.000	0.801	0.000	0.750	0.051	0.815	0.092	0.777	0.077	0.752	0.077	0.776	0.035	0.766	0.056	0.775	0.040	0.751	0.021	0.749	0.033
1/26/2006	0.790	0.000	0.865	0.000	0.800	0.000	0.750	0.050	0.817	0.092	0.776	0.078	0.751	0.075	0.776	0.035	0.767	0.056	0.775	0.041	0.751	0.021	0.749	0.033
1/27/2006	0.790	0.000	0.867	0.000	0.802	0.000	0.751	0.050	0.818	0.091	0.775	0.078	0.751	0.073	0.777	0.036	0.767	0.055	0.777	0.040	0.751	0.021	0.749	0.033
1/28/2006	0.792	0.000	0.867	0.000	0.802	0.000	0.750	0.049	0.818	0.091	0.775	0.078	0.751	0.073	0.777	0.036	0.767	0.055	0.777	0.040	0.751	0.021	0.749	0.033
1/29/2006	0.792	0.000	0.867	0.000	0.801	0.000	0.751	0.049	0.816	0.091	0.775	0.077	0.751	0.073	0.777	0.037	0.767	0.055	0.776	0.039	0.751	0.021	0.749	0.033
1/30/2006	0.791	0.000	0.867	0.000	0.802	0.000	0.751	0.049	0.816	0.091	0.775	0.077	0.751	0.075	0.778	0.037	0.767	0.055	0.775	0.038	0.751	0.021	0.749	0.033
1/31/2006	0.790	0.000	0.867	0.000	0.800	0.000	0.751	0.049	0.817	0.091	0.775	0.076	0.752	0.078	0.778	0.037	0.767	0.054	0.775	0.038	0.751	0.021	0.749	0.032
2/1/2006	0.791	0.000	0.867	0.000	0.799	0.000	0.751	0.048	0.818	0.091	0.775	0.076	0.752	0.077	0.778	0.038	0.767	0.055	0.774	0.037	0.751	0.021	0.749	0.032
2/2/2006	0.790	0.000	0.868	0.000	0.802	0.000	0.751	0.047	0.820	0.090	0.775	0.075	0.752	0.076	0.779	0.038	0.767	0.055	0.774	0.037	0.751	0.021	0.749	0.032
2/3/2006	0.789	0.000	0.868	0.000	0.802	0.000	0.751	0.047	0.819	0.089	0.776	0.074	0.752	0.077	0.779	0.038	0.768	0.055	0.773	0.036	0.751	0.021	0.749	0.032
2/4/2006	0.787	0.000	0.868	0.000	0.803	0.000	0.751	0.046	0.819	0.089	0.776	0.075	0.752	0.079	0.779	0.039	0.768	0.055	0.772	0.036	0.751	0.021	0.749	0.031
2/5/2006	0.789	0.000	0.866	0.000	0.799	0.000	0.751	0.045	0.820	0.089	0.776	0.075	0.752	0.077	0.779	0.040	0.768	0.055	0.770	0.035	0.751	0.021	0.749	0.031
2/6/2006	0.791	0.000	0.867	0.000	0.799	0.000	0.751	0.044	0.821	0.089	0.776	0.074	0.752	0.073	0.779	0.040	0.768	0.055	0.769	0.035	0.751	0.021	0.749	0.031
2/7/2006	0.792	0.000	0.867	0.000	0.800	0.000	0.751	0.043	0.821	0.088	0.776	0.074	0.752	0.070	0.779	0.040	0.768	0.054	0.768	0.035	0.751	0.021	0.749	0.031
2/8/2006	0.792	0.000	0.868	0.000	0.800	0.000	0.751	0.043	0.822	0.088	0.776	0.074	0.752	0.070	0.779	0.041	0.768	0.054	0.767	0.035	0.751	0.022	0.749	0.031
2/9/2006	0.794	0.000	0.868	0.000	0.798	0.000	0.751	0.042	0.823	0.088	0.777	0.074	0.752	0.069	0.780	0.041	0.767	0.054	0.768	0.035	0.752	0.022	0.749	0.030
2/10/2006	0.795	0.000	0.869	0.000	0.798	0.000	0.751	0.042	0.823	0.089	0.777	0.074	0.752	0.066	0.781	0.041	0.768	0.053	0.768	0.035	0.752	0.022	0.749	0.030
2/11/2006	0.795	0.000	0.870	0.000	0.799	0.000	0.751	0.042	0.824	0.088	0.776	0.074	0.752	0.066	0.782	0.041	0.768	0.053	0.768	0.035	0.752	0.022	0.749	0.030
2/12/2006	0.796	0.000	0.871	0.000	0.800	0.000	0.751	0.042	0.828	0.088	0.777	0.075	0.752	0.067	0.783	0.041	0.768	0.051	0.768	0.034	0.752	0.022	0.749	0.030
2/13/2006	0.797	0.000	0.870	0.000	0.798	0.000	0.751	0.041	0.828	0.088	0.778	0.074	0.752	0.064	0.784	0.041	0.769	0.051	0.768	0.034	0.752	0.022	0.749	0.030
2/14/2006	0.799	0.000	0.871	0.000	0.797	0.000	0.751	0.041	0.830	0.088	0.778	0.074	0.752	0.059	0.784	0.042	0.768	0.050	0.768	0.034	0.752	0.022	0.749	0.030
2/15/2006	0.799	0.000	0.873	0.000	0.799	0.000	0.751	0.041	0.832	0.088	0.778	0.075	0.752	0.058	0.785	0.042	0.768	0.049	0.768	0.035	0.752	0.022	0.749	0.029
2/16/2006	0.798	0.000	0.873	0.000	0.799	0.000	0.751	0.041	0.831	0.089	0.778	0.074	0.752	0.061	0.786	0.042	0.768	0.049	0.768	0.034	0.752	0.022	0.749	0.029
2/17/2006	0.798	0.000	0.872	0.000	0.798	0.000	0.751	0.042	0.832	0.089	0.778	0.075	0.752	0.064	0.786	0.043	0.769	0.049	0.766	0.034	0.752	0.021	0.749	0.029
2/18/2006	0.797	0.000	0.871	0.000	0.797	0.000	0.751	0.042	0.833	0.089	0.779	0.074	0.752	0.066	0.787	0.043	0.769	0.049	0.765	0.033	0.752	0.022	0.749	0.029
2/19/2006	0.796	0.000	0.870	0.000	0.797	0.000	0.751	0.042	0.834	0.089	0.779	0.075	0.752	0.066	0.787	0.043	0.769	0.048	0.763	0.033	0.752	0.022	0.749	0.028
2/20/2006	0.795	0.000	0.870	0.000	0.799	0.000	0.751	0.041	0.835	0.089	0.778	0.075	0.752	0.068	0.788	0.043	0.769	0.049	0.764	0.034	0.752	0.022	0.749	0.028
2/21/2006	0.794	0.000	0.869	0.000	0.798	0.000	0.751	0.043	0.834	0.089	0.778	0.075	0.753	0.070	0.788	0.043	0.769	0.049	0.763	0.033	0.752	0.022	0.749	0.029
2/22/2006	0.793	0.000	0.868	0.000	0.799	0.000	0.751	0.043	0.836	0.089	0.778	0.075	0.753	0.072	0.788	0.043	0.769	0.049	0.761	0.033	0.752	0.022	0.749	0.028
2/23/2006	0.792	0.000	0.868	0.000	0.798	0.000	0.751	0.043	0.833	0.091	0.778	0.075	0.753	0.074	0.789	0.043	0.769	0.050	0.761	0.034	0.752	0.023	0.749	0.028
2/24/2006	0.791	0.000	0.868	0.000	0.801	0.000	0.751	0.043	0.836	0.090	0.777	0.074	0.752	0.076	0.789	0.044	0.770	0.051	0.762	0.034	0.753	0.024	0.749	0.028
2/25/2006	0.790	0.000	0.868	0.000	0.802	0.000	0.751	0.044	0.838	0.091	0.777	0.074	0.752	0.078	0.790	0.043	0.770	0.051	0.762	0.033	0.753	0.024	0.749	0.029
2/26/2006	0.790	0.000	0.868	0.000	0.802	0.000	0.751	0.044	0.841	0.091	0.776	0.074	0.752	0.078	0.790	0.044	0.771	0.051	0.762	0.033	0.754	0.025	0.749	0.028
2/27/2006	0.791	0.000	0.868	0.000	0.800	0.000	0.751	0.044	0.842	0.091	0.777	0.074	0.753	0.076	0.791	0.045	0.771	0.051	0.763	0.033	0.755	0.025	0.749	0.029
2/28/2006	0.792	0.000	0.868	0.000	0.798	0.000	0.752	0.043	0.841	0.091	0.777	0.073	0.753	0.075	0.791	0.046	0.772	0.052	0.763	0.033	0.755	0.025	0.749	0.029
3/1/2006	0.792	0.000	0.868	0.000	0.799	0.000	0.752	0.043	0.840	0.091	0.777	0.073	0.753	0.074	0.792	0.046	0.772	0.053	0.762	0.032	0.754	0.026	0.749	0.029
3/2/2006	0.792	0.000	0.867	0.000	0.799	0.000	0.752	0.043	0.842	0.091	0.776	0.073	0.753	0.074	0.793	0.046	0.773	0.052	0.762	0.032	0.754	0.025	0.749	0.028

Table A-2. Continued.

	T7-145 (20 cm)		T7-145 (40 cm)		T7-145 (67 cm)		T7-90 (23 cm)		T7-90 (40 cm)		T7-90 (66 cm)		T7-25 (23 cm)		T7-25 (46 cm)		T7-25 (66 cm)		T7-2 (16 cm)		T7-2 (32 cm)		T7-2 (48 cm)	
Date	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w
3/3/2006	0.792	0.000	0.868	0.000	0.799	0.000	0.752	0.043	0.842	0.091	0.776	0.072	0.754	0.076	0.793	0.047	0.773	0.052	0.761	0.031	0.754	0.025	0.749	0.028
3/4/2006	0.791	0.000	0.869	0.000	0.800	0.000	0.752	0.043	0.842	0.091	0.776	0.072	0.754	0.077	0.794	0.047	0.774	0.053	0.761	0.031	0.754	0.025	0.749	0.028
3/5/2006	0.791	0.000	0.868	0.000	0.799	0.000	0.752	0.043	0.843	0.091	0.776	0.072	0.755	0.078	0.793	0.047	0.774	0.052	0.761	0.031	0.754	0.025	0.749	0.028
3/6/2006	0.793	0.000	0.868	0.000	0.799	0.000	0.752	0.043	0.843	0.091	0.776	0.072	0.755	0.077	0.794	0.048	0.774	0.053	0.760	0.030	0.754	0.025	0.749	0.027
3/7/2006	0.793	0.000	0.869	0.000	0.799	0.000	0.752	0.042	0.844	0.091	0.776	0.072	0.755	0.077	0.794	0.049	0.775	0.052	0.759	0.029	0.754	0.025	0.749	0.027
3/8/2006	0.794	0.000	0.868	0.000	0.798	0.000	0.752	0.043	0.847	0.090	0.776	0.072	0.755	0.076	0.795	0.049	0.775	0.052	0.759	0.030	0.754	0.025	0.749	0.027
3/9/2006	0.795	0.000	0.869	0.000	0.800	0.000	0.752	0.042	0.846	0.091	0.776	0.072	0.755	0.075	0.796	0.049	0.775	0.052	0.760	0.030	0.754	0.025	0.749	0.027
3/10/2006	0.795	0.000	0.870	0.000	0.800	0.000	0.752	0.043	0.847	0.090	0.777	0.072	0.755	0.076	0.795	0.049	0.775	0.052	0.759	0.030	0.754	0.025	0.749	0.027
3/11/2006	0.794	0.000	0.869	0.000	0.799	0.000	0.752	0.042	0.847	0.090	0.777	0.071	0.755	0.077	0.795	0.050	0.775	0.053	0.759	0.030	0.754	0.025	0.749	0.027
3/12/2006	0.793	0.000	0.868	0.000	0.800	0.000	0.752	0.043	0.845	0.090	0.777	0.071	0.755	0.078	0.796	0.050	0.776	0.053	0.758	0.030	0.754	0.024	0.750	0.027
3/13/2006	0.792	0.000	0.868	0.000	0.800	0.000	0.752	0.042	0.847	0.090	0.778	0.071	0.755	0.079	0.795	0.051	0.776	0.053	0.758	0.030	0.754	0.025	0.750	0.027
3/14/2006	0.791	0.000	0.868	0.000	0.800	0.000	0.752	0.043	0.845	0.091	0.777	0.072	0.756	0.080	0.796	0.051	0.776	0.054	0.758	0.030	0.754	0.025	0.750	0.027
3/15/2006	0.791	0.000	0.867	0.000	0.800	0.000	0.752	0.043	0.847	0.091	0.778	0.072	0.755	0.080	0.796	0.051	0.777	0.054	0.758	0.030	0.755	0.026	0.750	0.027
3/16/2006	0.792	0.000	0.866	0.000	0.799	0.000	0.752	0.043	0.849	0.091	0.777	0.073	0.755	0.080	0.796	0.051	0.777	0.054	0.758	0.030	0.755	0.026	0.749	0.027
3/17/2006	0.792	0.000	0.867	0.000	0.800	0.000	0.752	0.043	0.849	0.091	0.777	0.073	0.755	0.079	0.795	0.052	0.778	0.054	0.757	0.029	0.754	0.026	0.750	0.027
3/18/2006	0.792	0.000	0.867	0.000	0.800	0.000	0.752	0.043	0.849	0.092	0.778	0.073	0.755	0.078	0.795	0.052	0.778	0.054	0.757	0.029	0.755	0.026	0.750	0.027
3/19/2006	0.793	0.000	0.867	0.000	0.801	0.000	0.752	0.044	0.850	0.093	0.778	0.073	0.755	0.079	0.795	0.052	0.778	0.055	0.757	0.029	0.755	0.026	0.750	0.027
3/20/2006	0.792	0.000	0.869	0.000	0.801	0.000	0.753	0.044	0.851	0.093	0.778	0.072	0.755	0.080	0.795	0.052	0.779	0.055	0.757	0.029	0.755	0.026	0.750	0.026
3/21/2006	0.792	0.000	0.869	0.000	0.800	0.000	0.753	0.045	0.852	0.092	0.777	0.072	0.755	0.081	0.796	0.052	0.779	0.056	0.756	0.028	0.755	0.026	0.750	0.026
3/22/2006	0.791	0.000	0.868	0.001	0.801	0.000	0.753	0.045	0.850	0.093	0.777	0.072	0.756	0.083	0.795	0.053	0.779	0.056	0.755	0.028	0.754	0.026	0.750	0.026
3/23/2006	0.791	0.000	0.868	0.000	0.803	0.000	0.753	0.045	0.852	0.094	0.778	0.072	0.756	0.083	0.795	0.053	0.780	0.056	0.756	0.028	0.755	0.026	0.750	0.026
3/24/2006	0.791	0.000	0.868	0.001	0.801	0.000	0.753	0.046	0.855	0.094	0.778	0.072	0.756	0.082	0.795	0.053	0.781	0.056	0.756	0.028	0.754	0.026	0.750	0.026
3/25/2006	0.793	0.000	0.867	0.001	0.799	0.000	0.754	0.047	0.859	0.094	0.778	0.072	0.755	0.081	0.795	0.054	0.781	0.056	0.756	0.028	0.755	0.026	0.749	0.026
3/26/2006	0.794	0.000	0.868	0.002	0.799	0.000	0.754	0.047	0.862	0.095	0.779	0.072	0.755	0.078	0.796	0.053	0.781	0.056	0.756	0.029	0.755	0.026	0.749	0.026
3/27/2006	0.795	0.000	0.869	0.002	0.799	0.000	0.755	0.047	0.865	0.095	0.779	0.072	0.755	0.076	0.796	0.053	0.781	0.056	0.757	0.029	0.755	0.026	0.749	0.026
3/28/2006	0.797	0.000	0.869	0.003	0.799	0.000	0.756	0.048	0.867	0.095	0.780	0.071	0.755	0.076	0.795	0.054	0.781	0.056	0.757	0.029	0.755	0.026	0.749	0.026
3/29/2006	0.797	0.000	0.870	0.004	0.799	0.000	0.756	0.048	0.870	0.095	0.780	0.071	0.755	0.076	0.795	0.054	0.781	0.056	0.756	0.029	0.755	0.026	0.749	0.026
3/30/2006	0.797	0.000	0.870	0.005	0.800	0.000	0.757	0.048	0.872	0.095	0.780	0.071	0.755	0.077	0.795	0.055	0.781	0.056	0.756	0.029	0.755	0.026	0.749	0.026
3/31/2006	0.796	0.000	0.870	0.005	0.800	0.000	0.757	0.049	0.875	0.095	0.780	0.071	0.756	0.079	0.795	0.055	0.781	0.056	0.756	0.028	0.755	0.026	0.749	0.026
4/1/2006	0.796	0.000	0.869	0.007	0.799	0.000	0.757	0.049	0.878	0.096	0.782	0.071	0.757	0.080	0.795	0.056	0.781	0.056	0.755	0.028	0.754	0.026	0.750	0.026
4/2/2006	0.795	0.000	0.869	0.008	0.799	0.000	0.757	0.049	0.880	0.096	0.782	0.070	0.757	0.082	0.794	0.057	0.781	0.055	0.754	0.028	0.754	0.026	0.750	0.026
4/3/2006	0.795	0.000	0.869	0.009	0.799	0.000	0.757	0.050	0.881	0.097	0.782	0.070	0.758	0.084	0.794	0.059	0.782	0.056	0.754	0.028	0.754	0.026	0.750	0.026
4/4/2006	0.795	0.000	0.869	0.008	0.800	0.000	0.757	0.049	0.883	0.097	0.783	0.070	0.759	0.086	0.793	0.060	0.782	0.057	0.753	0.028	0.754	0.027	0.750	0.025
4/5/2006	0.794	0.000	0.868	0.007	0.800	0.000	0.757	0.049	0.885	0.097	0.784	0.070	0.761	0.087	0.792	0.062	0.782	0.057	0.753	0.028	0.754	0.027	0.750	0.026
4/6/2006	0.794	0.001	0.867	0.006	0.800	0.000	0.757	0.050	0.886	0.097	0.784	0.071	0.762	0.087	0.792	0.063	0.783	0.057	0.754	0.029	0.754	0.028	0.750	0.025
4/7/2006	0.794	0.002	0.867	0.006	0.801	0.000	0.757	0.050	0.887	0.097	0.783	0.071	0.763	0.088	0.792	0.063	0.784	0.059	0.754	0.029	0.754	0.029	0.750	0.026
4/8/2006	0.793	0.003	0.868	0.005	0.801	0.000	0.757	0.050	0.887	0.097	0.783	0.072	0.764	0.090	0.791	0.065	0.784	0.059	0.753	0.030	0.754	0.029	0.750	0.026
4/9/2006	0.793	0.003	0.868	0.005	0.802	0.000	0.757	0.051	0.886	0.099	0.783	0.072	0.766	0.091	0.791	0.066	0.785	0.059	0.753	0.030	0.754	0.029	0.750	0.026
4/10/2006	0.793	0.004	0.868	0.007	0.803	0.000	0.758	0.052	0.887	0.099	0.784	0.072	0.768	0.092	0.791	0.068	0.785	0.060	0.754	0.031	0.754	0.030	0.750	0.026
4/11/2006	0.794	0.005	0.868	0.008	0.803	0.000	0.758	0.052	0.888	0.100	0.785	0.072	0.769	0.093	0.790	0.069	0.786	0.060	0.754	0.032	0.754	0.031	0.750	0.026
4/12/2006	0.794	0.006	0.867	0.009	0.803	0.000	0.758	0.053	0.887	0.100	0.786	0.072	0.771	0.093	0.791	0.070	0.786	0.061	0.754	0.032	0.754	0.031	0.750	0.026
4/13/2006	0.794	0.007	0.868	0.010	0.803	0.000	0.758	0.054	0.887	0.100	0.787	0.071	0.772	0.093	0.790	0.072	0.787	0.061	0.753	0.032	0.754	0.031	0.750	0.026
4/14/2006	0.795	0.008	0.867	0.012	0.803	0.000	0.759	0.054	0.887	0.100	0.786	0.071	0.773	0.093	0.790	0.073	0.788	0.061	0.753	0.033	0.754	0.031	0.750	0.025
4/15/2006	0.794	0.010	0.867	0.014	0.801	0.000	0.759	0.054	0.888	0.099	0.786	0.070	0.775	0.093	0.789	0.075	0.789	0.062	0.753	0.033	0.754	0.031	0.750	0.025
4/16/2006	0.794	0.011	0.867	0.016	0.802	0.000	0.759	0.054	0.884	0.099	0.786	0.070	0.776	0.094	0.790	0.076	0.790	0.062	0.754	0.035	0.754	0.031	0.750	0.025
4/17/2006	0.795	0.013	0.868	0.018	0.802	0.000	0.759	0.055	0.882	0.099	0.786	0.069	0.777	0.095	0.789	0.078	0.791	0.063	0.753	0.036	0.754	0.032	0.750	0.025
4/18/2006	0.794	0.015	0.869	0.020	0.803	0.000	0.758	0.055	0.878	0.099	0.786	0.068	0.779	0.096	0.788	0.080	0.792	0.063	0.754	0.037	0.754	0.032	0.750	0.024
4/19/2006	0.794	0.017	0.869	0.022	0.803	0.000	0.758	0.056	0.876	0.098	0.786	0.067	0.780	0.097	0.788	0.082	0.793	0.064	0.754	0.039	0.754	0.033	0.750	0.024
4/20/2006	0.794	0.019	0.867	0.023	0.802	0.000	0.758	0.057	0.874	0.098	0.786	0.067	0.782	0.098	0.788	0.084	0.794	0.065	0.754	0.040	0.754	0.034	0.750	0.024
4/21/2006	0.793	0.021	0.867	0.024	0.803	0.000	0.757	0.057	0.869	0.098	0.786	0.067	0.786	0.100	0.787	0.085	0.796	0.065	0.754	0.040	0.754	0.035	0.750	0.025

Table A-2. Continued.

	T7-145 (20 cm)		T7-145 (40 cm)		T7-145 (67 cm)		T7-90 (23 cm)		T7-90 (40 cm)		T7-90 (66 cm)		T7-25 (23 cm)		T7-25 (46 cm)		T7-25 (66 cm)		T7-2 (16 cm)		T7-2 (32 cm)		T7-2 (48 cm)	
Date	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w
4/22/2006	0.818	0.029	0.867	0.021	0.807	0.000	0.757	0.058	0.868	0.098	0.786	0.067	0.806	0.123	0.787	0.087	0.791	0.065	0.753	0.041	0.754	0.036	0.750	0.025
4/23/2006	0.857	0.040	0.870	0.017	0.805	0.000	0.757	0.058	0.868	0.098	0.787	0.067	0.827	0.156	0.786	0.090	0.782	0.065	0.753	0.041	0.754	0.037	0.750	0.025
4/24/2006	0.854	0.040	0.871	0.012	0.796	0.000	0.757	0.058	0.863	0.099	0.787	0.067	0.814	0.161	0.786	0.093	0.780	0.064	0.752	0.042	0.754	0.038	0.750	0.025
4/25/2006	0.853	0.041	0.871	0.014	0.786	0.000	0.758	0.068	0.858	0.099	0.788	0.068	0.801	0.164	0.785	0.096	0.779	0.065	0.752	0.043	0.754	0.038	0.750	0.025
4/26/2006	0.844	0.045	0.871	0.018	0.779	0.000					0.785	0.070	0.792	0.163	0.785	0.097	0.781	0.075	0.752	0.045	0.754	0.038	0.750	0.024
4/27/2006	0.828	0.056	0.872	0.021	0.771	0.000							0.786	0.157	0.783	0.095	0.789	0.105	0.751	0.046	0.755	0.035	0.750	0.024
4/28/2006	0.827	0.058	0.871	0.024	0.765	0.000							0.780	0.157	0.784	0.097	0.787	0.105	0.751	0.046	0.755	0.036	0.750	0.024
4/29/2006	0.827	0.059	0.872	0.026	0.763	0.000							0.778	0.155	0.784	0.098	0.786	0.105	0.751	0.047	0.755	0.037	0.750	0.024
4/30/2006	0.828	0.060	0.873	0.028	0.762	0.000							0.776	0.154	0.784	0.100	0.785	0.105	0.751	0.049	0.755	0.038	0.750	0.024
5/1/2006	0.828	0.061	0.874	0.029	0.761	0.000							0.775	0.154	0.783	0.103	0.784	0.105	0.751	0.050	0.755	0.039	0.750	0.025
5/2/2006	0.828	0.062	0.874	0.030	0.760	0.000							0.773	0.153	0.783	0.106	0.783	0.105	0.751	0.051	0.755	0.040	0.750	0.025
5/3/2006	0.827	0.062	0.874	0.031	0.760	0.000							0.772	0.152	0.782	0.109	0.781	0.105	0.750	0.051	0.755	0.040	0.750	0.024
5/4/2006	0.825	0.064	0.873	0.033	0.759	0.000							0.770	0.151	0.782	0.113	0.781	0.105	0.750	0.052	0.755	0.041	0.750	0.025
5/5/2006	0.823	0.066	0.873	0.035	0.759	0.000							0.769	0.151	0.780	0.117	0.779	0.105	0.750	0.053	0.755	0.041	0.750	0.025
5/6/2006	0.823	0.068	0.873	0.037	0.759	0.000							0.767	0.153	0.782	0.119	0.779	0.105	0.750	0.054	0.755	0.042	0.750	0.025
5/7/2006	0.820	0.070	0.872	0.039	0.758	0.000							0.767	0.154	0.781	0.123	0.778	0.106	0.750	0.054	0.756	0.043	0.750	0.025
5/8/2006	0.819	0.072	0.872	0.041	0.759	0.000							0.765	0.159	0.780	0.125	0.778	0.106	0.751	0.055	0.756	0.044	0.750	0.024
5/9/2006	0.817	0.073	0.871	0.042	0.758	0.000							0.765	0.163	0.779	0.129	0.777	0.107	0.750	0.056	0.756	0.045	0.750	0.023
5/10/2006	0.814	0.074	0.874	0.044	0.759	0.000							0.764	0.168	0.780	0.131	0.776	0.108	0.752	0.062	0.756	0.046	0.750	0.024
5/11/2006	0.812	0.076	0.873	0.046	0.758	0.000							0.763	0.173	0.778	0.136	0.775	0.109	0.752	0.063	0.755	0.047	0.750	0.024
5/12/2006	0.809	0.078	0.872	0.048	0.758	0.000							0.766	0.177	0.779	0.139	0.775	0.109	0.752	0.064	0.755	0.048	0.750	0.023
5/13/2006	0.808	0.080	0.872	0.051	0.758	0.000							0.765	0.182	0.778	0.145	0.774	0.110	0.753	0.067	0.755	0.049	0.750	0.024
5/14/2006	0.807	0.083	0.872	0.054	0.758	0.000							0.764	0.187	0.777	0.151	0.772	0.111	0.753	0.068	0.755	0.050	0.750	0.023
5/15/2006	0.806	0.086	0.872	0.057	0.758	0.000							0.762	0.192	0.775	0.158	0.771	0.113	0.753	0.068	0.755	0.052	0.750	0.023
5/16/2006	0.804	0.088	0.872	0.059	0.757	0.000							0.762	0.198	0.776	0.164	0.770	0.114	0.753	0.070	0.755	0.053	0.750	0.023
5/17/2006	0.802	0.092	0.871	0.060	0.757	0.000							0.762	0.204	0.778	0.168	0.770	0.115	0.753	0.071	0.755	0.055	0.750	0.023
5/18/2006	0.803	0.095	0.872	0.063	0.758	0.000							0.762	0.211	0.776	0.174	0.769	0.116	0.753	0.073	0.755	0.056	0.750	0.024
5/19/2006	0.803	0.099	0.873	0.066	0.758	0.000							0.762	0.219	0.775	0.181	0.769	0.118	0.752	0.075	0.755	0.058	0.750	0.023
5/20/2006	0.800	0.104	0.873	0.070	0.758	0.000							0.760	0.229	0.777	0.185	0.769	0.119	0.752	0.075	0.755	0.059	0.750	0.024
5/21/2006	0.798	0.110	0.873	0.075	0.758	0.000							0.759	0.241	0.775	0.189	0.769	0.120	0.751	0.078	0.755	0.061	0.750	0.023
5/22/2006	0.796	0.117	0.873	0.079	0.757	0.000							0.758	0.252	0.774	0.193	0.768	0.122	0.750	0.084	0.755	0.064	0.750	0.023
5/23/2006	0.793	0.123	0.873	0.083	0.757	0.000							0.757	0.263	0.774	0.197	0.768	0.123	0.750	0.088	0.755	0.066	0.750	0.024
5/24/2006	0.794	0.128	0.873	0.087	0.757	0.000							0.756	0.271	0.777	0.198	0.767	0.126	0.750	0.087	0.755	0.067	0.750	0.024
5/25/2006	0.795	0.135	0.872	0.090	0.758	0.000							0.755	0.277	0.776	0.202	0.766	0.128	0.750	0.089	0.755	0.069	0.750	0.023
5/26/2006	0.793	0.139	0.873	0.093	0.757	0.000					0.813	0.085	0.756	0.279	0.775	0.208	0.765	0.131	0.750	0.091	0.755	0.071	0.750	0.024
5/27/2006	0.794	0.145	0.872	0.097	0.757	0.000					0.808	0.085	0.756	0.280	0.775	0.212	0.764	0.133	0.750	0.092	0.754	0.074	0.750	0.023
5/28/2006	0.791	0.149	0.872	0.100	0.757	0.000					0.807	0.088	0.756	0.283	0.776	0.217	0.764	0.135	0.750	0.094	0.754	0.076	0.750	0.024
5/29/2006	0.791	0.151	0.873	0.102	0.757	0.000					0.811	0.091	0.754	0.287	0.775	0.222	0.762	0.139	0.750	0.100	0.754	0.079	0.750	0.025
5/30/2006	0.787	0.154	0.872	0.104	0.757	0.000					0.815	0.092	0.756	0.287	0.777	0.224	0.761	0.141	0.750	0.108	0.754	0.081	0.750	0.025
5/31/2006	0.786	0.157	0.870	0.106	0.758	0.000	0.844	0.197	0.834	0.133	0.816	0.090	0.757	0.285	0.776	0.227	0.760	0.144	0.750	0.111	0.754	0.083	0.750	0.024
6/1/2006	0.786	0.158	0.871	0.106	0.758	0.000	0.843	0.201	0.836	0.134	0.820	0.094	0.755	0.287	0.778	0.228	0.759	0.147	0.750	0.115	0.754	0.086	0.750	0.024
6/2/2006	0.784	0.160	0.869	0.110	0.757	0.000	0.844	0.204	0.837	0.135	0.821	0.098	0.755	0.284	0.780	0.229	0.759	0.151	0.750	0.116	0.754	0.088	0.750	0.023
6/3/2006	0.782	0.161	0.867	0.107	0.756	0.000	0.844	0.204	0.837	0.135	0.824	0.099	0.760	0.273	0.779	0.232	0.758	0.154	0.750	0.116	0.754	0.089	0.750	0.024
6/4/2006	0.779	0.162	0.868	0.104	0.757	0.000	0.844	0.206	0.838	0.135	0.828	0.099	0.760	0.266	0.780	0.231	0.757	0.157	0.750	0.117	0.753	0.091	0.750	0.024
6/5/2006	0.779	0.161	0.866	0.098	0.757	0.000	0.843	0.208	0.837	0.136	0.830	0.098	0.761	0.267	0.779	0.233	0.757	0.159	0.750	0.119	0.753	0.092	0.750	0.023
6/6/2006	0.776	0.162	0.867	0.087	0.757	0.000	0.844	0.209	0.836	0.137	0.831	0.098	0.764	0.265	0.778	0.235	0.756	0.162	0.750	0.124	0.753	0.094	0.750	0.024
6/7/2006	0.777	0.161	0.867	0.074	0.756	0.000	0.844	0.210	0.836	0.137	0.831	0.098	0.764	0.265	0.780	0.233	0.755	0.166	0.749	0.131	0.753	0.097	0.750	0.024
6/8/2006	0.776	0.162	0.869	0.082	0.757	0.000	0.844	0.211	0.837	0.137	0.830	0.099	0.767	0.257	0.781	0.233	0.754	0.170	0.749	0.152	0.753	0.098	0.750	0.024
6/9/2006	0.779	0.162	0.869	0.094	0.757	0.000	0.843	0.217	0.838	0.137	0.831	0.100	0.766	0.251	0.779	0.234	0.754	0.174	0.749	0.167	0.753	0.100	0.750	0.024
6/10/2006	0.780	0.163	0.866	0.093	0.756	0.000	0.844	0.222	0.837	0.138	0.832	0.100	0.767	0.242	0.779	0.234	0.753	0.179	0.749	0.186	0.754	0.103	0.750	0.024

Table A-2. Continued.

	T7-145 (20 cm)		T7-145 (40 cm)		T7-145 (67 cm)		T7-90 (23 cm)		T7-90 (40 cm)		T7-90 (66 cm)		T7-25 (23 cm)		T7-25 (46 cm)		T7-25 (66 cm)		T7-2 (16 cm)		T7-2 (32 cm)		T7-2 (48 cm)	
Date	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w
6/11/2006	0.781	0.161	0.868	0.089	0.756	0.000	0.844	0.222	0.839	0.138	0.833	0.100	0.770	0.232	0.780	0.232	0.752	0.184	0.749	0.200	0.754	0.105	0.750	0.025
6/12/2006	0.779	0.160	0.867	0.100	0.756	0.000	0.844	0.222	0.839	0.139	0.836	0.099	0.772	0.226	0.782	0.227	0.752	0.188	0.749	0.206	0.753	0.107	0.750	0.025
6/13/2006	0.778	0.158	0.867	0.103	0.756	0.000	0.844	0.224	0.838	0.139	0.836	0.101	0.773	0.220	0.780	0.227	0.751	0.193	0.749	0.210	0.753	0.110	0.749	0.026
6/14/2006	0.775	0.160	0.866	0.102	0.756	0.000	0.844	0.224	0.838	0.139	0.838	0.102	0.776	0.210	0.778	0.226	0.750	0.198	0.749	0.235	0.753	0.112	0.749	0.026
6/15/2006	0.774	0.158	0.864	0.097	0.756	0.000	0.844	0.226	0.837	0.140	0.840	0.102	0.773	0.208	0.779	0.225	0.750	0.201	0.749	0.253	0.753	0.113	0.749	0.026
6/16/2006	0.772	0.157	0.864	0.083	0.755	0.000	0.843	0.227	0.838	0.140	0.842	0.103	0.770	0.209	0.778	0.224	0.750	0.203			0.753	0.115	0.749	0.028
6/17/2006	0.771	0.158	0.863	0.072	0.755	0.000	0.844	0.227	0.839	0.140	0.843	0.103	0.776	0.203	0.778	0.220	0.750	0.204			0.753	0.117	0.749	0.029
6/18/2006	0.767	0.162	0.866	0.071	0.756	0.000	0.844	0.225	0.837	0.142	0.842	0.103	0.779	0.197	0.780	0.218	0.749	0.211			0.753	0.120	0.749	0.028
6/19/2006	0.765	0.164	0.866	0.086	0.755	0.000	0.843	0.222	0.834	0.144	0.844	0.104	0.783	0.187	0.778	0.214	0.749	0.214			0.752	0.122	0.749	0.030
6/20/2006	0.763	0.164	0.866	0.089	0.756	0.000	0.842	0.222	0.834	0.144	0.846	0.105	0.786	0.179	0.777	0.213	0.749	0.217			0.753	0.123	0.749	0.031
6/21/2006	0.761	0.165	0.864	0.078	0.756	0.000	0.845	0.221	0.834	0.144	0.845	0.106	0.789	0.167	0.780	0.208	0.749	0.223			0.753	0.124	0.749	0.032
6/22/2006	0.761	0.164	0.865	0.074	0.755	0.000	0.848	0.221	0.835	0.144	0.843	0.107	0.795	0.151	0.778	0.206	0.749	0.227	0.791	0.197	0.753	0.124	0.749	0.033
6/23/2006	0.762	0.165	0.867	0.084	0.753	0.000	0.848	0.221	0.835	0.144	0.842	0.108	0.799	0.137	0.780	0.200	0.749	0.231	0.790	0.201	0.752	0.126	0.749	0.034
6/24/2006	0.764	0.165	0.870	0.092	0.753	0.000	0.846	0.222	0.836	0.145	0.843	0.108	0.802	0.129	0.779	0.197	0.750	0.235	0.784	0.201	0.752	0.127	0.749	0.035
6/25/2006	0.763	0.165	0.869	0.098	0.752	0.000	0.847	0.221	0.837	0.144	0.844	0.108	0.804	0.124	0.779	0.193	0.750	0.237	0.776	0.197	0.751	0.128	0.749	0.036
6/26/2006	0.763	0.166	0.869	0.102	0.752	0.000	0.843	0.220	0.836	0.145	0.842	0.109	0.805	0.122	0.781	0.188	0.750	0.240	0.771	0.191	0.751	0.130	0.749	0.037
6/27/2006	0.763	0.166	0.866	0.106	0.751	0.000	0.841	0.217	0.836	0.145	0.840	0.111	0.808	0.120	0.781	0.183	0.750	0.243	0.765	0.185	0.751	0.130	0.749	0.039
6/28/2006	0.763	0.165	0.867	0.110	0.752	0.000	0.841	0.216	0.836	0.146	0.842	0.111	0.809	0.119	0.778	0.180	0.750	0.247	0.759	0.173	0.750	0.131	0.749	0.040
6/29/2006	0.762	0.166	0.868	0.114	0.751	0.000	0.842	0.215	0.836	0.146	0.846	0.112	0.810	0.116	0.778	0.175	0.750	0.249	0.757	0.165	0.750	0.132	0.749	0.041
6/30/2006	0.763	0.164	0.866	0.109	0.751	0.000	0.843	0.214	0.836	0.146	0.849	0.112	0.811	0.114	0.779	0.170	0.750	0.251	0.757	0.158	0.750	0.133	0.749	0.042
7/1/2006	0.763	0.164	0.868	0.113	0.751	0.000	0.844	0.212	0.836	0.146	0.849	0.112	0.812	0.110	0.778	0.166	0.751	0.254	0.759	0.154	0.750	0.133	0.749	0.043
7/2/2006	0.762	0.163	0.867	0.117	0.751	0.000	0.846	0.211	0.836	0.146	0.848	0.112	0.811	0.107	0.777	0.162	0.750	0.254	0.759	0.150	0.750	0.133	0.749	0.044
7/3/2006	0.762	0.163	0.868	0.121	0.751	0.000	0.846	0.210	0.838	0.146	0.850	0.112	0.812	0.106	0.779	0.157	0.751	0.256	0.758	0.145	0.750	0.134	0.749	0.045
7/4/2006	0.762	0.162	0.868	0.120	0.751	0.000	0.842	0.210	0.838	0.146	0.853	0.113	0.812	0.106	0.779	0.155	0.751	0.256	0.758	0.140	0.750	0.134	0.749	0.047
7/5/2006	0.766	0.161	0.865	0.105	0.751	0.000	0.840	0.210	0.838	0.146	0.854	0.114	0.811	0.108	0.779	0.154	0.751	0.255	0.758	0.136	0.750	0.134	0.749	0.049
7/6/2006	0.767	0.159	0.865	0.095	0.751	0.000	0.847	0.208	0.838	0.147	0.855	0.114	0.821	0.105	0.779	0.150	0.751	0.258	0.757	0.133	0.750	0.133	0.749	0.049
7/7/2006	0.767	0.158	0.866	0.109	0.751	0.000	0.846	0.208	0.839	0.147	0.856	0.114	0.822	0.105	0.779	0.146	0.751	0.258	0.757	0.130	0.749	0.133	0.749	0.051
7/8/2006	0.769	0.155	0.869	0.115	0.751	0.000	0.846	0.207	0.839	0.147	0.859	0.115	0.826	0.103	0.781	0.141	0.751	0.259	0.758	0.127	0.750	0.133	0.749	0.052
7/9/2006	0.771	0.152	0.870	0.116	0.751	0.000	0.843	0.207	0.838	0.147	0.860	0.115	0.828	0.101	0.779	0.138	0.751	0.259	0.758	0.124	0.750	0.132	0.749	0.054
7/10/2006	0.771	0.150	0.870	0.116	0.751	0.000	0.844	0.205	0.838	0.147	0.861	0.116	0.825	0.093	0.779	0.136	0.751	0.259	0.758	0.122	0.750	0.132	0.749	0.055
7/11/2006	0.771	0.149	0.869	0.115	0.751	0.000	0.846	0.204	0.838	0.147	0.862	0.116	0.826	0.089	0.779	0.132	0.751	0.257	0.758	0.120	0.750	0.132	0.749	0.056
7/12/2006	0.771	0.146	0.871	0.113	0.750	0.000	0.844	0.204	0.837	0.147	0.863	0.117	0.825	0.083	0.780	0.128	0.751	0.256	0.757	0.118	0.750	0.132	0.749	0.057
7/13/2006	0.773	0.143	0.870	0.114	0.750	0.000	0.844	0.202	0.838	0.147	0.868	0.117	0.819	0.071	0.777	0.126	0.751	0.256	0.757	0.115	0.749	0.131	0.749	0.058
7/14/2006	0.772	0.142	0.868	0.113	0.751	0.000	0.842	0.201	0.839	0.147	0.868	0.116	0.805	0.055	0.777	0.122	0.751	0.255	0.757	0.113	0.750	0.132	0.749	0.059
7/15/2006	0.772	0.139	0.869	0.111	0.751	0.000	0.843	0.199	0.839	0.147	0.868	0.117	0.818	0.063	0.784	0.115	0.750	0.254	0.757	0.111	0.750	0.131	0.749	0.061
7/16/2006	0.773	0.136	0.866	0.108	0.751	0.000	0.842	0.197	0.839	0.147	0.868	0.117	0.814	0.053	0.786	0.111	0.750	0.251	0.756	0.108	0.750	0.131	0.749	0.062
7/17/2006	0.774	0.134	0.867	0.103	0.751	0.000	0.841	0.195	0.839	0.147	0.867	0.118	0.817	0.055	0.789	0.107	0.750	0.249	0.756	0.107	0.750	0.132	0.749	0.063
7/18/2006	0.778	0.128	0.874	0.106	0.750	0.000	0.839	0.194	0.840	0.147	0.868	0.118	0.810	0.046	0.792	0.101	0.750	0.246	0.756	0.105	0.749	0.133	0.749	0.064
7/19/2006	0.777	0.122	0.869	0.105	0.751	0.000	0.838	0.193	0.840	0.147	0.868	0.118	0.807	0.044	0.796	0.097	0.750	0.244	0.756	0.104	0.750	0.130	0.749	0.064
7/20/2006	0.778	0.117	0.868	0.103	0.751	0.000	0.841	0.190	0.840	0.147	0.868	0.118	0.811	0.046	0.797	0.094	0.750	0.242	0.756	0.103	0.750	0.128	0.749	0.065
7/21/2006	0.779	0.112	0.866	0.101	0.750	0.000	0.836	0.190	0.839	0.147	0.868	0.118	0.810	0.045	0.801	0.090	0.750	0.240	0.756	0.102	0.749	0.127	0.749	0.066
7/22/2006	0.781	0.106	0.867	0.098	0.750	0.000	0.835	0.189	0.838	0.147	0.868	0.118	0.802	0.041	0.809	0.084	0.750	0.236	0.756	0.101	0.749	0.126	0.749	0.067
7/23/2006	0.782	0.101	0.868	0.097	0.751	0.000	0.835	0.188	0.838	0.147	0.868	0.118	0.791	0.030	0.810	0.080	0.749	0.233	0.755	0.101	0.749	0.124	0.749	0.067
7/24/2006	0.783	0.096	0.866	0.097	0.751	0.000	0.831	0.188	0.837	0.147	0.869	0.118	0.785	0.024	0.813	0.077	0.749	0.228	0.755	0.100	0.749	0.124	0.749	0.067
7/25/2006	0.784	0.092	0.866	0.094	0.750	0.000	0.830	0.186	0.837	0.147	0.868	0.118	0.790	0.032	0.810	0.078	0.749	0.226	0.754	0.099	0.749	0.123	0.749	0.068
7/26/2006	0.785	0.090	0.867	0.092	0.750	0.000	0.830	0.185	0.836	0.147	0.868	0.118	0.792	0.040	0.811	0.077	0.749	0.224	0.754	0.098	0.749	0.122	0.749	0.068
7/27/2006	0.783	0.088	0.866	0.090	0.750	0.000	0.833	0.183	0.836	0.147	0.869	0.118	0.786	0.038	0.814	0.076	0.749	0.221	0.755	0.097	0.749	0.122	0.749	0.069
7/28/2006	0.783	0.088	0.864	0.076	0.750	0.000	0.829	0.184	0.835	0.148	0.868	0.119	0.781	0.035	0.813	0.076	0.749	0.219	0.755	0.096	0.749	0.121	0.749	0.069
7/29/2006	0.782	0.087	0.864	0.061	0.750	0.000	0.826	0.183	0.835	0.147	0.869	0.118	0.782	0.040	0.813	0.077	0.749	0.219	0.754	0.094	0.749	0.120	0.749	0.070
7/30/2006	0.780	0.088	0.864	0.054	0.750	0.000	0.827	0.183	0.836	0.147	0.869	0.119	0.779	0.041	0.812	0.077	0.749	0.219	0.754	0.093	0.749	0.120	0.749	0.070

Table A-2. Continued.

	T7-145 (20 cm)		T7-145 (40 cm)		T7-145 (67 cm)		T7-90 (23 cm)		T7-90 (40 cm)		T7-90 (66 cm)		T7-25 (23 cm)		T7-25 (46 cm)		T7-25 (66 cm)		T7-2 (16 cm)		T7-2 (32 cm)		T7-2 (48 cm)	
Date	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w
7/31/2006	0.779	0.088	0.864	0.046	0.750	0.000	0.829	0.183	0.836	0.147	0.869	0.119	0.775	0.043	0.815	0.077	0.749	0.218	0.754	0.091	0.749	0.120	0.749	0.071
8/1/2006	0.778	0.088	0.864	0.040	0.750	0.000	0.827	0.183	0.836	0.147	0.870	0.119	0.773	0.047	0.813	0.078	0.749	0.218	0.754	0.088	0.749	0.119	0.750	0.071
8/2/2006	0.777	0.089	0.864	0.037	0.750	0.000	0.827	0.183	0.837	0.147	0.871	0.119	0.765	0.048	0.809	0.081	0.749	0.214	0.754	0.084	0.749	0.118	0.750	0.071
8/3/2006	0.775	0.089	0.864	0.037	0.750	0.000	0.822	0.181	0.836	0.148	0.877	0.118	0.759	0.051	0.804	0.083	0.749	0.216	0.754	0.082	0.749	0.118	0.750	0.072
8/4/2006	0.775	0.090	0.862	0.035	0.750	0.000	0.813	0.183	0.830	0.152	0.880	0.120	0.757	0.054	0.802	0.084	0.749	0.214	0.754	0.081	0.749	0.118	0.750	0.075
8/5/2006	0.775	0.091	0.862	0.032	0.751	0.000	0.815	0.183	0.826	0.152	0.877	0.122	0.771	0.061	0.801	0.085	0.749	0.215	0.754	0.078	0.749	0.117	0.750	0.075
8/6/2006	0.776	0.090	0.863	0.039	0.751	0.000	0.826	0.182	0.823	0.153	0.869	0.123	0.799	0.061	0.806	0.082	0.749	0.217	0.754	0.076	0.749	0.116	0.750	0.075
8/7/2006	0.776	0.089	0.863	0.049	0.751	0.000	0.826	0.184	0.823	0.153	0.866	0.125	0.801	0.060	0.808	0.081	0.749	0.214	0.754	0.074	0.749	0.116	0.750	0.076
8/8/2006	0.776	0.089	0.863	0.057	0.751	0.000	0.824	0.185	0.824	0.153	0.868	0.125	0.802	0.058	0.809	0.081	0.749	0.211	0.754	0.073	0.749	0.115	0.750	0.076
8/9/2006	0.776	0.088	0.863	0.062	0.751	0.000	0.822	0.185	0.824	0.153	0.869	0.126	0.810	0.064	0.807	0.081	0.749	0.210	0.755	0.071	0.749	0.115	0.750	0.076
8/10/2006	0.777	0.088	0.863	0.065	0.751	0.000	0.821	0.185	0.822	0.154	0.869	0.129	0.813	0.063	0.806	0.081	0.749	0.207	0.754	0.071	0.749	0.114	0.750	0.076
8/11/2006	0.777	0.088	0.864	0.067	0.751	0.000	0.820	0.186	0.823	0.153	0.870	0.130	0.789	0.029	0.820	0.076	0.749	0.205	0.754	0.070	0.749	0.113	0.750	0.076
8/12/2006	0.778	0.088	0.864	0.069	0.751	0.000							0.782	0.017	0.825	0.073	0.749	0.202	0.755	0.070	0.749	0.112	0.750	0.076
8/13/2006	0.778	0.088	0.864	0.070	0.751	0.000							0.801	0.039	0.817	0.076	0.749	0.200	0.754	0.070	0.749	0.112	0.750	0.076
8/14/2006	0.778	0.088	0.865	0.072	0.751	0.000							0.818	0.055	0.811	0.077	0.750	0.198	0.754	0.070	0.749	0.111	0.750	0.076
8/15/2006	0.778	0.088	0.865	0.072	0.751	0.000							0.823	0.059	0.809	0.078	0.750	0.195	0.754	0.070	0.749	0.110	0.750	0.077
8/16/2006	0.778	0.088	0.864	0.073	0.751	0.000							0.827	0.062	0.809	0.078	0.750	0.192	0.754	0.069	0.749	0.109	0.750	0.077
8/17/2006	0.779	0.087	0.863	0.073	0.751	0.000							0.818	0.054	0.811	0.076	0.750	0.192	0.754	0.069	0.749	0.108	0.750	0.076
8/18/2006	0.778	0.087	0.863	0.073	0.751	0.000							0.823	0.058	0.810	0.076	0.750	0.189	0.754	0.070	0.749	0.108	0.750	0.076
8/19/2006	0.779	0.086	0.865	0.072	0.751	0.000							0.826	0.059	0.810	0.076	0.750	0.186	0.754	0.070	0.749	0.108	0.750	0.076
8/20/2006	0.779	0.085	0.866	0.072	0.751	0.000							0.818	0.051	0.813	0.074	0.750	0.184	0.753	0.070	0.749	0.107	0.750	0.076
8/21/2006	0.781	0.084	0.869	0.073	0.751	0.000							0.807	0.041	0.814	0.072	0.750	0.181	0.753	0.070	0.749	0.105	0.750	0.075
8/22/2006	0.781	0.084	0.869	0.072	0.751	0.000							0.808	0.041	0.815	0.071	0.751	0.178	0.753	0.069	0.749	0.104	0.750	0.075
8/23/2006	0.783	0.083	0.870	0.072	0.751	0.000							0.798	0.028	0.821	0.068	0.751	0.174	0.752	0.069	0.749	0.103	0.750	0.075
8/24/2006	0.781	0.081	0.868	0.070	0.751	0.000							0.796	0.026	0.823	0.066	0.752	0.171	0.753	0.070	0.749	0.099	0.750	0.074
8/25/2006	0.780	0.079	0.862	0.069	0.751	0.000							0.792	0.021	0.827	0.065	0.752	0.170	0.753	0.070	0.749	0.097	0.750	0.073
8/26/2006	0.780	0.078	0.864	0.068	0.751	0.000							0.784	0.014	0.830	0.062	0.752	0.168	0.753	0.070	0.749	0.096	0.750	0.073
8/27/2006	0.781	0.076	0.866	0.068	0.751	0.000							0.784	0.012	0.827	0.062	0.752	0.166	0.753	0.070	0.749	0.096	0.750	0.073
8/28/2006	0.782	0.076	0.866	0.068	0.751	0.000							0.784	0.013	0.827	0.060	0.753	0.162	0.753	0.070	0.749	0.095	0.750	0.073
8/29/2006	0.782	0.076	0.864	0.067	0.751	0.000							0.782	0.011	0.826	0.059	0.753	0.160	0.753	0.070	0.749	0.095	0.750	0.072
8/30/2006	0.781	0.074	0.864	0.065	0.751	0.000							0.777	0.005	0.825	0.058	0.754	0.157	0.753	0.069	0.749	0.096	0.750	0.072
8/31/2006	0.781	0.074	0.865	0.067	0.751	0.000							0.777	0.004	0.823	0.058	0.753	0.158	0.753	0.069	0.749	0.096	0.750	0.071
9/1/2006	0.780	0.073	0.866	0.067	0.750	0.000	0.820	0.154	0.811	0.152	0.848	0.129	0.784	0.000	0.806	0.062	0.754	0.156	0.752	0.070	0.749	0.094	0.750	0.072
9/2/2006	0.779	0.070	0.865	0.065	0.751	0.000	0.820	0.153	0.809	0.153	0.846	0.128	0.788	0.000	0.817	0.057	0.754	0.156						
9/3/2006	0.779	0.069	0.866	0.063	0.751	0.000	0.819	0.151	0.809	0.153	0.845	0.128	0.784	0.000	0.821	0.054	0.754	0.153						
9/4/2006	0.779	0.067	0.867	0.061	0.751	0.000	0.820	0.149	0.809	0.152	0.844	0.128	0.783	0.001	0.821	0.053	0.754	0.152						
9/5/2006	0.779	0.065	0.866	0.057	0.751	0.000	0.819	0.147	0.808	0.152	0.841	0.128	0.782	0.000	0.821	0.053	0.754	0.151						
9/6/2006	0.778	0.064	0.866	0.051	0.751	0.000	0.821	0.145	0.808	0.152	0.842	0.128	0.766	0.000	0.821	0.051	0.754	0.149						
9/7/2006	0.777	0.063	0.867	0.049	0.751	0.000	0.821	0.144	0.808	0.151	0.842	0.128	0.766	0.000	0.822	0.048	0.755	0.147						
9/8/2006	0.775	0.062	0.868	0.048	0.751	0.000	0.822	0.142	0.808	0.151	0.842	0.129	0.771	0.000	0.821	0.048	0.755	0.146	0.786	0.068	0.787	0.101	0.750	0.072
9/9/2006	0.776	0.063	0.868	0.045	0.751	0.000	0.823	0.141	0.808	0.152	0.846	0.129							0.801	0.071	0.811	0.102	0.750	0.072
9/10/2006	0.776	0.063	0.868	0.040	0.751	0.000	0.823	0.140	0.808	0.151	0.845	0.129							0.798	0.070	0.801	0.101	0.750	0.072
9/11/2006	0.775	0.064	0.868	0.035	0.751	0.000	0.821	0.140	0.808	0.151	0.845	0.129							0.793	0.069	0.789	0.099	0.750	0.071
9/12/2006	0.775	0.064	0.868	0.032	0.751	0.000	0.820	0.138	0.808	0.151	0.847	0.130							0.791	0.067	0.780	0.097	0.750	0.071
9/13/2006	0.774	0.064	0.868	0.030	0.751	0.000	0.819	0.138	0.808	0.151	0.847	0.130							0.788	0.065	0.773	0.094	0.750	0.070
9/14/2006	0.772	0.064	0.868	0.027	0.751	0.000	0.816	0.137	0.808	0.151	0.849	0.130							0.786	0.063	0.765	0.090	0.750	0.070
9/15/2006	0.771	0.066	0.867	0.027	0.753	0.000	0.817	0.137	0.807	0.153	0.839	0.130	0.779	0.000	0.818	0.039	0.757	0.138	0.784	0.061	0.761	0.087	0.750	0.069
9/16/2006	0.767	0.066	0.862	0.027	0.753	0.000	0.823	0.139	0.805	0.156	0.833	0.129	0.779	0.000	0.817	0.041	0.756	0.138	0.782	0.059	0.760	0.086	0.750	0.069
9/17/2006	0.764	0.065	0.856	0.027	0.753	0.000	0.822	0.140	0.803	0.156	0.834	0.129	0.779	0.000	0.816	0.039	0.757	0.136	0.780	0.058	0.760	0.087	0.750	0.068
9/18/2006	0.762	0.065	0.854	0.027	0.753	0.000	0.821	0.140	0.803	0.154	0.831	0.129	0.779	0.000	0.814	0.042	0.757	0.135	0.778	0.057	0.760	0.087	0.750	0.068

Table A-2. Continued.

	T7-145 (20 cm)		T7-145 (40 cm)		T7-145 (67 cm)		T7-90 (23 cm)		T7-90 (40 cm)		T7-90 (66 cm)		T7-25 (23 cm)		T7-25 (46 cm)		T7-25 (66 cm)		T7-2 (16 cm)		T7-2 (32 cm)		T7-2 (48 cm)	
Date	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w
9/19/2006	0.760	0.064	0.852	0.031	0.753	0.000	0.819	0.140	0.803	0.153	0.828	0.129	0.779	0.000	0.823	0.043	0.757	0.134	0.777	0.055	0.759	0.087	0.751	0.068
9/20/2006	0.758	0.062	0.853	0.040	0.751	0.000	0.818	0.140	0.801	0.151	0.828	0.128	0.779	0.000	0.863	0.046	0.756	0.133	0.769	0.057	0.756	0.090	0.751	0.065
9/21/2006	0.757	0.062	0.854	0.042	0.750	0.000	0.817	0.139	0.799	0.151	0.829	0.127	0.779	0.000	0.861	0.046	0.757	0.131	0.765	0.058	0.757	0.090	0.751	0.063
9/22/2006	0.757	0.062	0.854	0.043	0.750	0.000	0.817	0.139	0.797	0.150	0.825	0.128	0.779	0.000	0.854	0.047	0.757	0.130	0.763	0.060	0.756	0.090	0.751	0.063
9/23/2006	0.756	0.062	0.853	0.045	0.750	0.000	0.815	0.138	0.796	0.149	0.823	0.127	0.779	0.000	0.851	0.048	0.758	0.128	0.762	0.060	0.756	0.088	0.751	0.063
9/24/2006	0.756	0.061	0.853	0.046	0.750	0.000	0.816	0.137	0.794	0.148	0.823	0.126	0.779	0.000	0.855	0.045	0.758	0.127	0.761	0.059	0.756	0.086	0.751	0.062
9/25/2006	0.756	0.060	0.851	0.047	0.750	0.000	0.815	0.137	0.792	0.147	0.818	0.125	0.779	0.000	0.851	0.046	0.758	0.126	0.760	0.059	0.756	0.085	0.751	0.062
9/26/2006	0.756	0.059	0.852	0.048	0.750	0.000	0.814	0.137	0.793	0.145	0.813	0.125	0.779	0.000	0.842	0.051	0.760	0.123	0.760	0.059	0.756	0.083	0.751	0.061
9/27/2006	0.756	0.057	0.852	0.048	0.750	0.000	0.815	0.135	0.791	0.145	0.810	0.123	0.779	0.000	0.841	0.058	0.760	0.123	0.759	0.059	0.756	0.082	0.751	0.061
9/28/2006	0.756	0.056	0.851	0.047	0.750	0.000	0.812	0.136	0.791	0.143	0.808	0.122	0.779	0.000	0.822	0.059			0.759	0.059	0.756	0.080	0.751	0.062
9/29/2006	0.756	0.054	0.848	0.047	0.750	0.000	0.811	0.136	0.789	0.142	0.807	0.122	0.779	0.000	0.809	0.070			0.758	0.060	0.756	0.079	0.751	0.061
9/30/2006	0.757	0.052	0.850	0.047	0.750	0.000	0.812	0.134	0.789	0.141	0.807	0.122	0.779	0.000	0.807	0.073			0.756	0.062	0.756	0.077	0.751	0.062
10/1/2006	0.757	0.051	0.851	0.047	0.750	0.000	0.812	0.134	0.788	0.141	0.805	0.122	0.779	0.000	0.811	0.070			0.756	0.062	0.756	0.076	0.751	0.062
10/2/2006	0.757	0.049	0.853	0.046	0.750	0.000	0.810	0.134	0.789	0.140	0.805	0.122	0.779	0.000	0.796	0.077	0.753	0.092	0.756	0.062	0.755		0.751	0.062
10/3/2006	0.757	0.047	0.855	0.047	0.750	0.000	0.810	0.133	0.789	0.139	0.806	0.121	0.779	0.000	0.780	0.084	0.753	0.089	0.755	0.061	0.755		0.751	0.062
10/4/2006	0.757	0.046	0.855	0.046	0.750	0.000	0.809	0.133	0.789	0.139	0.805	0.122	0.779	0.000	0.779	0.084	0.753	0.090	0.755	0.061	0.755		0.751	0.062
10/5/2006	0.758	0.045	0.855	0.044	0.750	0.000	0.809	0.133	0.789	0.138	0.806	0.121	0.779	0.000	0.785	0.080	0.753	0.090	0.755	0.061	0.755		0.751	0.062
10/6/2006	0.758	0.045	0.856	0.042	0.750	0.000	0.810	0.132	0.789	0.138	0.806	0.121	0.779	0.000	0.781	0.082	0.753	0.087	0.755	0.062	0.754		0.751	0.062
10/7/2006	0.758	0.045	0.857	0.041	0.751	0.000	0.809	0.132	0.788	0.138	0.804	0.121	0.779	0.000	0.781	0.082	0.753	0.087	0.755	0.062	0.754		0.751	0.062
10/8/2006	0.758	0.044	0.856	0.041	0.751	0.000	0.809	0.132	0.789	0.137	0.804	0.120	0.779	0.000	0.785	0.079	0.753	0.086	0.755	0.062	0.754		0.751	0.061
10/9/2006	0.758	0.044	0.858	0.041	0.751	0.000	0.810	0.131	0.790	0.137	0.804	0.120	0.779	0.000	0.786	0.078	0.753	0.084	0.754	0.063	0.754		0.751	0.062
10/10/2006	0.759	0.045	0.860	0.039	0.751	0.000	0.810	0.131	0.791	0.137	0.805	0.120	0.779	0.000	0.786	0.078	0.753	0.085	0.754	0.063	0.754		0.751	0.062
10/11/2006	0.761	0.047	0.859	0.037	0.751	0.000	0.810	0.131	0.792	0.136	0.805	0.119	0.779	0.000	0.786	0.077	0.753	0.082	0.754	0.064	0.754		0.751	0.062
10/12/2006	0.761	0.048	0.857	0.036	0.751	0.000	0.808	0.131	0.792	0.136	0.805	0.119	0.779	0.002	0.788	0.076	0.753	0.083	0.754	0.064	0.753		0.751	0.061
10/13/2006	0.761	0.047	0.857	0.038	0.751	0.000	0.811	0.129	0.794	0.136	0.806	0.118	0.779	0.005	0.792	0.074	0.752	0.084	0.754	0.064	0.753		0.751	0.061
10/14/2006	0.761	0.047	0.855	0.039	0.751	0.000	0.812	0.129	0.794	0.136	0.805	0.118	0.779	0.006	0.784	0.077	0.753	0.084	0.753	0.064	0.753		0.751	0.061
10/15/2006	0.761	0.047	0.857	0.039	0.751	0.000	0.809	0.129	0.794	0.137	0.804	0.118	0.779	0.002	0.784	0.077	0.753	0.084	0.753	0.064	0.754		0.751	0.062
10/16/2006	0.761	0.046	0.859	0.041	0.751	0.000	0.809	0.129	0.797	0.136	0.805	0.118	0.779	0.003	0.787	0.074	0.754	0.082	0.753	0.065	0.754		0.751	0.061
10/17/2006	0.760	0.047	0.859	0.043	0.751	0.000	0.811	0.128	0.799	0.136	0.804	0.118	0.779	0.005	0.785	0.074	0.753	0.082	0.752	0.065	0.753		0.751	0.061
10/18/2006	0.761	0.047	0.858	0.043	0.751	0.000	0.810	0.128	0.799	0.136	0.805	0.118	0.779	0.008	0.789	0.073	0.754	0.081	0.752	0.065	0.753		0.751	0.061
10/19/2006	0.763	0.048	0.857	0.044	0.751	0.000	0.810	0.127	0.799	0.136	0.806	0.117	0.779	0.015	0.794	0.070	0.754	0.080	0.752	0.065	0.753		0.751	0.061
10/20/2006	0.763	0.047	0.858	0.045	0.751	0.000	0.810	0.126	0.800	0.135	0.806	0.117	0.779	0.023	0.793	0.070	0.754	0.079	0.752	0.064	0.753		0.751	0.060
10/21/2006	0.763	0.046	0.858	0.046	0.752	0.000	0.810	0.126	0.802	0.134	0.807	0.117	0.779	0.030	0.794	0.071	0.754	0.078	0.752	0.065	0.753		0.751	0.061
10/22/2006	0.763	0.045	0.859	0.046	0.752	0.000	0.811	0.125	0.803	0.134	0.808	0.117	0.779	0.027	0.796	0.069	0.755	0.077	0.752	0.065	0.753		0.751	0.060
10/23/2006	0.763	0.045	0.859	0.046	0.752	0.000	0.811	0.124	0.802	0.133	0.807	0.116	0.779	0.020	0.794	0.069	0.754	0.072	0.752	0.065	0.753		0.751	0.060
10/24/2006	0.764	0.045	0.859	0.046	0.752	0.000	0.810	0.124	0.805	0.132	0.808	0.116	0.779	0.022	0.784	0.074	0.755	0.058	0.751	0.066	0.753		0.751	0.060
10/25/2006	0.768	0.046	0.859	0.046	0.752	0.000	0.811	0.124	0.806	0.132	0.809	0.116	0.779	0.027	0.788	0.072	0.756	0.066	0.751	0.069	0.753		0.751	0.061
10/26/2006	0.770	0.047	0.860	0.046	0.752	0.000	0.811	0.123	0.808	0.131	0.811	0.115	0.779	0.037	0.794	0.069	0.756	0.068	0.751	0.070	0.753		0.751	0.060
10/27/2006	0.771	0.046	0.860	0.046	0.752	0.000	0.812	0.122	0.810	0.129	0.810	0.115	0.779	0.049	0.807	0.063	0.756	0.070	0.751	0.070	0.753		0.751	0.060
10/28/2006	0.771	0.046	0.861	0.046	0.752	0.000	0.812	0.121	0.810	0.128	0.810	0.114	0.779	0.046	0.802	0.063	0.756	0.070	0.751	0.070	0.753		0.751	0.060
10/29/2006	0.771	0.046	0.861	0.046	0.753	0.000	0.814	0.120	0.811	0.128	0.812	0.114	0.779	0.042	0.793	0.067	0.757	0.069	0.751	0.070	0.753		0.751	0.060
10/30/2006	0.772	0.046	0.862	0.045	0.753	0.000	0.813	0.120	0.811	0.126	0.812	0.113	0.779	0.041	0.801	0.063	0.757	0.068	0.751	0.070	0.753		0.751	0.061
10/31/2006	0.774	0.044	0.862	0.044	0.754	0.000	0.813	0.119	0.813	0.125	0.812	0.112	0.779	0.038	0.806	0.060	0.757	0.066	0.751	0.070	0.753		0.751	0.061
11/1/2006	0.774	0.044	0.862	0.045	0.755	0.000	0.814	0.118	0.813	0.124	0.813	0.112	0.779	0.048	0.804	0.060	0.757	0.065	0.751	0.070	0.753		0.751	0.061
11/2/2006	0.774	0.043	0.861	0.045	0.755	0.000	0.813	0.118	0.814	0.123	0.813	0.112	0.779	0.057	0.801	0.063	0.757	0.063	0.751	0.070	0.753		0.751	0.061
11/3/2006	0.773	0.043	0.861	0.045	0.755	0.000	0.814	0.117	0.814	0.123	0.814	0.111	0.779	0.055	0.798	0.065	0.758	0.059	0.751	0.070	0.752		0.751	0.061
11/4/2006	0.771	0.043	0.861	0.044	0.755	0.000	0.814	0.116	0.815	0.122	0.816	0.111	0.779	0.055	0.797	0.065	0.759	0.059	0.751	0.071	0.752		0.751	0.061
11/5/2006	0.771	0.043	0.860	0.044	0.756	0.000	0.814	0.116	0.815	0.121	0.817	0.110	0.779	0.055	0.795	0.066	0.758	0.059	0.751	0.071	0.751		0.751	0.062
11/6/2006	0.772	0.043	0.861	0.045	0.756	0.000	0.814	0.115	0.815	0.120	0.816	0.110	0.779	0.055	0.798	0.065	0.759	0.062	0.751	0.071	0.751		0.751	0.061
11/7/2006	0.771	0.043	0.861	0.045	0.756	0.000	0.813	0.114	0.815	0.119	0.817	0.109	0.779	0.051	0.802	0.063	0.759	0.062	0.751	0.071	0.751		0.751	0.058

Table A-2. Continued.

	T7-145 (20 cm)		T7-145 (40 cm)		T7-145 (67 cm)		T7-90 (23 cm)		T7-90 (40 cm)		T7-90 (66 cm)		T7-25 (23 cm)		T7-25 (46 cm)		T7-25 (66 cm)		T7-2 (16 cm)		T7-2 (32 cm)		T7-2 (48 cm)	
Date	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w
11/8/2006	0.771	0.044	0.862	0.045	0.756	0.000	0.813	0.114	0.814	0.119	0.817	0.109	0.779	0.041	0.803	0.063	0.759	0.061	0.751	0.071	0.751		0.751	0.056
11/9/2006	0.772	0.044	0.862	0.045	0.756	0.000	0.815	0.113	0.815	0.118	0.816	0.109	0.779	0.038	0.793	0.068	0.759	0.061	0.751	0.071	0.751		0.751	0.056
11/10/2006	0.773	0.044	0.862	0.045	0.756	0.000	0.814	0.113	0.817	0.117	0.816	0.109	0.779	0.045	0.796	0.067	0.759	0.059	0.751	0.071	0.751		0.751	0.055
11/11/2006	0.774	0.044	0.862	0.045	0.756	0.000	0.815	0.112	0.817	0.116	0.815	0.109	0.779	0.049	0.801	0.064	0.760	0.061	0.751	0.072	0.751		0.751	0.056
11/12/2006	0.774	0.044	0.863	0.045	0.756	0.000	0.816	0.111	0.816	0.115	0.817	0.108	0.779	0.050	0.804	0.063	0.760	0.060	0.750	0.073	0.751		0.751	0.055
11/13/2006	0.775	0.045	0.864	0.044	0.757	0.000	0.816	0.111	0.817	0.115	0.817	0.108	0.794	0.055	0.807	0.063	0.760	0.060	0.825	0.075	0.774	0.093	0.751	0.055
11/14/2006	0.775	0.045	0.864	0.044	0.757	0.000	0.816	0.110	0.819	0.113	0.816	0.108	0.813	0.061	0.812	0.059	0.761	0.059	0.920	0.080	0.802	0.093		
11/15/2006	0.777	0.044	0.869	0.043	0.758	0.000	0.818	0.109	0.819	0.113	0.817	0.107	0.805	0.058	0.801	0.056	0.761	0.059	0.900	0.080	0.798	0.091		
11/16/2006	0.777	0.044	0.869	0.042	0.758	0.000	0.817	0.108	0.819	0.112	0.818	0.105	0.796	0.056	0.789	0.051	0.760	0.059	0.878	0.080	0.792	0.089		
11/17/2006	0.776	0.044	0.866	0.041	0.757	0.000	0.816	0.108	0.819	0.111	0.819	0.104	0.787	0.053	0.780	0.047	0.759	0.058	0.860	0.078	0.788	0.087		
11/18/2006	0.776	0.044	0.866	0.041	0.758	0.000	0.817	0.107	0.821	0.110	0.819	0.104	0.781	0.049	0.775	0.043	0.758	0.056	0.843	0.077	0.783	0.087		
11/19/2006	0.778	0.044	0.866	0.041	0.758	0.000	0.818	0.106	0.820	0.110	0.819	0.104	0.776	0.047	0.772	0.041	0.757	0.054	0.837	0.075	0.781	0.085		
11/20/2006	0.780	0.043	0.866	0.041	0.758	0.000	0.819	0.106	0.822	0.108	0.820	0.104	0.774	0.045	0.771	0.040	0.756	0.054	0.835	0.076	0.777	0.084		
11/21/2006	0.782	0.044	0.869	0.041	0.759	0.000	0.820	0.104	0.823	0.107	0.822	0.103	0.773	0.043	0.770	0.039	0.756	0.052	0.837	0.075	0.777	0.084		
11/22/2006	0.785	0.044	0.871	0.042	0.760	0.000	0.823	0.103	0.825	0.107	0.823	0.102	0.772	0.042	0.770	0.038	0.755	0.052	0.838	0.074	0.776	0.084		
11/23/2006	0.786	0.044	0.872	0.042	0.760	0.000	0.825	0.102	0.828	0.106	0.824	0.102	0.773	0.042	0.770	0.037	0.756	0.050	0.838	0.074	0.777	0.084		
11/24/2006	0.786	0.044	0.873	0.041	0.762	0.000	0.827	0.101	0.830	0.105	0.827	0.102	0.773	0.041	0.770	0.036	0.755	0.049	0.836	0.075	0.776	0.084		
11/25/2006	0.787	0.044	0.873	0.042	0.761	0.000	0.827	0.100	0.833	0.104	0.827	0.101	0.772	0.041	0.769	0.035	0.755	0.049	0.836	0.075	0.777	0.083		
11/26/2006	0.786	0.044	0.872	0.041	0.767	0.000	0.830	0.100	0.836	0.105	0.829	0.101	0.773	0.041	0.769	0.035	0.756	0.048	0.835	0.076	0.777	0.083		
11/27/2006	0.786	0.044	0.872	0.042	0.766	0.000	0.831	0.100	0.837	0.104	0.831	0.101	0.771	0.041	0.768	0.035	0.755	0.048	0.833	0.077	0.777	0.083		
11/28/2006	0.786	0.044	0.871	0.043	0.761	0.000	0.827	0.099	0.835	0.103	0.828	0.100	0.771	0.041	0.766	0.034	0.755	0.047	0.832	0.078	0.775	0.083		
11/29/2006	0.785	0.044	0.869	0.042	0.762	0.000	0.826	0.099	0.835	0.102	0.828	0.100	0.770	0.041	0.765	0.033	0.755	0.047	0.830	0.080	0.775	0.082		
11/30/2006	0.785	0.044	0.868	0.042	0.762	0.000	0.826	0.099	0.834	0.102	0.830	0.099	0.769	0.040	0.764	0.033	0.755	0.046	0.829	0.082	0.775	0.082		
12/1/2006	0.785	0.044	0.867	0.043	0.762	0.000	0.825	0.098	0.832	0.101	0.829	0.099	0.768	0.040	0.763	0.032	0.755	0.046	0.825	0.087	0.775	0.082		
12/2/2006	0.784	0.044	0.867	0.043	0.762	0.000	0.825	0.098	0.831	0.101	0.830	0.098	0.767	0.041	0.762	0.032	0.755	0.046	0.823	0.092	0.775	0.082		
12/3/2006	0.784	0.044	0.865	0.042	0.762	0.000	0.826	0.097	0.831	0.100	0.831	0.098	0.766	0.041	0.761	0.032	0.755	0.044	0.822	0.095	0.775	0.082		
12/4/2006	0.785	0.044	0.863	0.042	0.762	0.000	0.826	0.097	0.830	0.099	0.832	0.097	0.766	0.042	0.761	0.032	0.754	0.045	0.821	0.098	0.774	0.083		
12/5/2006	0.784	0.046	0.863	0.042	0.763	0.000	0.829	0.095	0.832	0.098	0.832	0.097	0.766	0.042	0.760	0.033	0.754	0.045	0.822	0.101	0.773	0.083		
12/6/2006	0.786	0.046	0.865	0.042	0.763	0.000	0.828	0.095	0.832	0.097	0.833	0.097	0.766	0.043	0.760	0.033	0.755	0.044	0.822	0.102	0.773	0.084		
12/7/2006	0.786	0.047	0.866	0.042	0.763	0.000	0.829	0.094	0.832	0.096	0.834	0.096	0.765	0.043	0.759	0.033	0.754	0.043	0.821	0.104	0.774	0.085		
12/8/2006	0.787	0.048	0.864	0.041	0.764	0.000	0.832	0.093	0.833	0.096	0.836	0.096	0.766	0.044	0.759	0.033	0.755	0.043	0.820	0.106	0.774	0.086		
12/9/2006	0.789	0.049	0.866	0.042	0.764	0.000	0.831	0.093	0.832	0.095	0.836	0.095	0.766	0.044	0.759	0.033	0.755	0.042	0.821	0.106	0.774	0.085		
12/10/2006	0.789	0.049	0.867	0.042	0.764	0.000	0.831	0.092	0.833	0.094	0.835	0.095	0.766	0.045	0.758	0.033	0.754	0.042	0.820	0.107	0.773	0.085		
12/11/2006	0.790	0.050	0.867	0.042	0.765	0.000	0.835	0.091	0.832	0.093	0.836	0.095	0.766	0.046	0.757	0.033	0.755	0.042	0.821	0.107	0.772	0.085		
12/12/2006	0.790	0.051	0.867	0.041	0.764	0.000	0.835	0.091	0.832	0.093	0.838	0.094	0.766	0.046	0.757	0.032	0.754	0.042	0.820	0.107	0.772	0.086		
12/13/2006	0.789	0.052	0.865	0.041	0.765	0.000	0.835	0.091	0.832	0.092	0.838	0.093	0.766	0.046	0.756	0.032	0.754	0.041	0.818	0.108	0.772	0.087		
12/14/2006	0.789	0.052	0.862	0.041	0.765	0.000	0.833	0.090	0.833	0.092	0.838	0.093	0.765	0.046	0.757	0.032	0.754	0.041	0.817	0.108	0.773	0.089		
12/15/2006	0.791	0.052	0.866	0.042	0.766	0.000	0.834	0.090	0.833	0.091	0.838	0.093	0.765	0.047	0.756	0.032	0.755	0.042	0.818	0.108	0.772	0.089	0.749	0.086
12/16/2006	0.792	0.053	0.868	0.042	0.767	0.000	0.834	0.090	0.833	0.090	0.839	0.093	0.765	0.048	0.756	0.033	0.755	0.042	0.817	0.107	0.773	0.089	0.749	0.086
12/17/2006	0.792	0.053	0.870	0.043	0.767	0.000	0.835	0.089	0.832	0.091	0.839	0.093	0.765	0.048	0.756	0.033	0.754	0.042	0.818	0.106	0.773	0.089	0.749	0.087
12/18/2006	0.793	0.053	0.869	0.043	0.767	0.000	0.836	0.089	0.832	0.091	0.839	0.093	0.765	0.047	0.756	0.032	0.754	0.042	0.818	0.105	0.772	0.090	0.749	0.086
12/19/2006	0.800	0.055	0.877	0.043	0.776	0.000	0.838	0.089	0.834	0.091	0.842	0.092	0.765	0.047	0.755	0.032	0.754	0.042	0.818	0.105	0.772	0.091	0.749	0.086
12/20/2006	0.795	0.054	0.878	0.044	0.775	0.000	0.838	0.089	0.833	0.091	0.841	0.092	0.765	0.047	0.755	0.032	0.754	0.041	0.819	0.105	0.772	0.091	0.749	0.086
12/21/2006	0.796	0.055	0.878	0.043	0.775	0.000	0.838	0.090	0.834	0.090	0.841	0.092	0.765	0.047	0.755	0.032	0.754	0.041	0.818	0.104	0.772	0.091	0.749	0.086
12/22/2006	0.792	0.054	0.878	0.043	0.773	0.000	0.839	0.089	0.832	0.090	0.841	0.091	0.765	0.046	0.755	0.031	0.754	0.041	0.818	0.103	0.772	0.091	0.749	0.086
12/23/2006	0.793	0.055	0.878	0.043	0.773	0.000	0.839	0.090	0.832	0.090	0.841	0.091	0.765	0.046	0.754	0.031	0.754	0.041	0.818	0.102	0.772	0.091	0.749	0.085
12/24/2006	0.796	0.054	0.878	0.043	0.773	0.000	0.841	0.090	0.833	0.090	0.843	0.091	0.765	0.047	0.754	0.031	0.754	0.041	0.818	0.101	0.771	0.092	0.749	0.085
12/25/2006	0.796	0.054	0.867	0.042	0.767	0.000	0.840	0.089	0.832	0.089	0.841	0.091	0.765	0.047	0.757	0.033	0.754	0.041	0.816	0.101	0.770	0.093	0.749	0.085
12/26/2006	0.798	0.055	0.867	0.041	0.768	0.000	0.843	0.089	0.830	0.090	0.843	0.091	0.765	0.048	0.757	0.034	0.755	0.043	0.817	0.100	0.771	0.092	0.749	0.084
12/27/2006	0.801	0.056	0.870	0.042	0.768	0.000	0.843	0.090	0.830	0.090	0.842	0.091	0.766	0.048	0.757	0.035	0.755	0.043	0.821	0.098	0.772	0.092	0.749	0.084

Table A-2. Continued.

	T7-145 (20 cm)		T7-145 (40 cm)		T7-145 (67 cm)		T7-90 (23 cm)		T7-90 (40 cm)		T7-90 (66 cm)		T7-25 (23 cm)		T7-25 (46 cm)		T7-25 (66 cm)		T7-2 (16 cm)		T7-2 (32 cm)		T7-2 (48 cm)	
Date	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w
12/28/2006	0.820	0.059	0.877	0.043	0.773	0.000	0.845	0.090	0.832	0.090	0.844	0.091	0.766	0.047	0.757	0.033	0.755	0.042	0.822	0.095	0.773	0.092	0.749	0.084
12/29/2006	0.822	0.059	0.878	0.043	0.773	0.000	0.848	0.089	0.834	0.090	0.846	0.090	0.766	0.046	0.757	0.032	0.754	0.042	0.821	0.092	0.773	0.091	0.749	0.084
12/30/2006	0.824	0.059	0.878	0.043	0.773	0.000	0.848	0.089	0.834	0.090	0.846	0.090	0.767	0.045	0.756	0.031	0.754	0.041	0.820	0.092	0.773	0.091	0.749	0.083
12/31/2006	0.824	0.059	0.878	0.042	0.773	0.000	0.850	0.089	0.835	0.090	0.847	0.090	0.767	0.045	0.756	0.031	0.754	0.041	0.819	0.091	0.773	0.091	0.749	0.083
1/1/2007	0.826	0.060	0.878	0.042	0.773	0.000	0.852	0.089	0.836	0.090	0.851	0.090	0.766	0.045	0.756	0.031	0.755	0.041	0.818	0.090	0.773	0.091	0.749	0.082
1/2/2007	0.825	0.059	0.878	0.042	0.773	0.000	0.851	0.088	0.834	0.090	0.849	0.089	0.766	0.044	0.756	0.030	0.755	0.041	0.819	0.090	0.773	0.090	0.749	0.082
1/3/2007	0.825	0.059	0.878	0.043	0.773	0.000	0.853	0.089	0.835	0.090	0.850	0.090	0.767	0.044	0.756	0.030	0.755	0.041	0.819	0.089	0.774	0.090	0.749	0.082
1/4/2007	0.823	0.059	0.878	0.042	0.772	0.000	0.855	0.089	0.836	0.090	0.853	0.090	0.766	0.044	0.756	0.031	0.755	0.041	0.820	0.089	0.773	0.090	0.749	0.082
1/5/2007	0.826	0.059	0.878	0.043	0.773	0.000	0.850	0.088	0.834	0.090	0.853	0.089	0.766	0.044	0.755	0.030	0.755	0.041	0.819	0.089	0.772	0.089	0.749	0.082
1/6/2007	0.827	0.059	0.873	0.041	0.770	0.000	0.842	0.086	0.828	0.088	0.840	0.087	0.766	0.044	0.755	0.031	0.755	0.042	0.818	0.089	0.772	0.089	0.749	0.081
1/7/2007	0.826	0.058	0.869	0.040	0.767	0.000	0.845	0.087	0.830	0.089	0.843	0.088	0.766	0.043	0.755	0.030	0.755	0.042	0.818	0.088	0.772	0.089	0.749	0.081
1/8/2007	0.828	0.057	0.871	0.039	0.768	0.000	0.845	0.086	0.830	0.088	0.842	0.087	0.767	0.043	0.754	0.030	0.755	0.042	0.819	0.088	0.771	0.089	0.749	0.081
1/9/2007	0.829	0.057	0.874	0.040	0.769	0.000	0.846	0.086	0.831	0.088	0.843	0.087	0.767	0.043	0.754	0.030	0.755	0.044	0.820	0.088	0.771	0.090	0.749	0.081
1/10/2007	0.829	0.057	0.874	0.039	0.769	0.000	0.845	0.086	0.830	0.088	0.843	0.087	0.768	0.042	0.754	0.028	0.755	0.044	0.822	0.087	0.772	0.090	0.749	0.081
1/11/2007	0.829	0.056	0.875	0.036	0.769	0.000	0.846	0.086	0.831	0.088	0.843	0.086	0.768	0.042	0.753	0.028	0.755	0.042	0.824	0.086	0.773	0.089	0.749	0.080
1/12/2007	0.827	0.056	0.878	0.036	0.771	0.000	0.847	0.085	0.831	0.087	0.842	0.086	0.768	0.041	0.753	0.028	0.755	0.042	0.826	0.085	0.772	0.088	0.749	0.080
1/13/2007	0.829	0.057	0.878	0.035	0.771	0.000	0.847	0.085	0.833	0.087	0.844	0.086	0.768	0.041	0.753	0.028	0.755	0.042	0.823	0.086	0.772	0.087	0.749	0.080
1/14/2007	0.831	0.057	0.878	0.034	0.772	0.000	0.848	0.086	0.833	0.087	0.844	0.086	0.768	0.041	0.753	0.028	0.755	0.043	0.825	0.085	0.773	0.086	0.749	0.080
1/15/2007	0.835	0.057	0.878	0.032	0.773	0.000	0.849	0.086	0.833	0.088	0.845	0.086	0.769	0.042	0.754	0.028	0.756	0.042	0.825	0.085	0.773	0.085	0.749	0.080
1/16/2007	0.836	0.057	0.878	0.032	0.773	0.000	0.849	0.086	0.833	0.088	0.845	0.086	0.768	0.043	0.753	0.028	0.756	0.043	0.826	0.084	0.772	0.086	0.749	0.080
1/17/2007	0.832	0.056	0.878	0.033	0.772	0.000	0.847	0.087	0.833	0.088	0.845	0.086	0.769	0.043	0.754	0.027	0.756	0.043	0.826	0.083	0.773	0.086	0.749	0.080
1/18/2007	0.836	0.056	0.878	0.034	0.773	0.000	0.849	0.086	0.834	0.088	0.846	0.087	0.770	0.043	0.754	0.027	0.756	0.044	0.826	0.082	0.773	0.086	0.749	0.080
1/19/2007	0.836	0.056	0.878	0.036	0.774	0.000	0.849	0.087	0.834	0.088	0.847	0.086	0.770	0.042	0.754	0.027	0.756	0.043	0.827	0.082	0.773	0.085	0.749	0.080
1/20/2007	0.837	0.056	0.878	0.037	0.774	0.000	0.849	0.086	0.834	0.088	0.847	0.087	0.770	0.042	0.754	0.028	0.756	0.043	0.827	0.081	0.773	0.085	0.749	0.080
1/21/2007	0.838	0.056	0.878	0.037	0.774	0.000	0.850	0.086	0.836	0.088	0.848	0.086	0.770	0.041	0.754	0.027	0.756	0.043	0.825	0.081	0.773	0.084	0.749	0.080
1/22/2007	0.840	0.056	0.878	0.038	0.774	0.000	0.853	0.086	0.836	0.088	0.851	0.087	0.770	0.041	0.754	0.026	0.756	0.042	0.824	0.080	0.772	0.084	0.749	0.079
1/23/2007	0.840	0.056	0.878	0.039	0.774	0.000	0.849	0.086	0.833	0.088	0.849	0.086	0.770	0.041	0.754	0.027	0.756	0.043	0.825	0.080	0.772	0.083	0.749	0.080
1/24/2007	0.842	0.057	0.878	0.039	0.775	0.000	0.841	0.084	0.829	0.087	0.840	0.085	0.770	0.042	0.754	0.027	0.757	0.043	0.826	0.080	0.773	0.082	0.749	0.079
1/25/2007	0.843	0.057	0.874	0.038	0.773	0.000	0.843	0.085	0.829	0.087	0.842	0.085	0.770	0.043	0.754	0.028	0.757	0.045	0.826	0.079	0.772	0.082	0.749	0.079
1/26/2007	0.845	0.058	0.874	0.038	0.772	0.000	0.843	0.085	0.830	0.087	0.842	0.085	0.771	0.042	0.754	0.028	0.757	0.044	0.828	0.080	0.772	0.082	0.749	0.078
1/27/2007	0.846	0.058	0.875	0.039	0.771	0.000	0.845	0.084	0.831	0.087	0.841	0.085	0.771	0.041	0.754	0.027	0.757	0.044	0.826	0.079	0.772	0.082	0.749	0.078
1/28/2007	0.845	0.058	0.874	0.039	0.771	0.000	0.845	0.084	0.832	0.087	0.840	0.085	0.771	0.041	0.754	0.027	0.757	0.042	0.825	0.079	0.772	0.081	0.749	0.078
1/29/2007	0.847	0.059	0.878	0.039	0.774	0.000	0.843	0.084	0.829	0.086	0.839	0.084	0.772	0.043	0.755	0.029	0.757	0.044	0.827	0.079	0.773	0.081	0.749	0.077
1/30/2007	0.844	0.059	0.877	0.039	0.774	0.000	0.844	0.083	0.831	0.086	0.839	0.084	0.773	0.042	0.755	0.029	0.757	0.043	0.829	0.079	0.773	0.082	0.749	0.077
1/31/2007	0.836	0.058	0.874	0.038	0.771	0.000	0.846	0.083	0.835	0.086	0.842	0.084	0.773	0.042	0.755	0.029	0.757	0.043	0.829	0.079	0.773	0.082	0.749	0.077
2/1/2007	0.836	0.057	0.876	0.039	0.771	0.000	0.846	0.082	0.836	0.086	0.843	0.084	0.773	0.041	0.755	0.028	0.757	0.042	0.829	0.079	0.773	0.083	0.749	0.077
2/2/2007	0.834	0.058	0.875	0.040	0.771	0.000	0.847	0.082	0.836	0.086	0.843	0.083	0.773	0.041	0.756	0.028	0.757	0.041	0.826	0.079	0.773	0.082	0.749	0.077
2/3/2007	0.833	0.059	0.874	0.040	0.772	0.000	0.847	0.082	0.837	0.086	0.841	0.084	0.773	0.042	0.757	0.029	0.758	0.043	0.824	0.079	0.772	0.083	0.749	0.076
2/4/2007	0.832	0.059	0.869	0.038	0.773	0.000	0.847	0.081	0.837	0.085	0.843	0.083	0.773	0.043	0.757	0.031	0.758	0.044	0.824	0.079	0.773	0.083	0.749	0.076
2/5/2007	0.834	0.059	0.871	0.038	0.774	0.000	0.847	0.081	0.837	0.085	0.845	0.083	0.774	0.043	0.757	0.031	0.758	0.044	0.826	0.079	0.773	0.083	0.749	0.076
2/6/2007	0.833	0.060	0.872	0.039	0.773	0.000	0.847	0.082	0.836	0.085	0.843	0.083	0.773	0.044	0.757	0.032	0.759	0.043	0.825	0.079	0.772	0.083	0.749	0.075
2/7/2007	0.834	0.060	0.875	0.040	0.773	0.000	0.848	0.081	0.836	0.085	0.843	0.082	0.773	0.044	0.757	0.032	0.759	0.043	0.825	0.080	0.772	0.083	0.749	0.075
2/8/2007	0.834	0.060	0.875	0.040	0.772	0.000	0.847	0.081	0.836	0.084	0.843	0.082	0.772	0.045	0.757	0.031	0.758	0.043	0.827	0.080	0.771	0.083	0.749	0.075
2/9/2007	0.833	0.061	0.875	0.040	0.772	0.000	0.849	0.081	0.836	0.084	0.843	0.082	0.773	0.045	0.757	0.031	0.758	0.043	0.827	0.081	0.772	0.083	0.749	0.075
2/10/2007	0.833	0.061	0.874	0.041	0.773	0.000	0.849	0.081	0.837	0.084	0.843	0.082	0.773	0.045	0.757	0.031	0.758	0.043	0.828	0.081	0.772	0.082	0.749	0.074
2/11/2007	0.832	0.061	0.874	0.040	0.773	0.000	0.849	0.081	0.837	0.084	0.844	0.081	0.773	0.046	0.757	0.031	0.758	0.043	0.830	0.081	0.773	0.082	0.749	0.074
2/12/2007	0.832	0.061	0.874	0.039	0.773	0.000	0.848	0.081	0.837	0.084	0.842	0.080	0.774	0.046	0.757	0.032	0.758	0.042	0.827	0.082	0.773	0.082	0.749	0.074
2/13/2007	0.831	0.061	0.873	0.040	0.773	0.000	0.848	0.081	0.837	0.084	0.843	0.081	0.774	0.046	0.758	0.031	0.759	0.043	0.827	0.082	0.773	0.082	0.749	0.074
2/14/2007	0.830	0.061	0.872	0.040	0.773	0.000	0.848	0.081	0.837	0.084	0.845	0.081	0.773	0.046	0.757	0.031	0.759	0.042	0.827	0.083	0.772	0.083	0.749	0.074
2/15/2007	0.830	0.062	0.873	0.038	0.774	0.000	0.849	0.081	0.837	0.084	0.844	0.080	0.774	0.048	0.759	0.033	0.759	0.044	0.827	0.084	0.772	0.084	0.749	0.074

Table A-2. Continued.

	T7-145 (20 cm)		T7-145 (40 cm)		T7-145 (67 cm)		T7-90 (23 cm)		T7-90 (40 cm)		T7-90 (66 cm)		T7-25 (23 cm)		T7-25 (46 cm)		T7-25 (66 cm)		T7-2 (16 cm)		T7-2 (32 cm)		T7-2 (48 cm)	
Date	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w
2/16/2007	0.831	0.063	0.874	0.038	0.775	0.000	0.847	0.081	0.837	0.084	0.844	0.081	0.775	0.048	0.760	0.034	0.760	0.044	0.829	0.084	0.773	0.084	0.749	0.074
2/17/2007	0.835	0.064	0.875	0.040	0.776	0.000	0.848	0.081	0.837	0.084	0.844	0.080	0.776	0.048	0.760	0.035	0.760	0.044	0.831	0.084	0.774	0.084	0.749	0.073
2/18/2007	0.836	0.065	0.875	0.041	0.776	0.000	0.848	0.081	0.837	0.084	0.844	0.081	0.777	0.048	0.761	0.035	0.760	0.044	0.833	0.084	0.774	0.084	0.749	0.073
2/19/2007	0.837	0.067	0.876	0.042	0.776	0.000	0.849	0.081	0.839	0.083	0.843	0.080	0.779	0.049	0.762	0.036	0.760	0.044	0.835	0.084	0.775	0.084	0.749	0.073
2/20/2007	0.837	0.068	0.877	0.043	0.776	0.000	0.849	0.080	0.839	0.083	0.846	0.081	0.780	0.049	0.763	0.036	0.760	0.044	0.835	0.084	0.775	0.085	0.749	0.073
2/21/2007	0.835	0.069	0.878	0.044	0.776	0.000	0.851	0.080	0.840	0.083	0.845	0.080	0.779	0.049	0.763	0.037	0.760	0.044	0.833	0.084	0.774	0.085	0.749	0.073
2/22/2007	0.834	0.070	0.878	0.044	0.777	0.000	0.851	0.080	0.841	0.083	0.846	0.080	0.779	0.050	0.763	0.037	0.760	0.044	0.833	0.084	0.774	0.085	0.749	0.073
2/23/2007	0.832	0.071	0.877	0.044	0.778	0.000	0.850	0.080	0.839	0.083	0.846	0.080	0.779	0.052	0.763	0.038	0.761	0.044	0.831	0.086	0.774	0.085	0.749	0.073
2/24/2007	0.831	0.072	0.875	0.045	0.778	0.000	0.852	0.080	0.839	0.083	0.846	0.080	0.779	0.053	0.764	0.040	0.761	0.045	0.831	0.086	0.775	0.084	0.749	0.073
2/25/2007	0.829	0.074	0.875	0.046	0.778	0.000	0.851	0.081	0.839	0.083	0.845	0.080	0.779	0.054	0.764	0.041	0.761	0.045	0.830	0.088	0.774	0.085	0.749	0.072
2/26/2007	0.828	0.074	0.872	0.045	0.778	0.000	0.851	0.080	0.839	0.083	0.846	0.079	0.778	0.056	0.764	0.043	0.761	0.045	0.828	0.090	0.774	0.085	0.749	0.072
2/27/2007	0.825	0.075	0.871	0.045	0.779	0.000	0.851	0.080	0.839	0.083	0.846	0.080	0.777	0.058	0.764	0.044	0.761	0.045	0.827	0.093	0.773	0.085	0.749	0.072
2/28/2007	0.824	0.074	0.871	0.043	0.779	0.000	0.849	0.081	0.839	0.084	0.846	0.079	0.776	0.061	0.764	0.047	0.761	0.046	0.826	0.096	0.773	0.085	0.749	0.072
3/1/2007	0.821	0.075	0.871	0.044	0.780	0.000	0.849	0.081	0.837	0.084	0.846	0.080	0.776	0.063	0.764	0.049	0.761	0.046	0.827	0.098	0.772	0.086	0.749	0.072
3/2/2007	0.820	0.077	0.869	0.045	0.781	0.000	0.849	0.081	0.837	0.084	0.845	0.080	0.776	0.064	0.764	0.050	0.761	0.046	0.825	0.100	0.772	0.086	0.749	0.072
3/3/2007	0.819	0.078	0.869	0.046	0.781	0.000	0.848	0.081	0.837	0.084	0.845	0.080	0.775	0.066	0.765	0.051	0.762	0.047	0.824	0.102	0.772	0.086	0.749	0.072
3/4/2007	0.819	0.079	0.870	0.046	0.782	0.000	0.848	0.082	0.836	0.084	0.845	0.080	0.775	0.069	0.765	0.053	0.762	0.048	0.824	0.104	0.772	0.087	0.749	0.072
3/5/2007	0.821	0.080	0.869	0.046	0.783	0.000	0.848	0.082	0.836	0.084	0.845	0.080	0.775	0.070	0.765	0.055	0.762	0.048	0.826	0.106	0.772	0.087	0.749	0.072
3/6/2007	0.823	0.080	0.870	0.043	0.783	0.000	0.849	0.082	0.836	0.085	0.845	0.080	0.775	0.073	0.765	0.056	0.762	0.049	0.829	0.108	0.772	0.088	0.749	0.072
3/7/2007	0.822	0.082	0.870	0.044	0.784	0.000	0.849	0.082	0.838	0.085	0.846	0.081	0.777	0.074	0.766	0.057	0.762	0.049	0.829	0.110	0.772	0.089	0.749	0.072
3/8/2007	0.822	0.084	0.870	0.046	0.784	0.000	0.850	0.082	0.837	0.085	0.845	0.080	0.776	0.076	0.766	0.058	0.762	0.050	0.831	0.111	0.772	0.090	0.749	0.072
3/9/2007	0.819	0.088	0.870	0.049	0.785	0.000	0.851	0.082	0.840	0.085	0.845	0.081	0.777	0.077	0.766	0.059	0.762	0.051	0.830	0.114	0.771	0.091	0.749	0.072
3/10/2007	0.819	0.090	0.869	0.049	0.785	0.000	0.849	0.083	0.839	0.085	0.845	0.081	0.776	0.079	0.766	0.060	0.762	0.051	0.828	0.117	0.772	0.091	0.749	0.072
3/11/2007	0.818	0.090	0.869	0.046	0.785	0.000	0.850	0.082	0.838	0.085	0.846	0.080	0.775	0.082	0.766	0.062	0.762	0.052	0.826	0.122	0.772	0.092	0.749	0.072
3/12/2007	0.817	0.089	0.869	0.043	0.786	0.000	0.851	0.082	0.839	0.085	0.846	0.080	0.775	0.087	0.767	0.065	0.762	0.053	0.827	0.126	0.773	0.092	0.749	0.072
3/13/2007	0.816	0.090	0.868	0.040	0.787	0.000	0.849	0.083	0.837	0.086	0.846	0.080	0.774	0.091	0.766	0.069	0.762	0.054	0.826	0.130	0.772	0.094	0.749	0.072
3/14/2007	0.816	0.090	0.870	0.039	0.787	0.000	0.849	0.083	0.837	0.086	0.845	0.080	0.772	0.099	0.766	0.076	0.762	0.055	0.826	0.135	0.771	0.096	0.749	0.072
3/15/2007	0.816	0.091	0.870	0.037	0.787	0.000	0.847	0.084	0.837	0.086	0.844	0.080	0.770	0.113	0.765	0.084	0.762	0.056	0.824	0.142	0.770	0.098	0.749	0.072
3/16/2007	0.814	0.093	0.871	0.038	0.789	0.000	0.847	0.083	0.835	0.087	0.843	0.080	0.768	0.125	0.765	0.094	0.762	0.057	0.824	0.148	0.771	0.099	0.749	0.072
3/17/2007	0.813	0.098	0.873	0.044	0.790	0.001	0.846	0.084	0.836	0.087	0.844	0.080	0.769	0.126	0.764	0.100	0.762	0.059	0.822	0.157	0.770	0.104	0.749	0.072
3/18/2007	0.814	0.101	0.873	0.049	0.791	0.001	0.846	0.084	0.836	0.087	0.847	0.083	0.769	0.128	0.765	0.104	0.762	0.060	0.823	0.164	0.771	0.108	0.749	0.072
3/19/2007	0.813	0.104	0.873	0.054	0.792	0.002	0.847	0.084	0.836	0.087	0.850	0.085	0.770	0.129	0.765	0.106	0.761	0.062	0.825	0.171	0.770	0.112	0.749	0.073
3/20/2007	0.811	0.109	0.872	0.058	0.792	0.002	0.848	0.084	0.836	0.088	0.847	0.083	0.771	0.131	0.766	0.107	0.761	0.064	0.821	0.181	0.770	0.116	0.749	0.072
3/21/2007	0.806	0.116	0.869	0.063	0.791	0.002	0.849	0.085	0.837	0.087	0.846	0.082	0.769	0.136	0.765	0.109	0.761	0.065	0.823	0.194	0.769	0.120	0.749	0.073
3/22/2007	0.801	0.123	0.865	0.067	0.791	0.002	0.848	0.085	0.835	0.088	0.845	0.081	0.769	0.141	0.765	0.113	0.761	0.067	0.813	0.214	0.769	0.125	0.749	0.073
3/23/2007	0.796	0.130	0.865	0.071	0.791	0.002	0.848	0.086	0.836	0.088	0.844	0.082	0.768	0.147	0.763	0.119	0.761	0.069	0.809	0.236	0.769	0.129	0.749	0.073
3/24/2007	0.791	0.138	0.864	0.078	0.791	0.002	0.847	0.087	0.836	0.088	0.843	0.082	0.765	0.157	0.762	0.128	0.761	0.072	0.806	0.261	0.769	0.136	0.749	0.072
3/25/2007	0.787	0.146	0.861	0.080	0.791	0.002	0.848	0.088	0.835	0.089	0.843	0.082	0.763	0.170	0.760	0.141	0.760	0.074	0.803	0.289	0.768	0.148	0.749	0.073
3/26/2007	0.785	0.150	0.860	0.078	0.791	0.003	0.847	0.089	0.834	0.090	0.841	0.083	0.761	0.184	0.760	0.151	0.760	0.077	0.803	0.313	0.767	0.164	0.749	0.073
3/27/2007	0.782	0.153	0.860	0.072	0.791	0.003	0.846	0.090	0.833	0.090	0.842	0.083	0.758	0.198	0.759	0.159	0.760	0.080	0.799	0.335	0.767	0.164	0.749	0.073
3/28/2007	0.782	0.153	0.861	0.068	0.791	0.002	0.844	0.090	0.830	0.089	0.838	0.082	0.756	0.201	0.758	0.157	0.759	0.082	0.793	0.346	0.767	0.169	0.749	0.071
3/29/2007							0.846	0.090	0.835	0.090	0.843	0.083	0.757	0.208	0.759	0.159	0.760	0.086	0.794	0.352	0.767	0.188	0.749	0.073
3/30/2007							0.847	0.092	0.833	0.092	0.841	0.084	0.755	0.227	0.758	0.175	0.759	0.091	0.791	0.362	0.767	0.211	0.749	0.074
3/31/2007							0.845	0.093	0.834	0.093	0.842	0.085	0.755	0.238	0.757	0.188	0.759	0.094	0.791	0.369	0.767	0.235	0.749	0.075
4/1/2007							0.846	0.094	0.834	0.093	0.843	0.086	0.755	0.248	0.756	0.196	0.759	0.098	0.794	0.373	0.767	0.253	0.749	0.077
4/2/2007							0.846	0.095	0.834	0.094	0.843	0.086	0.754	0.258	0.757	0.202	0.759	0.100	0.795	0.376	0.767	0.266	0.749	0.077
4/3/2007							0.845	0.097	0.832	0.095	0.843	0.087	0.753	0.268	0.755	0.210	0.759	0.104	0.797	0.374	0.767	0.268	0.749	0.078
4/4/2007							0.844	0.098	0.832	0.095	0.844	0.087	0.752	0.279	0.755	0.218	0.759	0.108	0.789	0.379	0.767	0.269	0.749	0.078
4/5/2007							0.845	0.100	0.833	0.096	0.841	0.088	0.751	0.289	0.754	0.227	0.759	0.111	0.790	0.381	0.767	0.273	0.749	0.079
4/6/2007							0.842	0.101	0.832	0.096	0.840	0.088	0.751	0.301	0.754	0.235	0.758	0.116	0.791	0.379	0.767	0.275	0.749	0.079

Table A-2. Continued.

	T7-145 (20 cm)		T7-145 (40 cm)		T7-145 (67 cm)		T7-90 (23 cm)		T7-90 (40 cm)		T7-90 (66 cm)		T7-25 (23 cm)		T7-25 (46 cm)		T7-25 (66 cm)		T7-2 (16 cm)		T7-2 (32 cm)		T7-2 (48 cm)	
Date	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w
4/7/2007							0.843	0.102	0.831	0.098	0.841	0.088	0.750	0.310	0.754	0.239	0.758	0.120	0.790	0.381	0.767	0.277	0.749	0.080
4/8/2007							0.843	0.103	0.831	0.099	0.840	0.088	0.750	0.316	0.753	0.246	0.758	0.124	0.798	0.374	0.767	0.289	0.749	0.081
4/9/2007							0.844	0.104	0.831	0.101	0.841	0.090	0.750	0.324	0.754	0.251	0.758	0.128	0.799	0.372	0.767	0.289	0.749	0.082
4/10/2007							0.837	0.104	0.825	0.101	0.832	0.087	0.750	0.324	0.752	0.254	0.756	0.131	0.782	0.369	0.767	0.291	0.749	0.082
4/11/2007							0.791	0.090	0.792	0.091	0.787	0.070	0.750	0.282	0.749	0.227	0.750	0.106	0.750	0.321	0.767	0.244	0.752	0.069
4/12/2007							0.777	0.084	0.772	0.082	0.765	0.063	0.751	0.257	0.750	0.222	0.750	0.095	0.750	0.318	0.767	0.228	0.752	0.078
4/13/2007							0.767	0.075	0.757	0.069	0.758	0.057	0.751	0.235	0.750	0.216	0.751	0.091	0.750	0.314	0.767	0.215	0.752	0.081
4/14/2007							0.762	0.066	0.752	0.060	0.754	0.046	0.751	0.228	0.750	0.218	0.751	0.088	0.750	0.319	0.767	0.201	0.752	0.079
4/15/2007							0.763	0.072	0.754	0.069	0.756	0.051	0.752	0.253	0.750	0.240	0.750	0.100	0.751	0.335	0.767	0.211	0.752	0.087
4/16/2007							0.762	0.077	0.754	0.073	0.758	0.055	0.752	0.266	0.751	0.253	0.751	0.107	0.751	0.348	0.767	0.218	0.752	0.090
4/17/2007							0.761	0.077	0.754	0.073	0.762	0.054	0.752	0.272	0.751	0.262	0.751	0.113	0.753	0.349	0.767	0.222	0.752	0.092
4/18/2007							0.761	0.076	0.755	0.074	0.762	0.053	0.752	0.278	0.751	0.268	0.751	0.117	0.753	0.347	0.767	0.223	0.752	0.092
4/19/2007							0.761	0.073	0.754	0.071	0.761	0.050	0.752	0.273	0.751	0.269	0.751	0.118	0.752	0.345	0.767	0.209	0.752	0.093
4/20/2007							0.759	0.072	0.752	0.066	0.759	0.048	0.752	0.263	0.751	0.266	0.751	0.119	0.752	0.343	0.767	0.209	0.752	0.094
4/21/2007							0.758	0.074	0.750	0.062	0.758	0.048	0.752	0.267	0.751	0.268	0.751	0.117	0.752	0.339	0.767	0.206	0.752	0.097
4/22/2007							0.758	0.078	0.749	0.060	0.754	0.046	0.752	0.266	0.751	0.272	0.751	0.123	0.752	0.340	0.767	0.200	0.752	0.101
4/23/2007							0.758	0.083	0.749	0.065	0.753	0.048	0.752	0.263	0.751	0.273	0.751	0.129	0.752	0.341	0.767	0.199	0.752	0.104
4/24/2007							0.757	0.087	0.749	0.069	0.751	0.051	0.752	0.258	0.751	0.274	0.751	0.135	0.752	0.344	0.767	0.200	0.752	0.108
4/25/2007							0.761	0.096	0.751	0.081	0.755	0.058	0.752	0.259	0.750	0.278	0.751	0.145						
4/26/2007							0.765	0.119	0.752	0.113	0.763	0.078	0.752	0.297	0.750	0.316	0.750	0.173						
4/27/2007							0.765	0.132	0.753	0.129	0.764	0.089	0.752	0.309	0.750	0.328	0.750	0.191						
4/28/2007							0.767	0.139	0.753	0.137	0.764	0.096	0.752	0.311	0.750	0.338	0.749	0.207						
4/29/2007							0.770	0.145	0.753	0.141	0.766	0.103	0.752	0.320	0.750	0.347	0.749	0.219						
4/30/2007							0.771	0.151	0.754	0.145	0.767	0.109	0.752	0.323	0.750	0.355	0.749	0.229						
5/1/2007							0.774	0.153	0.758	0.151	0.769	0.116	0.752	0.329	0.750	0.365	0.749	0.239						
5/2/2007							0.775	0.157	0.760	0.155	0.771	0.120	0.752	0.331	0.750	0.369	0.749	0.247						
5/3/2007									0.762	0.157			0.752	0.320	0.751	0.335	0.749	0.229						
5/4/2007													0.752	0.308	0.750	0.334	0.750	0.212						
5/5/2007													0.752	0.309	0.750	0.340	0.750	0.213						
5/6/2007													0.751	0.318	0.750	0.348	0.750	0.221						
5/7/2007													0.751	0.323	0.751	0.351	0.750	0.225						
5/8/2007	0.787	0.269	0.754	0.163	0.757	0.018							0.750	0.327	0.751	0.349	0.751	0.225						
5/9/2007	0.787	0.212	0.752	0.129	0.749	0.000							0.750	0.327	0.751	0.348	0.751	0.227						
5/10/2007	0.787	0.217	0.752	0.138	0.749	0.000							0.750	0.332	0.751	0.350	0.751	0.230						
5/11/2007	0.787	0.242	0.751	0.151	0.749	0.000							0.750	0.336	0.751	0.352	0.751	0.236						
5/12/2007	0.787	0.252	0.751	0.161	0.749	0.000							0.750	0.341	0.751	0.353	0.751	0.241						
5/13/2007	0.787	0.253	0.752	0.152	0.749	0.000							0.750	0.348	0.750	0.359	0.751	0.248						
5/14/2007	0.787	0.250	0.752	0.146	0.749	0.000							0.750	0.359	0.750	0.367	0.750	0.265						
5/15/2007	0.787	0.257	0.750	0.156	0.749	0.000							0.751	0.364	0.750	0.367	0.750	0.280						
5/16/2007	0.787	0.277	0.749	0.169	0.750	0.004							0.749	0.368	0.750	0.368	0.750	0.289						
5/17/2007	0.787	0.306	0.751	0.192	0.751	0.008													0.759	0.412	0.767	0.359	0.751	0.142
5/18/2007	0.787	0.321	0.756	0.213	0.752	0.011													0.760	0.418	0.767	0.383	0.751	0.144
5/19/2007	0.787	0.341	0.757	0.241	0.752	0.012													0.759	0.425	0.767	0.396	0.751	0.148
5/20/2007	0.787	0.345	0.757	0.258	0.752	0.013													0.761	0.426	0.767	0.391	0.751	0.151
5/21/2007	0.787	0.349	0.757	0.271	0.751	0.012													0.760	0.434	0.767	0.392	0.751	0.154
5/22/2007																			0.761	0.438	0.767	0.394	0.751	0.157
5/23/2007																			0.758	0.451	0.767	0.396	0.751	0.160
5/24/2007													0.740	0.435	0.750	0.405	0.749	0.338	0.760	0.452	0.767	0.400	0.751	0.162
5/25/2007							0.784	0.215	0.891	0.144	0.788	0.238	0.740	0.456	0.750	0.418	0.749	0.343	0.760	0.464	0.767	0.403	0.750	0.165
5/26/2007							0.785	0.213	0.891	0.146	0.787	0.242	0.740	0.475	0.750	0.421	0.749	0.350	0.762	0.469	0.767	0.409	0.750	0.168

Table A-2. Continued.

	T7-145 (20 cm)		T7-145 (40 cm)		T7-145 (67 cm)		T7-90 (23 cm)		T7-90 (40 cm)		T7-90 (66 cm)		T7-25 (23 cm)		T7-25 (46 cm)		T7-25 (66 cm)		T7-2 (16 cm)		T7-2 (32 cm)		T7-2 (48 cm)	
Date	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w
5/27/2007							0.786	0.214	0.895	0.147	0.787	0.245	0.741	0.483	0.749	0.424	0.749	0.353	0.762	0.478	0.767	0.418	0.750	0.170
5/28/2007							0.786	0.215	0.895	0.149	0.789	0.248	0.745	0.498	0.749	0.430	0.749	0.361	0.761	0.488	0.767	0.428	0.750	0.173
5/29/2007							0.787	0.216	0.893	0.152	0.790	0.251	0.750	0.499	0.749	0.434	0.749	0.364	0.762	0.493	0.767	0.428	0.750	0.175
5/30/2007							0.787	0.219	0.892	0.155	0.790	0.255	0.752	0.509	0.750	0.440	0.749	0.368	0.762	0.505	0.767	0.428	0.750	0.178
5/31/2007							0.787	0.222	0.894	0.159	0.794	0.256	0.752	0.512	0.753	0.441	0.749	0.375	0.762	0.514	0.767	0.429	0.750	0.180
6/1/2007							0.787	0.225	0.896	0.163	0.792	0.264	0.751	0.527	0.758	0.451	0.749	0.379	0.762	0.521	0.767	0.435	0.750	0.185
6/2/2007							0.789	0.226	0.891	0.167	0.794	0.266	0.750	0.514	0.760	0.418	0.750	0.373	0.762	0.515	0.767	0.444	0.750	0.186
6/3/2007							0.791	0.227	0.892	0.170	0.798	0.265	0.749	0.531	0.761	0.429	0.750	0.380	0.762	0.529	0.767	0.445	0.750	0.188
6/4/2007							0.789	0.231	0.883	0.176	0.798	0.268	0.749	0.532	0.766	0.435	0.749	0.386	0.762	0.525	0.767	0.451	0.750	0.189
6/5/2007							0.790	0.233	0.883	0.182	0.797	0.271	0.749	0.533	0.780	0.436	0.749	0.393	0.762	0.528	0.767	0.449	0.750	0.193
6/6/2007							0.790	0.237	0.878	0.188	0.798	0.278	0.749	0.547	0.786	0.430	0.749	0.401	0.762	0.535	0.767	0.439	0.750	0.196
6/7/2007							0.794	0.238	0.865	0.195	0.800	0.279	0.750	0.552	0.786	0.419	0.750	0.402	0.762	0.526	0.767	0.434	0.750	0.200
6/8/2007							0.792	0.242	0.868	0.199	0.799	0.285	0.753	0.554	0.785	0.426	0.750	0.403	0.762	0.525	0.767	0.427	0.750	0.204
6/9/2007							0.787	0.247	0.866	0.204	0.799	0.287	0.764	0.542	0.790	0.431	0.749	0.413	0.762	0.524	0.767	0.426	0.750	0.205
6/10/2007							0.794	0.245	0.855	0.211	0.804	0.287	0.773	0.533	0.800	0.423	0.750	0.420	0.762	0.524	0.767	0.424	0.750	0.208
6/11/2007							0.791	0.251	0.852	0.216	0.802	0.292	0.777	0.521	0.805	0.418	0.750	0.418	0.762	0.524	0.767	0.419	0.750	0.210
6/12/2007							0.793	0.252	0.847	0.222	0.801	0.298	0.773	0.528	0.814	0.419	0.750	0.422	0.762	0.521	0.767	0.407	0.750	0.213
6/13/2007							0.794	0.253	0.844	0.226	0.805	0.297	0.773	0.532	0.826	0.411	0.750	0.427	0.762	0.515	0.767	0.396	0.750	0.216
6/14/2007							0.792	0.256	0.840	0.230	0.806	0.299	0.781	0.535	0.842	0.404	0.751	0.431	0.762	0.515	0.767	0.395	0.750	0.217
6/15/2007							0.793	0.256	0.841	0.232	0.811	0.297	0.789	0.519	0.848	0.392	0.751	0.431	0.762	0.517	0.767	0.395	0.750	0.222
6/16/2007							0.794	0.257	0.841	0.235	0.807	0.303	0.800	0.509	0.852	0.389	0.752	0.436	0.762	0.512	0.767	0.389	0.750	0.223
6/17/2007							0.795	0.257	0.838	0.237	0.810	0.304	0.808	0.505	0.847	0.392	0.754	0.436	0.762	0.509	0.767	0.382	0.750	0.224
6/18/2007							0.793	0.259	0.842	0.238	0.812	0.305	0.806	0.493	0.841	0.393	0.756	0.434	0.762	0.508	0.767	0.376	0.750	0.227
6/19/2007							0.794	0.260	0.832	0.244	0.814	0.305	0.782	0.503	0.794	0.412	0.753	0.438	0.762	0.494	0.767	0.371	0.750	0.228
6/20/2007							0.793	0.262	0.832	0.246	0.816	0.306	0.762	0.526	0.760	0.435	0.752	0.447	0.762	0.489	0.767	0.371	0.750	0.232
6/21/2007							0.794	0.263	0.828	0.249	0.814	0.310	0.755	0.537	0.750	0.453	0.751	0.454	0.762	0.488	0.767	0.367	0.750	0.234
6/22/2007							0.797	0.262	0.823	0.252	0.823	0.306	0.758	0.553	0.750	0.514	0.752	0.457	0.762	0.477	0.767	0.362	0.750	0.236
6/23/2007							0.796	0.262	0.820	0.255	0.820	0.308	0.761	0.550	0.750	0.518	0.750	0.463	0.762	0.469	0.767	0.358	0.750	0.240
6/24/2007							0.794	0.265	0.817	0.257	0.816	0.314	0.756	0.543	0.750	0.525	0.751	0.472	0.762	0.466	0.767	0.354	0.750	0.242
6/25/2007							0.796	0.265	0.806	0.264	0.827	0.308	0.751	0.544	0.750	0.520	0.750	0.470	0.762	0.463	0.767	0.344	0.750	0.246
6/26/2007							0.799	0.264	0.813	0.262	0.806	0.324	0.751	0.547	0.751	0.525	0.750	0.479	0.762	0.452	0.767	0.342	0.750	0.246
6/27/2007	0.910	0.321	0.920	0.272	0.786	0.089	0.799	0.279	0.827	0.258	0.809	0.325												
6/28/2007	0.955	0.306	0.906	0.276	0.786	0.083	0.804	0.273	0.853	0.253	0.834	0.316												
6/29/2007	0.920	0.314	0.878	0.278	0.782	0.079	0.797	0.276	0.851	0.254	0.829	0.315												
6/30/2007	0.887	0.317	0.855	0.276	0.782	0.076	0.797	0.275	0.850	0.255	0.836	0.310												
7/1/2007	0.862	0.313	0.830	0.275	0.779	0.076	0.798	0.274	0.853	0.255	0.830	0.311												
7/2/2007	0.838	0.307	0.810	0.275	0.778	0.075	0.795	0.276	0.852	0.256	0.827	0.312												
7/3/2007	0.816	0.301	0.793	0.271	0.777	0.075	0.804	0.273	0.853	0.258	0.837	0.310												
7/4/2007	0.797	0.299	0.781	0.263	0.776	0.075	0.805	0.272	0.862	0.257	0.843	0.306												
7/5/2007	0.788	0.295	0.773	0.251	0.775	0.074	0.808	0.270	0.865	0.256	0.840	0.305												
7/6/2007	0.780	0.294	0.766	0.239	0.774	0.074	0.799	0.272	0.852	0.256	0.839	0.296							0.761	0.383	0.767	0.278	0.750	0.273
7/7/2007	0.775	0.291	0.764	0.234	0.773	0.073	0.800	0.272	0.854	0.254	0.826	0.297							0.760	0.380	0.767	0.273	0.750	0.276
7/8/2007	0.769	0.290	0.762	0.228	0.772	0.073	0.799	0.272	0.855	0.253	0.832	0.292							0.760	0.373	0.767	0.268	0.750	0.278
7/9/2007	0.768	0.285	0.764	0.225	0.772	0.072	0.798	0.273	0.853	0.252	0.831	0.289							0.761	0.365	0.767	0.259	0.750	0.279
7/10/2007	0.766	0.282	0.763	0.227	0.770	0.073	0.799	0.273	0.855	0.249	0.832	0.286							0.760	0.359	0.767	0.251	0.750	0.278
7/11/2007	0.764	0.276	0.761	0.232	0.770	0.073	0.799	0.273	0.851	0.250	0.837	0.283							0.761	0.347	0.767	0.244	0.751	0.284
7/12/2007	0.762	0.269	0.761	0.235	0.770	0.072	0.800	0.273	0.849	0.251	0.835	0.285							0.761	0.340	0.767	0.239	0.750	0.287
7/13/2007	0.759	0.265	0.760	0.240	0.769	0.073	0.801	0.273	0.852	0.249	0.834	0.286							0.761	0.333	0.767	0.230	0.750	0.287
7/14/2007	0.758	0.258	0.761	0.241	0.769	0.073	0.799	0.274	0.852	0.249	0.830	0.290							0.761	0.327	0.767	0.223	0.751	0.293
7/15/2007	0.756	0.253	0.759	0.244	0.767	0.073	0.797	0.277	0.853	0.249	0.829	0.293							0.762	0.321	0.767	0.223	0.751	0.296

Table A-2. Continued.

	T7-145 (20 cm)		T7-145 (40 cm)		T7-145 (67 cm)		T7-90 (23 cm)		T7-90 (40 cm)		T7-90 (66 cm)		T7-25 (23 cm)		T7-25 (46 cm)		T7-25 (66 cm)		T7-2 (16 cm)		T7-2 (32 cm)		T7-2 (48 cm)	
Date	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w
7/16/2007	0.755	0.248	0.758	0.245	0.767	0.073	0.796	0.278	0.854	0.249	0.832	0.292							0.762	0.314	0.767	0.221	0.750	0.296
7/17/2007	0.754	0.244	0.757	0.244	0.767	0.074	0.796	0.278	0.847	0.252	0.833	0.292							0.762	0.305	0.767	0.212	0.750	0.298
7/18/2007	0.754	0.230	0.757	0.241	0.767	0.074	0.797	0.277	0.851	0.251	0.833	0.292							0.761	0.299	0.767	0.208	0.750	0.298
7/19/2007	0.753	0.215	0.756	0.243	0.767	0.074	0.795	0.279	0.850	0.251	0.836	0.291							0.761	0.291	0.767	0.195	0.751	0.303
7/20/2007	0.753	0.202	0.756	0.242	0.765	0.075	0.795	0.280	0.851	0.252	0.830	0.296							0.760	0.285	0.767	0.191	0.751	0.307
7/21/2007	0.753	0.186	0.755	0.243	0.765	0.076	0.795	0.279	0.851	0.252	0.834	0.294							0.762	0.271	0.767	0.187	0.751	0.307
7/22/2007																								
7/23/2007																								
7/24/2007																								
7/25/2007																								
7/26/2007																								
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8/18/2007																								
8/19/2007																								
8/20/2007																								
8/21/2007																								
8/22/2007																								
8/23/2007													0.785	0.154	0.781	0.247	0.783	0.286	0.848	0.247	0.871	0.259	0.874	0.313
8/24/2007													0.778	0.160	0.779	0.249	0.791	0.289	0.836	0.241	0.848	0.260	0.870	0.318
8/25/2007													0.766	0.152	0.777	0.247	0.785	0.291	0.811	0.231	0.826	0.262	0.858	0.323
8/26/2007													0.757	0.139	0.774	0.242	0.779	0.288	0.790	0.223	0.806	0.262	0.845	0.322
8/27/2007													0.754	0.129	0.770	0.237	0.772	0.286	0.784	0.217	0.804	0.261	0.827	0.323
8/28/2007													0.752	0.122	0.767	0.233	0.773	0.281	0.780	0.212	0.805	0.260	0.816	0.321
8/29/2007													0.751	0.118	0.766	0.226	0.772	0.278	0.779	0.206	0.809	0.257	0.807	0.318
8/30/2007													0.751	0.115	0.763	0.222	0.774	0.277	0.774	0.202	0.804	0.258	0.794	0.318
8/31/2007													0.751	0.113	0.762	0.218	0.773	0.276	0.772	0.197	0.799	0.259	0.789	0.315
9/1/2007													0.751	0.111	0.761	0.214	0.777	0.270	0.769	0.193	0.799	0.258	0.786	0.312
9/2/2007													0.751	0.109	0.761	0.211	0.773	0.271	0.767	0.189	0.796	0.258	0.783	0.311
9/3/2007													0.751	0.108	0.760	0.210	0.774	0.271	0.766	0.186	0.796	0.257	0.779	0.309

Table A-2. Continued.

	T7-145 (20 cm)		T7-145 (40 cm)		T7-145 (67 cm)		T7-90 (23 cm)		T7-90 (40 cm)		T7-90 (66 cm)		T7-25 (23 cm)		T7-25 (46 cm)		T7-25 (66 cm)		T7-2 (16 cm)		T7-2 (32 cm)		T7-2 (48 cm)	
Date	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w
9/4/2007													0.751	0.106	0.761	0.206	0.774	0.267	0.765	0.185	0.796	0.256	0.777	0.306
9/5/2007													0.751	0.105	0.763	0.202	0.774	0.263	0.766	0.183	0.797	0.254	0.775	0.305
9/6/2007							0.810	0.219	0.815	0.231	0.930	0.199	0.750	0.104	0.761	0.199	0.769	0.263	0.766	0.182	0.795	0.254	0.772	0.302
9/7/2007							0.815	0.215	0.810	0.222	0.917	0.197	0.750	0.105	0.760	0.197	0.764	0.261	0.765	0.184	0.790	0.253	0.767	0.299
9/8/2007							0.813	0.218	0.804	0.214	0.918	0.196	0.750	0.104	0.757	0.196	0.761	0.259	0.764	0.183	0.786	0.253	0.764	0.297
9/9/2007							0.823	0.218	0.800	0.207	0.909	0.194	0.749	0.106	0.756	0.193	0.756	0.253	0.762	0.185	0.781	0.250	0.761	0.292
9/10/2007							0.825	0.217	0.797	0.205	0.902	0.195	0.749	0.109	0.758	0.195	0.758	0.252	0.763	0.188	0.782	0.251	0.761	0.291
9/11/2007							0.823	0.217	0.791	0.207	0.913	0.195	0.749	0.107	0.763	0.197	0.766	0.257	0.764	0.189	0.782	0.255	0.762	0.294
9/12/2007							0.820	0.215	0.790	0.207	0.909	0.196	0.749	0.103	0.762	0.195	0.765	0.258	0.764	0.187	0.782	0.252	0.763	0.291
9/13/2007							0.813	0.215	0.786	0.209	0.902	0.197	0.749	0.099	0.763	0.191	0.767	0.254	0.764	0.185	0.787	0.247	0.762	0.290
9/14/2007	0.756	0.257	0.777	0.163	0.779	0.059	0.816	0.214	0.787	0.208	0.907	0.196	0.749	0.095	0.764	0.188	0.766	0.252	0.765	0.182	0.786	0.245	0.763	0.288
9/15/2007	0.754	0.253	0.776	0.164	0.780	0.061	0.812	0.216	0.785	0.209	0.902	0.197	0.749	0.093	0.763	0.187	0.765	0.251	0.764	0.181	0.785	0.243	0.761	0.288
9/16/2007	0.752	0.246	0.770	0.161	0.780	0.060	0.810	0.216	0.786	0.208	0.902	0.196	0.749	0.091	0.764	0.184	0.763	0.251	0.764	0.179	0.782	0.242	0.761	0.286
9/17/2007	0.750	0.237	0.765	0.155	0.779	0.059	0.809	0.215	0.786	0.208	0.896	0.197	0.749	0.089	0.764	0.182	0.765	0.247	0.765	0.177	0.781	0.242	0.761	0.285
9/18/2007	0.749	0.227	0.759	0.149	0.779	0.057	0.811	0.214	0.783	0.209	0.892	0.195	0.749	0.088	0.763	0.180	0.762	0.248	0.765	0.176	0.781	0.241	0.760	0.286
9/19/2007	0.749	0.219	0.756	0.143	0.778	0.057	0.816	0.214	0.783	0.207	0.884	0.195	0.750	0.087	0.764	0.178	0.761	0.247	0.766	0.174	0.781	0.241	0.760	0.284
9/20/2007	0.749	0.213	0.753	0.140	0.777	0.059	0.813	0.214	0.784	0.205	0.879	0.194	0.749	0.087	0.764	0.176	0.762	0.244	0.765	0.174	0.782	0.238	0.760	0.284
9/21/2007	0.749	0.209	0.753	0.138	0.776	0.058	0.812	0.214	0.780	0.204	0.875	0.193	0.749	0.086	0.765	0.175	0.760	0.245	0.764	0.172	0.784	0.235	0.762	0.280
9/22/2007	0.749	0.206	0.753	0.137	0.776	0.058	0.812	0.215	0.783	0.201	0.864	0.193	0.750	0.085	0.765	0.172	0.760	0.242	0.764	0.173	0.779	0.238	0.762	0.279
9/23/2007	0.749	0.203	0.753	0.136	0.776	0.058	0.815	0.215	0.781	0.199	0.853	0.192	0.750	0.084	0.766	0.170	0.762	0.237	0.764	0.172	0.777	0.238	0.760	0.280
9/24/2007	0.750	0.200	0.753	0.136	0.776	0.055	0.814	0.215	0.778	0.198	0.838	0.189	0.750	0.084	0.766	0.170	0.760	0.238	0.765	0.172	0.780	0.236	0.760	0.280
9/25/2007	0.750	0.199	0.753	0.136	0.776	0.056	0.814	0.215	0.780	0.196	0.829	0.188	0.750	0.083	0.767	0.168	0.761	0.235	0.766	0.171	0.780	0.235	0.761	0.280
9/26/2007	0.750	0.196	0.753	0.137	0.775	0.056	0.813	0.214	0.777	0.195	0.820	0.186	0.750	0.083	0.767	0.167	0.759	0.236	0.765	0.171	0.781	0.235	0.760	0.280
9/27/2007	0.750	0.195	0.753	0.136	0.775	0.056	0.816	0.213	0.781	0.191	0.818	0.185	0.750	0.083	0.767	0.166	0.760	0.233	0.765	0.171	0.781	0.234	0.761	0.279
9/28/2007	0.750	0.193	0.753	0.136	0.774	0.056	0.815	0.211	0.782	0.188	0.822	0.182	0.750	0.082	0.768	0.164	0.758	0.232	0.764	0.171	0.782	0.232	0.761	0.278
9/29/2007	0.750	0.192	0.753	0.136	0.774	0.055	0.816	0.210	0.783	0.185	0.819	0.181	0.750	0.082	0.768	0.163	0.758	0.230	0.765	0.170	0.781	0.232	0.761	0.277
9/30/2007	0.750	0.192	0.753	0.136	0.774	0.056	0.815	0.209	0.785	0.181	0.816	0.179	0.750	0.082	0.769	0.161	0.760	0.227	0.764	0.170	0.781	0.232	0.762	0.278
10/1/2007	0.750	0.190	0.753	0.136	0.774	0.055	0.815	0.209	0.784	0.178	0.815	0.176	0.750	0.082	0.769	0.160	0.760	0.225	0.764	0.170	0.780	0.233	0.761	0.278
10/2/2007	0.750	0.192	0.754	0.137	0.775	0.055	0.820	0.208	0.784	0.175	0.812	0.173	0.750	0.082	0.769	0.160	0.758	0.226	0.764	0.170	0.781	0.232	0.762	0.278
10/3/2007	0.750	0.189	0.752	0.139	0.775	0.055	0.817	0.207	0.784	0.172	0.807	0.172	0.750	0.081	0.769	0.159	0.758	0.225	0.763	0.169	0.780	0.231	0.761	0.276
10/4/2007	0.750	0.188	0.750	0.142	0.775	0.053	0.813	0.205	0.786	0.170	0.807	0.171	0.750	0.081	0.769	0.159	0.757	0.227	0.764	0.169	0.779	0.230	0.762	0.274
10/5/2007	0.750	0.187	0.751	0.142	0.775	0.053	0.814	0.203	0.786	0.168	0.808	0.170	0.750	0.081	0.769	0.159	0.756	0.228	0.764	0.168	0.781	0.228	0.762	0.273
10/6/2007	0.750	0.187	0.751	0.141	0.775	0.053	0.814	0.201	0.787	0.164	0.810	0.168	0.750	0.081	0.769	0.159	0.756	0.227	0.764	0.168	0.780	0.229	0.761	0.272
10/7/2007	0.750	0.186	0.751	0.140	0.775	0.052	0.814	0.200	0.786	0.163	0.809	0.166	0.750	0.081	0.767	0.159	0.757	0.223	0.764	0.168	0.781	0.228	0.760	0.273
10/8/2007	0.750	0.186	0.751	0.139	0.775	0.051	0.813	0.200	0.787	0.161	0.809	0.166	0.750	0.080	0.767	0.159	0.757	0.223	0.764	0.168	0.782	0.228	0.759	0.273
10/9/2007	0.750	0.186	0.751	0.138	0.774	0.051	0.813	0.200	0.787	0.160	0.809	0.165	0.750	0.080	0.767	0.158	0.756	0.223	0.764	0.168	0.782	0.227	0.760	0.272
10/10/2007	0.750	0.185	0.751	0.137	0.774	0.050	0.814	0.200	0.787	0.158	0.809	0.164	0.750	0.079	0.767	0.158	0.756	0.222	0.764	0.168	0.782	0.227	0.759	0.273
10/11/2007	0.750	0.184	0.751	0.137	0.774	0.049	0.817	0.199	0.787	0.157	0.810	0.164	0.750	0.079	0.767	0.158	0.757	0.220	0.765	0.167	0.782	0.226	0.759	0.273
10/12/2007	0.750	0.183	0.751	0.136	0.774	0.049	0.817	0.198	0.788	0.156	0.811	0.163	0.750	0.079	0.767	0.157	0.757	0.220	0.764	0.167	0.783	0.225	0.758	0.272
10/13/2007	0.750	0.183	0.751	0.135	0.774	0.049	0.820	0.196	0.788	0.155	0.813	0.163	0.750	0.078	0.767	0.157	0.757	0.218	0.764	0.166	0.781	0.227	0.759	0.271
10/14/2007	0.750	0.184	0.751	0.134	0.774	0.048	0.817	0.195	0.790	0.152	0.817	0.160	0.750	0.078	0.767	0.157	0.757	0.217	0.764	0.166	0.780	0.227	0.760	0.270
10/15/2007	0.750	0.182	0.751	0.134	0.774	0.048	0.812	0.194	0.792	0.148	0.820	0.158	0.750	0.077	0.767	0.156	0.757	0.214	0.764	0.166	0.781	0.225	0.760	0.269
10/16/2007	0.750	0.180	0.750	0.138	0.775	0.047	0.810	0.193	0.793	0.147	0.820	0.157	0.750	0.076	0.768	0.155	0.757	0.214	0.764	0.165	0.779	0.226	0.758	0.268
10/17/2007	0.750	0.180	0.750	0.137	0.774	0.047	0.808	0.193	0.790	0.147	0.820	0.156	0.750	0.076	0.768	0.154	0.756	0.214	0.765	0.164	0.778	0.226	0.759	0.268
10/18/2007	0.750	0.184	0.751	0.137	0.774	0.046	0.803	0.194	0.793	0.147	0.819	0.157	0.750	0.076	0.770	0.153	0.756	0.214	0.764	0.164	0.778	0.226	0.759	0.267
10/19/2007	0.749	0.190	0.752	0.137	0.774	0.046	0.795	0.193	0.794	0.147	0.821	0.156	0.750	0.075	0.771	0.152	0.756	0.213	0.764	0.164	0.779	0.224	0.759	0.265
10/20/2007	0.749	0.186	0.751	0.138	0.774	0.046	0.797	0.190	0.791	0.146	0.817	0.156	0.750	0.075	0.771	0.151	0.755	0.212	0.764	0.164	0.778	0.225	0.758	0.266
10/21/2007	0.749	0.184	0.751	0.136	0.774	0.046	0.796	0.189	0.789	0.146	0.814	0.157	0.750	0.074	0.771	0.150	0.755	0.210	0.765	0.163	0.778	0.223	0.760	0.264
10/22/2007	0.749	0.181	0.751	0.135	0.775	0.045	0.794	0.189	0.791	0.146	0.816	0.157	0.750	0.074	0.771	0.149	0.754	0.209	0.764	0.164	0.779	0.222	0.761	0.262
10/23/2007	0.749	0.179	0.751	0.134	0.775	0.045	0.792	0.190	0.790	0.146	0.818	0.157	0.750	0.072	0.771	0.148	0.755	0.206	0.764	0.163	0.780	0.221	0.759	0.263

Table A-2. Continued.

	T7-145 (20 cm)		T7-145 (40 cm)		T7-145 (67 cm)		T7-90 (23 cm)		T7-90 (40 cm)		T7-90 (66 cm)		T7-25 (23 cm)		T7-25 (46 cm)		T7-25 (66 cm)		T7-2 (16 cm)		T7-2 (32 cm)		T7-2 (48 cm)	
Date	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w
10/24/2007	0.749	0.176	0.751	0.132	0.774	0.043	0.794	0.188	0.792	0.146	0.818	0.157	0.750	0.072	0.772	0.147	0.754	0.205	0.764	0.163	0.779	0.222	0.758	0.265
10/25/2007	0.749	0.174	0.751	0.131	0.774	0.043	0.794	0.188	0.792	0.146	0.818	0.156	0.750	0.072	0.772	0.146	0.754	0.203	0.764	0.162	0.779	0.221	0.758	0.265
10/26/2007	0.749	0.173	0.751	0.131	0.774	0.043	0.795	0.187	0.791	0.147	0.819	0.155	0.751	0.072	0.773	0.145	0.754	0.202	0.764	0.162	0.780	0.220	0.758	0.263
10/27/2007	0.749	0.170	0.751	0.129	0.774	0.043	0.795	0.187	0.792	0.146	0.818	0.155	0.751	0.071	0.774	0.143	0.754	0.198	0.765	0.161	0.780	0.220	0.759	0.261
10/28/2007	0.749	0.168	0.751	0.128	0.775	0.042	0.795	0.187	0.792	0.146	0.819	0.155	0.751	0.071	0.773	0.143	0.754	0.197	0.765	0.160	0.782	0.218	0.758	0.261
10/29/2007	0.749	0.168	0.751	0.127	0.775	0.042	0.793	0.186	0.791	0.147	0.819	0.154	0.751	0.070	0.773	0.142	0.754	0.194	0.765	0.159	0.781	0.218	0.758	0.260
10/30/2007	0.749	0.167	0.751	0.127	0.776	0.041	0.795	0.185	0.791	0.145	0.818	0.152	0.751	0.071	0.773	0.142	0.755	0.193	0.766	0.159	0.781	0.218	0.759	0.261
10/31/2007	0.749	0.166	0.752	0.127	0.776	0.040	0.794	0.186	0.789	0.144	0.813	0.150	0.752	0.071	0.774	0.141	0.754	0.191	0.766	0.159	0.780	0.219	0.759	0.261
11/1/2007	0.749	0.165	0.752	0.125	0.776	0.040	0.789	0.187	0.792	0.142	0.812	0.147	0.752	0.071	0.773	0.140	0.754	0.191	0.765	0.158	0.780	0.218	0.758	0.260
11/2/2007	0.749	0.164	0.752	0.124	0.775	0.040	0.789	0.186	0.792	0.141	0.812	0.146	0.752	0.071	0.774	0.140	0.753	0.192	0.766	0.158	0.779	0.219	0.758	0.260
11/3/2007	0.749	0.163	0.751	0.126	0.775	0.039	0.792	0.183	0.795	0.138	0.812	0.145	0.752	0.072	0.774	0.141	0.754	0.192	0.766	0.158	0.779	0.219	0.757	0.261
11/4/2007	0.749	0.161	0.750	0.126	0.776	0.037	0.790	0.183	0.796	0.135	0.813	0.143	0.752	0.072	0.775	0.140	0.754	0.192	0.766	0.158	0.780	0.218	0.757	0.261
11/5/2007	0.749	0.160	0.750	0.125	0.776	0.036	0.791	0.181	0.796	0.134	0.815	0.141	0.752	0.071	0.776	0.139	0.754	0.190	0.766	0.158	0.779	0.218	0.758	0.260
11/6/2007	0.749	0.158	0.750	0.126	0.776	0.035	0.792	0.178	0.797	0.132	0.815	0.140	0.752	0.071	0.775	0.139	0.755	0.189	0.766	0.158	0.780	0.217	0.757	0.259
11/7/2007	0.749	0.156	0.750	0.124	0.776	0.034	0.793	0.177	0.796	0.131	0.815	0.139	0.752	0.071	0.776	0.139	0.754	0.190	0.766	0.158	0.779	0.216	0.757	0.259
11/8/2007	0.749	0.157	0.750	0.124	0.776	0.033	0.794	0.175	0.798	0.129	0.816	0.138	0.752	0.071	0.776	0.139	0.754	0.189	0.766	0.157	0.779	0.216	0.757	0.260
11/9/2007	0.749	0.155	0.750	0.122	0.776	0.032	0.793	0.174	0.797	0.129	0.815	0.138	0.752	0.070	0.776	0.138	0.754	0.188	0.767	0.156	0.779	0.216	0.757	0.259
11/10/2007	0.749	0.154	0.750	0.121	0.776	0.032	0.795	0.172	0.796	0.128	0.818	0.137	0.752	0.070	0.777	0.138	0.754	0.187	0.766	0.156	0.778	0.216	0.757	0.258
11/11/2007	0.749	0.152	0.750	0.120	0.776	0.032	0.797	0.170	0.798	0.126	0.818	0.137	0.753	0.070	0.778	0.137	0.755	0.185	0.767	0.155	0.778	0.214	0.757	0.257
11/12/2007	0.749	0.151	0.750	0.120	0.776	0.031	0.798	0.170	0.797	0.126	0.817	0.137	0.753	0.069	0.777	0.137	0.754	0.185	0.767	0.155	0.779	0.213	0.757	0.256
11/13/2007	0.749	0.150	0.750	0.119	0.777	0.030	0.798	0.169	0.797	0.124	0.816	0.137	0.753	0.069	0.779	0.136	0.754	0.184	0.766	0.154	0.780	0.212	0.757	0.255
11/14/2007	0.749	0.149	0.750	0.119	0.777	0.030	0.798	0.168	0.796	0.125	0.815	0.137	0.753	0.068	0.778	0.135	0.754	0.182	0.766	0.153	0.780	0.211	0.757	0.252
11/15/2007	0.749	0.148	0.750	0.117	0.777	0.030	0.799	0.167	0.797	0.125	0.816	0.137	0.753	0.068	0.778	0.136	0.754	0.181	0.766	0.152	0.779	0.210	0.756	0.254
11/16/2007	0.749	0.147	0.751	0.116	0.777	0.028	0.799	0.167	0.797	0.125	0.819	0.138	0.754	0.067	0.780	0.134	0.754	0.180	0.766	0.152	0.777	0.211	0.757	0.252
11/17/2007	0.749	0.145	0.751	0.115	0.777	0.029	0.799	0.167	0.797	0.125	0.818	0.140	0.755	0.067	0.781	0.134	0.754	0.179	0.767	0.151	0.777	0.210	0.757	0.253
11/18/2007	0.749	0.146	0.750	0.117	0.777	0.028	0.800	0.166	0.799	0.125	0.821	0.140	0.755	0.066	0.783	0.131	0.754	0.177	0.767	0.150	0.780	0.207	0.756	0.254
11/19/2007	0.749	0.144	0.751	0.114	0.778	0.028	0.802	0.165	0.799	0.125	0.821	0.140	0.756	0.066	0.782	0.131	0.754	0.176	0.767	0.149	0.781	0.205	0.756	0.252
11/20/2007	0.749	0.143	0.751	0.113	0.778	0.028	0.802	0.165	0.798	0.126	0.821	0.141	0.757	0.065	0.784	0.130	0.754	0.174	0.767	0.149	0.781	0.203	0.756	0.250
11/21/2007	0.749	0.144	0.751	0.112	0.779	0.028	0.802	0.165	0.799	0.126	0.824	0.141	0.757	0.065	0.784	0.130	0.754	0.173	0.767	0.148	0.779	0.204	0.757	0.249
11/22/2007	0.749	0.145	0.751	0.110	0.779	0.028	0.803	0.165	0.799	0.126	0.824	0.142	0.757	0.064	0.784	0.129	0.754	0.170	0.767	0.147	0.778	0.204	0.757	0.246
11/23/2007	0.749	0.145	0.752	0.109	0.779	0.028	0.803	0.164	0.799	0.127	0.824	0.143	0.758	0.063	0.784	0.129	0.754	0.169	0.767	0.146	0.780	0.201	0.756	0.247
11/24/2007	0.749	0.145	0.752	0.108	0.780	0.027	0.803	0.164	0.798	0.127	0.822	0.144	0.758	0.063	0.785	0.128	0.754	0.169	0.767	0.144	0.782	0.199	0.756	0.246
11/25/2007	0.749	0.144	0.752	0.107	0.780	0.028	0.803	0.164	0.798	0.127	0.822	0.144	0.758	0.063	0.787	0.126	0.754	0.167	0.767	0.144	0.779	0.200	0.756	0.244
11/26/2007	0.749	0.143	0.752	0.107	0.780	0.028	0.803	0.164	0.798	0.128	0.827	0.143	0.759	0.061	0.788	0.125	0.754	0.165	0.766	0.143	0.778	0.199	0.757	0.242
11/27/2007	0.750	0.142	0.752	0.105	0.781	0.027	0.803	0.164	0.798	0.128	0.829	0.143	0.759	0.060	0.788	0.125	0.754	0.162	0.766	0.141	0.779	0.197	0.756	0.241
11/28/2007	0.750	0.141	0.752	0.104	0.781	0.027	0.802	0.164	0.796	0.128	0.827	0.143	0.759	0.059	0.788	0.124	0.755	0.159	0.767	0.140	0.781	0.193	0.756	0.239
11/29/2007	0.749	0.140	0.753	0.101	0.782	0.027	0.800	0.165	0.795	0.130	0.826	0.144	0.759	0.058	0.789	0.123	0.754	0.158	0.768	0.138	0.780	0.193	0.756	0.239
11/30/2007	0.749	0.139	0.753	0.099	0.782	0.027	0.800	0.165	0.798	0.130	0.830	0.144	0.760	0.058	0.789	0.122	0.754	0.157	0.768	0.136	0.779	0.192	0.756	0.238
12/1/2007	0.749	0.137	0.753	0.097	0.781	0.026	0.800	0.165	0.795	0.132	0.830	0.144	0.760	0.057	0.789	0.121	0.754	0.154	0.768	0.135	0.779	0.190	0.756	0.237
12/2/2007	0.749	0.135	0.753	0.092	0.781	0.026	0.800	0.165	0.797	0.132	0.831	0.145	0.761	0.056	0.790	0.120	0.755	0.152	0.768	0.134	0.779	0.189	0.757	0.235
12/3/2007	0.749	0.133	0.754	0.087	0.781	0.026	0.800	0.165	0.798	0.132	0.831	0.145	0.761	0.054	0.790	0.119	0.754	0.151	0.767	0.133	0.776	0.190	0.755	0.235
12/4/2007	0.749	0.128	0.756	0.080	0.781	0.025	0.800	0.165	0.798	0.133	0.832	0.145	0.760	0.053	0.791	0.119	0.754	0.150	0.768	0.131	0.777	0.187	0.756	0.231
12/5/2007	0.750	0.124	0.757	0.071	0.783	0.024	0.801	0.164	0.799	0.134	0.832	0.145	0.762	0.053	0.794	0.118	0.756	0.148	0.768	0.130	0.779	0.185	0.756	0.231
12/6/2007	0.750	0.120	0.757	0.067	0.782	0.024	0.804	0.163	0.797	0.135	0.834	0.144	0.762	0.052	0.793	0.116	0.755	0.145	0.768	0.129	0.779	0.183	0.755	0.232
12/7/2007	0.750	0.114	0.758	0.060	0.782	0.025	0.804	0.163	0.797	0.135	0.836	0.143	0.763	0.050	0.793	0.115	0.755	0.143	0.768	0.127	0.778	0.181	0.755	0.230
12/8/2007	0.750	0.106	0.759	0.053	0.782	0.025	0.803	0.163	0.796	0.137	0.835	0.143	0.763	0.049	0.793	0.114	0.754	0.143	0.768	0.126	0.778	0.179	0.756	0.227
12/9/2007	0.751	0.102	0.760	0.048	0.782	0.024	0.806	0.162	0.797	0.137	0.836	0.143	0.764	0.049	0.795	0.113	0.754	0.141	0.769	0.125	0.778	0.178	0.756	0.227
12/10/2007	0.751	0.098	0.760	0.044	0.783	0.024	0.805	0.162	0.795	0.137	0.835	0.144	0.765	0.048	0.796	0.112	0.755	0.139	0.769	0.123	0.780	0.175	0.757	0.224
12/11/2007	0.751	0.091	0.760	0.040	0.783	0.023	0.803	0.163	0.795	0.138	0.835	0.143	0.765	0.048	0.797	0.111	0.755	0.137	0.769	0.122	0.782	0.172	0.756	0.223
12/12/2007	0.751	0.085	0.761	0.034	0.783	0.023	0.803	0.163	0.795	0.138	0.835	0.143	0.766	0.048	0.798	0.110	0.754	0.135	0.769	0.121	0.779	0.172	0.756	0.221

Table A-2. Continued.

	T7-145 (20 cm)		T7-145 (40 cm)		T7-145 (67 cm)		T7-90 (23 cm)		T7-90 (40 cm)		T7-90 (66 cm)		T7-25 (23 cm)		T7-25 (46 cm)		T7-25 (66 cm)		T7-2 (16 cm)		T7-2 (32 cm)		T7-2 (48 cm)	
Date	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w
12/13/2007	0.751	0.078	0.761	0.030	0.783	0.023	0.803	0.163	0.795	0.139	0.834	0.143	0.766	0.047	0.799	0.108	0.755	0.132	0.769	0.121	0.779	0.170	0.756	0.219
12/14/2007	0.751	0.077	0.762	0.028	0.783	0.023	0.801	0.163	0.796	0.139	0.830	0.143	0.767	0.045	0.800	0.107	0.755	0.131	0.770	0.120	0.779	0.169	0.755	0.219
12/15/2007	0.751	0.077	0.761	0.029	0.783	0.023	0.801	0.163	0.795	0.139	0.828	0.144	0.767	0.045	0.800	0.107	0.755	0.129	0.769	0.119	0.779	0.167	0.755	0.217
12/16/2007	0.751	0.073	0.761	0.026	0.782	0.022	0.802	0.163	0.794	0.140	0.825	0.144	0.767	0.044	0.800	0.106	0.755	0.128	0.769	0.118	0.778	0.166	0.755	0.215
12/17/2007	0.752	0.067	0.763	0.020	0.783	0.021	0.802	0.164	0.796	0.141	0.823	0.144	0.767	0.043	0.800	0.106	0.755	0.126	0.769	0.119	0.778	0.165	0.755	0.215
12/18/2007	0.752	0.060	0.763	0.018	0.782	0.021	0.802	0.167	0.793	0.144	0.812	0.146	0.769	0.041	0.801	0.105	0.756	0.125	0.771	0.118	0.779	0.164	0.755	0.216
12/19/2007	0.753	0.055	0.764	0.016	0.780	0.019	0.806	0.165	0.787	0.146	0.803	0.143	0.771	0.041	0.804	0.104	0.756	0.125	0.772	0.118	0.780	0.163	0.755	0.214
12/20/2007	0.753	0.052	0.764	0.014	0.780	0.017	0.810	0.162	0.784	0.144	0.794	0.138	0.772	0.040	0.805	0.102	0.757	0.124	0.772	0.117	0.780	0.161	0.756	0.210
12/21/2007	0.753	0.051	0.765	0.013	0.781	0.016	0.809	0.162	0.783	0.143	0.789	0.133	0.773	0.039	0.805	0.101	0.757	0.122	0.772	0.116	0.780	0.160	0.757	0.209
12/22/2007	0.753	0.051	0.765	0.013	0.781	0.015	0.800	0.161	0.776	0.143	0.781	0.130	0.774	0.038	0.807	0.100	0.757	0.119	0.772	0.115	0.782	0.159	0.757	0.208
12/23/2007	0.753	0.053	0.764	0.014	0.780	0.014	0.802	0.162	0.774	0.142	0.779	0.130	0.775	0.038	0.807	0.099	0.757	0.117	0.773	0.114	0.782	0.158	0.757	0.207
12/24/2007	0.753	0.055	0.764	0.015	0.778	0.012	0.804	0.161	0.776	0.140	0.780	0.129	0.775	0.037	0.810	0.098	0.758	0.115	0.772	0.113	0.783	0.157	0.758	0.206
12/25/2007	0.753	0.056	0.762	0.017	0.774	0.007	0.800	0.161	0.775	0.141	0.779	0.131	0.775	0.037	0.811	0.097	0.758	0.113	0.773	0.112	0.782	0.156	0.758	0.204
12/26/2007	0.752	0.059	0.760	0.018	0.769	0.005	0.793	0.161	0.772	0.142	0.779	0.131	0.776	0.037	0.811	0.097	0.758	0.111	0.773	0.111	0.782	0.156	0.758	0.204
12/27/2007	0.751	0.063	0.757	0.020	0.766	0.006	0.779	0.158	0.765	0.140	0.778	0.132	0.776	0.036	0.811	0.096	0.758	0.109	0.773	0.111	0.784	0.155	0.758	0.202
12/28/2007	0.750	0.069	0.752	0.024	0.763	0.007	0.758	0.144	0.755	0.129	0.772	0.130	0.777	0.036	0.814	0.095	0.758	0.107	0.773	0.110	0.784	0.154	0.758	0.202
12/29/2007	0.750	0.076	0.752	0.029	0.767	0.013	0.760	0.145	0.758	0.122	0.774	0.132	0.776	0.034	0.811	0.095	0.758	0.104	0.772	0.109	0.784	0.152	0.758	0.198
12/30/2007	0.750	0.076	0.753	0.031	0.769	0.014	0.772	0.163	0.763	0.138	0.786	0.140	0.775	0.033	0.807	0.095	0.758	0.101	0.771	0.108	0.781	0.151	0.758	0.198
12/31/2007	0.750	0.072	0.754	0.031	0.769	0.016	0.775	0.166	0.764	0.141	0.789	0.143	0.775	0.033	0.809	0.093	0.758	0.099	0.771	0.107	0.780	0.151	0.756	0.197
1/1/2008	0.750	0.068	0.754	0.031	0.768	0.015	0.776	0.167	0.766	0.141	0.789	0.144	0.775	0.034	0.808	0.093	0.754	0.097	0.771	0.107	0.780	0.150	0.754	0.196
1/2/2008	0.751	0.063	0.757	0.025	0.770	0.016	0.780	0.168	0.768	0.142	0.794	0.145	0.776	0.035	0.811	0.094	0.752	0.095	0.771	0.108	0.781	0.149	0.754	0.195
1/3/2008	0.751	0.058	0.759	0.023	0.771	0.016	0.783	0.168	0.771	0.143	0.797	0.144	0.777	0.035	0.810	0.094	0.751	0.092	0.773	0.107	0.780	0.149	0.754	0.194
1/4/2008	0.752	0.056	0.759	0.024	0.770	0.015	0.787	0.167	0.773	0.143	0.796	0.144	0.778	0.033	0.811	0.093	0.751	0.090	0.774	0.106	0.782	0.148	0.754	0.193
1/5/2008	0.752	0.055	0.760	0.024	0.771	0.014	0.791	0.168	0.775	0.143	0.796	0.143	0.778	0.032	0.811	0.090	0.751	0.088	0.773	0.105	0.781	0.147	0.753	0.191
1/6/2008	0.752	0.053	0.760	0.024	0.770	0.014	0.795	0.168	0.777	0.142	0.797	0.142	0.778	0.032	0.813	0.090	0.750	0.086	0.773	0.104	0.782	0.145	0.754	0.190
1/7/2008	0.753	0.050	0.760	0.025	0.770	0.013	0.797	0.167	0.779	0.143	0.796	0.142	0.778	0.032	0.813	0.088	0.750	0.084	0.773	0.104	0.782	0.144	0.754	0.189
1/8/2008	0.753	0.048	0.761	0.024	0.770	0.012	0.798	0.168	0.781	0.144	0.797	0.142	0.779	0.031	0.813	0.088	0.750	0.081	0.772	0.103	0.782	0.142	0.754	0.188
1/9/2008	0.753	0.043	0.762	0.022	0.771	0.013	0.800	0.168	0.782	0.145	0.797	0.142	0.779	0.031	0.815	0.087	0.751	0.079	0.772	0.103	0.781	0.142	0.753	0.187
1/10/2008	0.753	0.040	0.762	0.020	0.771	0.012	0.803	0.167	0.783	0.145	0.798	0.141	0.778	0.030	0.815	0.087	0.750	0.077	0.772	0.102	0.781	0.140	0.754	0.183
1/11/2008	0.753	0.037	0.763	0.019	0.772	0.013	0.803	0.167	0.785	0.145	0.799	0.140	0.779	0.030	0.815	0.086	0.751	0.074	0.772	0.101	0.781	0.139	0.754	0.180
1/12/2008	0.754	0.035	0.763	0.018	0.771	0.013	0.804	0.167	0.786	0.146	0.798	0.140	0.779	0.029	0.814	0.085	0.751	0.071	0.772	0.100	0.781	0.138	0.753	0.180
1/13/2008	0.754	0.032	0.763	0.017	0.771	0.013	0.804	0.168	0.787	0.146	0.798	0.141	0.779	0.029	0.815	0.085	0.751	0.070	0.772	0.098	0.779	0.138	0.753	0.179
1/14/2008	0.754	0.029	0.764	0.014	0.772	0.013	0.804	0.169	0.789	0.147	0.800	0.140	0.779	0.029	0.816	0.086	0.751	0.070	0.772	0.098	0.779	0.137	0.753	0.178
1/15/2008	0.754	0.026	0.765	0.010	0.774	0.015	0.806	0.167	0.789	0.147	0.799	0.140	0.779	0.029	0.817	0.086	0.751	0.070	0.773	0.097	0.780	0.136	0.754	0.177
1/16/2008	0.756	0.024	0.765	0.010	0.774	0.014	0.807	0.168	0.789	0.148	0.801	0.139	0.780	0.028	0.818	0.085	0.751	0.068	0.774	0.096	0.782	0.134	0.754	0.175
1/17/2008	0.757	0.023	0.765	0.011	0.773	0.013	0.809	0.167	0.792	0.147	0.801	0.139	0.780	0.027	0.818	0.083	0.751	0.067	0.774	0.095	0.782	0.134	0.754	0.173
1/18/2008	0.757	0.021	0.766	0.008	0.774	0.015																		
1/19/2008	0.757	0.019	0.766	0.007	0.774	0.014	0.805	0.171	0.790	0.152	0.796	0.141	0.781	0.027	0.817	0.081	0.751	0.064	0.773	0.093	0.782	0.129	0.754	0.170
1/20/2008	0.758	0.018	0.767	0.006	0.773	0.013	0.806	0.172	0.792	0.152	0.798	0.141	0.781	0.027	0.818	0.083	0.751	0.065	0.774	0.093	0.781	0.130	0.754	0.171
1/21/2008	0.758	0.019	0.767	0.007	0.775	0.013	0.809	0.171	0.793	0.152	0.800	0.140	0.782	0.027	0.817	0.082	0.751	0.063	0.775	0.093	0.783	0.129	0.754	0.171
1/22/2008	0.758	0.020	0.767	0.009	0.775	0.013	0.808	0.170	0.794	0.151	0.802	0.139	0.781	0.026	0.817	0.080	0.752	0.062	0.774	0.092	0.782	0.128	0.754	0.169
1/23/2008	0.758	0.020	0.767	0.009	0.775	0.014	0.812	0.166	0.796	0.149	0.804	0.137	0.781	0.025	0.816	0.079	0.751	0.061	0.774	0.091	0.781	0.128	0.754	0.167
1/24/2008	0.758	0.019	0.767	0.009	0.774	0.013	0.811	0.167	0.796	0.149	0.804	0.137	0.781	0.025	0.817	0.079	0.751	0.061	0.774	0.090	0.780	0.128	0.754	0.167
1/25/2008	0.758	0.020	0.767	0.009	0.774	0.013	0.813	0.167	0.795	0.150	0.806	0.137	0.781	0.025	0.818	0.080	0.752	0.061	0.774	0.090	0.781	0.127	0.754	0.166
1/26/2008	0.758	0.020	0.767	0.008	0.775	0.014	0.813	0.168	0.796	0.149	0.806	0.137	0.781	0.025	0.818	0.079	0.752	0.060	0.774	0.090	0.781	0.126	0.754	0.166
1/27/2008	0.759	0.020	0.767	0.009	0.774	0.012	0.814	0.167	0.796	0.149	0.807	0.137	0.781	0.025	0.818	0.079	0.752	0.060	0.775	0.089	0.781	0.125	0.754	0.165
1/28/2008	0.759	0.021	0.768	0.007	0.777	0.014	0.813	0.168	0.796	0.149	0.809	0.135	0.782	0.025	0.818	0.080	0.752	0.060	0.775	0.089	0.782	0.123	0.754	0.165
1/29/2008	0.760	0.021	0.768	0.009	0.775	0.013	0.813	0.168	0.796	0.150	0.807	0.137	0.781	0.024	0.816	0.078	0.752	0.059	0.775	0.088	0.782	0.123	0.754	0.164
1/30/2008	0.760	0.020	0.768	0.008	0.777	0.015	0.814	0.167	0.798	0.148	0.809	0.136	0.781	0.023	0.817	0.077	0.752	0.058	0.775	0.087	0.783	0.121	0.754	0.162
1/31/2008	0.762	0.017	0.768	0.008	0.775	0.013	0.815	0.169	0.798	0.150	0.807	0.137	0.781	0.023	0.815	0.076	0.752	0.057	0.774	0.087	0.782	0.120	0.754	0.160

Table A-2. Continued.

	T7-145 (20 cm)		T7-145 (40 cm)		T7-145 (67 cm)		T7-90 (23 cm)		T7-90 (40 cm)		T7-90 (66 cm)		T7-25 (23 cm)		T7-25 (46 cm)		T7-25 (66 cm)		T7-2 (16 cm)		T7-2 (32 cm)		T7-2 (48 cm)	
Date	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w
2/1/2008	0.762	0.015	0.768	0.007	0.776	0.014	0.816	0.168	0.798	0.148	0.808	0.136	0.781	0.023	0.815	0.076	0.752	0.057	0.774	0.086	0.782	0.119	0.753	0.160
2/2/2008	0.762	0.013	0.768	0.006	0.776	0.014	0.816	0.169	0.797	0.149	0.808	0.136	0.781	0.024	0.817	0.077	0.752	0.057	0.773	0.087	0.781	0.118	0.753	0.159
2/3/2008	0.762	0.011	0.769	0.005	0.775	0.014	0.816	0.169	0.798	0.148	0.809	0.135	0.781	0.025	0.817	0.077	0.753	0.057	0.774	0.088	0.781	0.118	0.754	0.159
2/4/2008	0.762	0.010	0.769	0.004	0.777	0.014	0.814	0.171	0.796	0.151	0.806	0.137	0.782	0.025	0.819	0.077	0.753	0.056	0.773	0.090	0.782	0.117	0.754	0.158
2/5/2008	0.763	0.009	0.769	0.004	0.776	0.013	0.815	0.172	0.796	0.152	0.807	0.137	0.781	0.025	0.819	0.076	0.753	0.056	0.773	0.090	0.782	0.117	0.753	0.157
2/6/2008	0.764	0.008	0.769	0.004	0.776	0.013	0.816	0.172	0.795	0.152	0.808	0.137	0.782	0.024	0.817	0.075	0.753	0.056	0.774	0.090	0.782	0.116	0.753	0.155
2/7/2008	0.764	0.008	0.769	0.002	0.778	0.014	0.815	0.172	0.794	0.152	0.808	0.137	0.782	0.025	0.817	0.075	0.753	0.055	0.773	0.090	0.781	0.116	0.753	0.154
2/8/2008	0.765	0.008	0.769	0.002	0.778	0.014	0.815	0.173	0.795	0.152	0.809	0.137	0.782	0.026	0.818	0.076	0.753	0.056	0.773	0.089	0.781	0.116	0.753	0.154
2/9/2008	0.765	0.007	0.769	0.002	0.777	0.014	0.814	0.173	0.795	0.152	0.809	0.137	0.783	0.027	0.818	0.075	0.753	0.055	0.773	0.088	0.781	0.115	0.753	0.152
2/10/2008	0.765	0.007	0.770	0.001	0.777	0.013	0.817	0.169	0.801	0.148	0.814	0.134	0.784	0.027	0.819	0.075	0.753	0.055	0.774	0.086	0.781	0.114	0.754	0.151
2/11/2008	0.765	0.006	0.771	0.000	0.779	0.014	0.817	0.169			0.815	0.134	0.784	0.026	0.820	0.076	0.754	0.055	0.774	0.086	0.781	0.113	0.753	0.151
2/12/2008	0.768	0.006	0.769	0.002	0.775	0.010	0.820	0.168			0.817	0.133	0.784	0.025	0.818	0.074	0.754	0.053	0.775	0.084	0.784	0.111	0.753	0.149
2/13/2008	0.767	0.006	0.770	0.001	0.776	0.011	0.821	0.168			0.818	0.133	0.784	0.026	0.817	0.074	0.754	0.052	0.774	0.084	0.783	0.110	0.753	0.147
2/14/2008	0.767	0.007	0.771	0.000	0.779	0.013	0.816	0.168			0.814	0.133	0.786	0.027	0.819	0.076	0.754	0.053	0.774	0.083	0.783	0.109	0.753	0.146
2/15/2008	0.768	0.005	0.771	0.000	0.778	0.013	0.816	0.168			0.814	0.133	0.784	0.026	0.819	0.074	0.754	0.052	0.775	0.081	0.783	0.107	0.753	0.145
2/16/2008	0.768	0.005	0.772	0.000	0.778	0.013	0.816	0.169			0.816	0.132	0.784	0.025	0.818	0.074	0.754	0.051	0.776	0.081	0.782	0.107	0.753	0.143
2/17/2008	0.770	0.005	0.772	0.000	0.778	0.012	0.817	0.168			0.816	0.132	0.784	0.025	0.818	0.073	0.754	0.051	0.776	0.082	0.784	0.105	0.753	0.142
2/18/2008	0.770	0.005	0.772	0.000	0.777	0.012	0.818	0.168			0.817	0.132	0.784	0.025	0.817	0.072	0.754	0.050	0.775	0.082	0.783	0.105	0.753	0.140
2/19/2008	0.770	0.004	0.772	0.000	0.777	0.011	0.820	0.168			0.819	0.131	0.786	0.027	0.818	0.074	0.754	0.050	0.775	0.081	0.784	0.103	0.753	0.140
2/20/2008	0.769	0.003	0.773	0.000	0.778	0.012	0.818	0.168			0.818	0.132	0.787	0.027	0.820	0.074	0.754	0.049	0.775	0.081	0.784	0.103	0.754	0.139
2/21/2008	0.770	0.002	0.772	0.000	0.775	0.009	0.819	0.168			0.820	0.131	0.787	0.027	0.819	0.073	0.754	0.048	0.776	0.079	0.785	0.102	0.753	0.138
2/22/2008	0.770	0.002	0.773	0.000	0.777	0.010	0.819	0.168			0.820	0.131	0.786	0.027	0.818	0.072	0.754	0.047						
2/23/2008	0.770	0.001	0.773	0.000	0.776	0.010	0.818	0.168			0.819	0.132	0.785	0.027	0.818	0.071	0.754	0.047						
2/24/2008	0.770	0.001	0.773	0.000	0.776	0.010	0.815	0.170			0.820	0.131	0.785	0.028	0.818	0.071	0.754	0.046						
2/25/2008	0.770	0.000	0.773	0.000	0.776	0.010	0.816	0.169			0.821	0.131	0.785	0.028	0.819	0.071	0.754	0.046						
2/26/2008	0.769	0.000	0.773	0.000	0.777	0.010	0.820	0.169			0.824	0.132	0.787	0.030	0.818	0.072	0.754	0.046						
2/27/2008	0.769	0.000	0.773	0.000	0.774	0.006	0.818	0.169			0.824	0.131	0.789	0.033	0.819	0.073	0.754	0.046						
2/28/2008	0.769	0.000	0.776	0.000	0.779	0.010	0.817	0.170			0.823	0.131	0.790	0.034	0.819	0.075	0.754	0.046						
2/29/2008	0.770	0.000	0.775	0.000	0.777	0.009	0.818	0.169			0.823	0.131	0.789	0.032	0.819	0.073	0.754	0.045						
3/1/2008	0.771	0.000	0.775	0.000	0.776	0.008	0.819	0.168			0.825	0.130	0.790	0.032	0.819	0.073	0.754	0.045						
3/2/2008	0.771	0.000	0.776	0.000	0.775	0.007	0.821	0.168			0.823	0.130	0.789	0.031	0.819	0.072	0.754	0.045						
3/3/2008	0.772	0.000	0.775	0.000	0.772	0.004	0.819	0.169			0.823	0.129	0.788	0.031	0.818	0.071	0.754	0.045						
3/4/2008	0.771	0.000	0.775	0.000	0.773	0.006	0.821	0.167			0.823	0.129	0.788	0.032	0.818	0.071	0.754	0.045						
3/5/2008	0.772	0.000	0.776	0.000	0.774	0.006	0.818	0.168			0.824	0.129	0.789	0.033	0.818	0.072	0.754	0.045						
3/6/2008	0.772	0.000	0.777	0.000	0.776	0.007	0.819	0.168			0.824	0.129	0.790	0.034	0.819	0.072	0.754	0.045	0.776	0.073	0.782	0.090	0.754	0.120
3/7/2008	0.773	0.000	0.777	0.000	0.775	0.006	0.815	0.170			0.824	0.129	0.790	0.035	0.818	0.072	0.754	0.045	0.774	0.070	0.780	0.087	0.753	0.114
3/8/2008	0.773	0.000	0.777	0.000	0.774	0.005	0.818	0.168			0.824	0.129	0.791	0.037	0.820	0.073	0.754	0.045	0.774	0.070	0.781	0.087	0.753	0.113
3/9/2008	0.773	0.000	0.780	0.000	0.779	0.009	0.819	0.169			0.825	0.129	0.792	0.038	0.820	0.074	0.754	0.045	0.774	0.070	0.781	0.087	0.753	0.111
3/10/2008	0.775	0.000	0.777	0.000	0.773	0.002	0.820	0.168			0.825	0.128	0.791	0.037	0.818	0.073	0.754	0.044	0.774	0.067	0.780	0.086	0.753	0.108
3/11/2008	0.776	0.000	0.777	0.000	0.772	0.002	0.819	0.168			0.823	0.128	0.792	0.038	0.818	0.073	0.754	0.043	0.775	0.067	0.780	0.085	0.754	0.109
3/12/2008	0.776	0.000	0.778	0.000	0.773	0.003	0.820	0.167			0.823	0.128	0.791	0.038	0.819	0.073	0.754	0.044	0.774	0.066	0.781	0.084	0.753	0.107
3/13/2008	0.775	0.000	0.781	0.000	0.778	0.007	0.818	0.168			0.826	0.128	0.791	0.039	0.818	0.074	0.754	0.044	0.775	0.067	0.781	0.083	0.753	0.109
3/14/2008	0.775	0.000	0.780	0.000	0.776	0.006	0.819	0.169			0.826	0.128	0.791	0.039	0.817	0.073	0.754	0.044	0.775	0.065	0.781	0.082	0.753	0.104
3/15/2008	0.776	0.000	0.780	0.000	0.775	0.005	0.819	0.168			0.826	0.128	0.791	0.040	0.816	0.072	0.754	0.043	0.774	0.062	0.780	0.081	0.753	0.100
3/16/2008	0.777	0.000	0.779	0.000	0.772	0.003	0.818	0.168			0.827	0.128	0.791	0.042	0.817	0.071	0.754	0.043	0.772	0.060	0.780	0.079	0.754	0.100
3/17/2008	0.777	0.000	0.779	0.000	0.772	0.002	0.815	0.170			0.827	0.128	0.791	0.043	0.817	0.072	0.754	0.043	0.773	0.060	0.781	0.079	0.754	0.100
3/18/2008	0.776	0.000	0.778	0.000	0.771	0.000	0.817	0.169			0.827	0.128	0.792	0.043	0.817	0.072	0.754	0.043	0.774	0.061	0.782	0.080	0.754	0.102
3/19/2008	0.774	0.000	0.779	0.000	0.774	0.003	0.816	0.169			0.829	0.128	0.793	0.045	0.818	0.074	0.754	0.044	0.774	0.061	0.782	0.080	0.754	0.101
3/20/2008	0.773	0.000	0.778	0.000	0.772	0.002	0.819	0.168	0.769	0.142	0.829	0.128	0.793	0.047	0.818	0.075	0.754	0.044	0.775	0.062	0.781	0.080	0.754	0.101
3/21/2008	0.774	0.000	0.780	0.000	0.776	0.004	0.819	0.169	0.767	0.142	0.829	0.128	0.794	0.048	0.818	0.075	0.754	0.044	0.775	0.060	0.782	0.080	0.754	0.099

Table A-2. Continued.

	T7-145 (20 cm)		T7-145 (40 cm)		T7-145 (67 cm)		T7-90 (23 cm)		T7-90 (40 cm)		T7-90 (66 cm)		T7-25 (23 cm)		T7-25 (46 cm)		T7-25 (66 cm)		T7-2 (16 cm)		T7-2 (32 cm)		T7-2 (48 cm)	
Date	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w
3/22/2008	0.774	0.000	0.779	0.000	0.774	0.001	0.820	0.167	0.766	0.141	0.830	0.128	0.795	0.048	0.819	0.076	0.754	0.044	0.776	0.061	0.783	0.079	0.754	0.100
3/23/2008	0.776	0.000	0.777	0.000	0.770	0.000	0.819	0.167	0.764	0.141	0.832	0.127	0.795	0.049	0.818	0.076	0.754	0.044	0.775	0.059	0.783	0.078	0.754	0.098
3/24/2008	0.775	0.000	0.777	0.000	0.771	0.000	0.819	0.167	0.763	0.139	0.833	0.128	0.795	0.050	0.819	0.077	0.754	0.044	0.775	0.057	0.782	0.077	0.754	0.097
3/25/2008	0.775	0.000	0.781	0.000	0.776	0.002	0.819	0.167	0.763	0.137	0.833	0.128	0.797	0.051	0.820	0.076	0.754	0.044	0.777	0.058	0.784	0.077	0.754	0.097
3/26/2008	0.776	0.000	0.778	0.001	0.771	0.000	0.821	0.166	0.761	0.136	0.835	0.127	0.796	0.051	0.818	0.075	0.754	0.042	0.775	0.055	0.782	0.075	0.754	0.093
3/27/2008	0.775	0.000	0.778	0.001	0.770	0.000	0.821	0.166	0.760	0.134	0.835	0.127	0.795	0.050	0.817	0.074	0.754	0.041	0.774	0.053	0.782	0.074	0.754	0.091
3/28/2008	0.775	0.000	0.778	0.001	0.769	0.000	0.821	0.166	0.758	0.133	0.834	0.128	0.795	0.051	0.817	0.074	0.754	0.041	0.774	0.054	0.782	0.074	0.754	0.091
3/29/2008	0.774	0.000	0.779	0.001	0.772	0.001	0.820	0.166	0.758	0.131	0.838	0.127	0.795	0.052	0.817	0.075	0.754	0.041	0.774	0.054	0.781	0.073	0.754	0.090
3/30/2008	0.774	0.000	0.779	0.001	0.771	0.000	0.822	0.165	0.756	0.129	0.837	0.127	0.795	0.052	0.817	0.075	0.754	0.041	0.773	0.055	0.781	0.072	0.754	0.088
3/31/2008	0.774	0.000	0.777	0.002	0.768	0.000	0.821	0.165	0.756	0.127	0.839	0.126	0.794	0.051	0.817	0.074	0.754	0.040	0.772	0.051	0.780	0.070	0.753	0.085
4/1/2008	0.774	0.000	0.777	0.002	0.768	0.000	0.818	0.165	0.755	0.126	0.839	0.126	0.794	0.052	0.816	0.074	0.754	0.040	0.773	0.052	0.781	0.072	0.754	0.087
4/2/2008	0.774	0.000	0.777	0.002	0.768	0.000	0.819	0.165	0.754	0.125	0.841	0.127	0.794	0.053	0.816	0.074	0.754	0.040	0.772	0.050	0.780	0.071	0.754	0.085
4/3/2008	0.773	0.000	0.776	0.003	0.767	0.000	0.819	0.165	0.754	0.124	0.842	0.127	0.794	0.054	0.815	0.075	0.754	0.040	0.772	0.048	0.781	0.071	0.754	0.085
4/4/2008	0.773	0.000	0.776	0.003	0.768	0.000	0.819	0.165	0.753	0.122	0.842	0.128	0.795	0.055	0.815	0.075	0.754	0.040	0.772	0.047	0.781	0.070	0.754	0.084
4/5/2008	0.773	0.000	0.775	0.003	0.768	0.000	0.816	0.166	0.753	0.122	0.844	0.128	0.795	0.055	0.815	0.075	0.754	0.040	0.773	0.049	0.781	0.071	0.754	0.085
4/6/2008	0.772	0.000	0.775	0.004	0.767	0.000	0.817	0.165	0.752	0.121	0.845	0.127	0.795	0.057	0.815	0.077	0.754	0.040	0.774	0.050	0.782	0.071	0.754	0.085
4/7/2008	0.772	0.000	0.773	0.005	0.765	0.000	0.817	0.165	0.752	0.120	0.845	0.127	0.796	0.057	0.816	0.077	0.754	0.041	0.773	0.048	0.782	0.070	0.754	0.084
4/8/2008	0.771	0.000	0.772	0.005	0.765	0.000	0.817	0.165	0.752	0.119	0.846	0.127	0.796	0.057	0.813	0.077	0.754	0.040	0.771	0.043	0.781	0.068	0.754	0.080
4/9/2008	0.771	0.000	0.773	0.005	0.766	0.000	0.816	0.165	0.751	0.119	0.847	0.127	0.796	0.056	0.813	0.077	0.754	0.040	0.770	0.040	0.780	0.067	0.754	0.078
4/10/2008	0.770	0.000	0.774	0.006	0.767	0.000	0.817	0.165	0.751	0.118	0.848	0.127	0.796	0.056	0.814	0.077	0.754	0.039	0.770	0.040	0.780	0.067	0.754	0.075
4/11/2008	0.770	0.000	0.774	0.006	0.768	0.000	0.817	0.165	0.751	0.117	0.849	0.127	0.796	0.057	0.814	0.077	0.754	0.039	0.769	0.039	0.780	0.066	0.754	0.074
4/12/2008	0.770	0.000	0.772	0.007	0.765	0.000	0.817	0.165	0.751	0.116	0.849	0.127	0.795	0.056	0.813	0.076	0.754	0.039	0.769	0.038	0.779	0.065	0.754	0.073
4/13/2008	0.769	0.000	0.772	0.007	0.767	0.000	0.815	0.166	0.750	0.115	0.850	0.127	0.796	0.057	0.813	0.078	0.754	0.040	0.770	0.042	0.780	0.067	0.754	0.077
4/14/2008	0.769	0.000	0.774	0.005	0.770	0.000	0.816	0.166	0.750	0.114	0.850	0.127	0.798	0.059	0.815	0.080	0.754	0.041	0.772	0.045	0.781	0.066	0.754	0.078
4/15/2008	0.768	0.000	0.774	0.005	0.770	0.000	0.818	0.165	0.750	0.114	0.852	0.127	0.798	0.059	0.815	0.082	0.754	0.041	0.774	0.048	0.782	0.067	0.754	0.079
4/16/2008	0.769	0.000	0.774	0.006	0.770	0.000	0.818	0.165	0.750	0.114	0.851	0.127	0.798	0.059	0.816	0.082	0.754	0.041	0.774	0.046	0.783	0.067	0.755	0.078
4/17/2008	0.770	0.000	0.773	0.007	0.769	0.000	0.820	0.164	0.750	0.114	0.852	0.127	0.800	0.058	0.816	0.082	0.754	0.041	0.775	0.047	0.784	0.067	0.755	0.080
4/18/2008	0.769	0.000	0.773	0.008	0.769	0.000	0.822	0.163	0.750	0.113	0.852	0.127	0.801	0.058	0.818	0.082	0.754	0.041	0.775	0.047	0.784	0.067	0.755	0.081
4/19/2008	0.769	0.000	0.774	0.008	0.771	0.000	0.820	0.165	0.750	0.113	0.850	0.128	0.801	0.058	0.818	0.083	0.755	0.041	0.775	0.049	0.785	0.067	0.755	0.080
4/20/2008	0.769	0.000	0.773	0.008	0.770	0.000	0.819	0.166	0.750	0.112	0.847	0.127	0.802	0.058	0.820	0.083	0.755	0.041	0.774	0.047	0.784	0.066	0.755	0.078
4/21/2008	0.771	0.000	0.773	0.008	0.770	0.000	0.820	0.163	0.750	0.109	0.852	0.125	0.802	0.058	0.820	0.083	0.755	0.041	0.774	0.046	0.784	0.065	0.755	0.077
4/22/2008	0.770	0.000	0.773	0.009	0.771	0.000	0.820	0.163	0.750	0.110	0.851	0.124	0.801	0.059	0.820	0.084	0.755	0.041	0.775	0.047	0.784	0.066	0.755	0.077
4/23/2008	0.769	0.000	0.772	0.009	0.770	0.000	0.819	0.164	0.750	0.109	0.847	0.124	0.802	0.058	0.821	0.085	0.755	0.041	0.775	0.048	0.785	0.066	0.755	0.077
4/24/2008	0.769	0.001	0.771	0.010	0.768	0.000	0.819	0.164	0.750	0.109	0.842	0.123	0.802	0.058	0.820	0.085	0.756	0.041	0.775	0.046	0.786	0.065	0.757	0.078
4/25/2008	0.767	0.003	0.768	0.010	0.765	0.000	0.807	0.163	0.749	0.107	0.826	0.119	0.803	0.057	0.823	0.084			0.774	0.044	0.787	0.065	0.758	0.077
4/26/2008							0.764	0.120	0.751	0.089	0.778	0.095	0.805	0.057					0.777	0.046	0.795	0.070	0.758	0.076
4/27/2008							0.750	0.080	0.752	0.064	0.749	0.067	0.802	0.054					0.775	0.043			0.758	0.075
4/28/2008							0.750	0.093	0.752	0.072	0.750	0.069	0.802	0.058					0.778	0.046			0.758	0.074
4/29/2008							0.750	0.109	0.752	0.080	0.751	0.078	0.803	0.060					0.777	0.047			0.758	0.073
4/30/2008							0.751	0.121	0.750	0.086	0.752	0.093	0.802	0.056									0.758	0.072
5/1/2008							0.754	0.168	0.751	0.114	0.769	0.136	0.800	0.058									0.758	0.071
5/2/2008							0.832	0.210	0.751	0.143	0.895	0.154	0.798	0.066									0.758	0.070
5/3/2008							0.851	0.222	0.751	0.159	0.944	0.167	0.797	0.062									0.758	0.069
5/4/2008							0.840	0.226	0.750	0.169	0.952	0.173	0.796	0.057									0.758	0.068
5/5/2008							0.839	0.223	0.750	0.172	0.956	0.174	0.795	0.051									0.758	0.067
5/6/2008							0.834	0.221	0.749	0.176	0.942	0.174	0.788	0.047									0.752	0.065
5/7/2008							0.824	0.222	0.749	0.173	0.918	0.172	0.793	0.047							0.772	0.059	0.752	0.064
5/8/2008							0.818	0.216	0.750	0.170	0.904	0.166	0.794	0.046							0.772	0.057	0.752	0.063
5/9/2008							0.814	0.209	0.750	0.165	0.895	0.160	0.794	0.045							0.773	0.055	0.751	0.062
5/10/2008							0.812	0.203	0.750	0.158	0.885	0.156	0.793	0.044							0.773	0.052	0.751	0.061

Table A-2. Continued.

	T7-145 (20 cm)		T7-145 (40 cm)		T7-145 (67 cm)		T7-90 (23 cm)		T7-90 (40 cm)		T7-90 (66 cm)		T7-25 (23 cm)		T7-25 (46 cm)		T7-25 (66 cm)		T7-2 (16 cm)		T7-2 (32 cm)		T7-2 (48 cm)	
Date	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w
5/11/2008			0.750	0.025			0.811	0.199	0.750	0.152	0.879	0.153	0.794	0.043	0.784	0.088	0.750	0.039	0.765	0.040	0.774	0.051	0.751	0.060
5/12/2008			0.750	0.023			0.806	0.198	0.750	0.147	0.874	0.149	0.793	0.043	0.784	0.086	0.750	0.037	0.764	0.038	0.774	0.050	0.751	0.059
5/13/2008			0.750	0.020			0.800	0.199	0.750	0.141	0.873	0.148	0.794	0.043	0.786	0.085	0.750	0.035	0.766	0.042	0.775	0.050	0.751	0.058
5/14/2008			0.750	0.021			0.800	0.199	0.750	0.140	0.869	0.148	0.794	0.042	0.786	0.083	0.750	0.033	0.765	0.038	0.775	0.050	0.751	0.054
5/15/2008			0.750	0.020			0.796	0.203	0.750	0.135	0.866	0.149	0.794	0.043	0.788	0.082	0.750	0.032	0.765	0.039	0.776	0.050	0.751	0.053
5/16/2008			0.751	0.019			0.791	0.205	0.751	0.128	0.868	0.149	0.793	0.043	0.789	0.082	0.750	0.030	0.766	0.041	0.776	0.050	0.751	0.052
5/17/2008			0.751	0.020			0.790	0.207	0.751	0.124	0.869	0.149	0.793	0.042	0.789	0.081	0.750	0.029	0.765	0.039	0.776	0.049	0.751	0.049
5/18/2008			0.751	0.019			0.790	0.207	0.751	0.120	0.870	0.149	0.793	0.043	0.789	0.080	0.750	0.028	0.766	0.040	0.776	0.049	0.751	0.049
5/19/2008			0.751	0.018			0.789	0.209	0.751	0.118	0.869	0.149	0.793	0.044	0.790	0.080	0.750	0.027	0.766	0.041	0.777	0.049	0.752	0.052
5/20/2008			0.751	0.017			0.788	0.209	0.751	0.115	0.873	0.147	0.792	0.045	0.791	0.080	0.750	0.027	0.766	0.043	0.777	0.050	0.752	0.054
5/21/2008			0.750	0.021			0.785	0.211	0.752	0.113	0.870	0.147	0.791	0.047	0.791	0.079	0.750	0.026	0.765	0.040	0.776	0.049	0.751	0.048
5/22/2008			0.750	0.023			0.785	0.210	0.752	0.112	0.869	0.147	0.792	0.050	0.792	0.079	0.750	0.026	0.767	0.044	0.777	0.050	0.752	0.054
5/23/2008			0.751	0.020			0.784	0.208	0.752	0.110	0.871	0.144	0.790	0.052	0.794	0.079	0.750	0.025	0.765	0.041	0.777	0.049	0.752	0.050
5/24/2008	0.749	0.008	0.751	0.020			0.785	0.208	0.752	0.110	0.865	0.144	0.790	0.055	0.793	0.078	0.750	0.025	0.766	0.042	0.777	0.049	0.752	0.050
5/25/2008	0.749	0.007	0.751	0.019			0.784	0.207	0.752	0.108	0.870	0.142	0.792	0.058	0.794	0.078	0.751	0.026	0.765	0.041	0.777	0.049	0.752	0.048
5/26/2008							0.789	0.202	0.752	0.108	0.873	0.142	0.792	0.060	0.794	0.079	0.751	0.026	0.764	0.040	0.778	0.049	0.752	0.047
5/27/2008							0.788	0.200	0.752	0.106	0.871	0.140	0.790	0.062	0.794	0.079	0.751	0.026	0.765	0.043	0.778	0.050	0.752	0.049
5/28/2008							0.787	0.201	0.752	0.105	0.873	0.139	0.788	0.063	0.794	0.079	0.751	0.026	0.765	0.043	0.778	0.050	0.752	0.048
5/29/2008	0.749	0.007	0.752	0.018			0.789	0.200	0.752	0.104	0.875	0.138	0.788	0.066	0.795	0.079	0.751	0.026	0.767	0.049	0.779	0.051	0.752	0.051
5/30/2008	0.749	0.007	0.752	0.019			0.789	0.198	0.752	0.103	0.878	0.138	0.789	0.069	0.796	0.080	0.751	0.027	0.767	0.049	0.779	0.052	0.752	0.049
5/31/2008	0.750	0.009	0.752	0.020			0.789	0.196	0.752	0.103	0.879	0.137	0.788	0.072	0.797	0.080	0.751	0.027	0.766	0.049	0.779	0.052	0.752	0.049
6/1/2008	0.750	0.010	0.752	0.019			0.788	0.196	0.752	0.102	0.880	0.136	0.788	0.076	0.798	0.081	0.751	0.028	0.767	0.052	0.780	0.052	0.752	0.049
6/2/2008	0.749	0.010	0.752	0.019			0.788	0.196	0.752	0.102	0.877	0.135	0.788	0.079	0.799	0.083	0.751	0.030	0.767	0.053	0.780	0.053	0.752	0.051
6/3/2008	0.749	0.012	0.751	0.019			0.787	0.196	0.752	0.103	0.872	0.135	0.788	0.081	0.798	0.084	0.751	0.029	0.767	0.053	0.781	0.054	0.752	0.049
6/4/2008							0.771	0.178	0.752	0.098	0.840	0.124	0.788	0.083	0.800	0.085	0.751	0.029	0.767	0.054	0.783	0.060	0.752	0.048
6/5/2008							0.749	0.103	0.752	0.085	0.777	0.084	0.788	0.086			0.752	0.030	0.768	0.061			0.753	0.049
6/6/2008							0.749	0.087	0.752	0.088	0.760	0.070	0.789	0.091					0.772	0.084			0.753	0.056
6/7/2008							0.749	0.086	0.752	0.098	0.756	0.074	0.789	0.097					0.777	0.103			0.754	0.062
6/8/2008							0.749	0.091	0.752	0.104	0.755	0.087	0.789	0.101					0.779	0.117			0.755	0.066
6/9/2008							0.750	0.101	0.752	0.112	0.756	0.102	0.788	0.104					0.779	0.122			0.755	0.070
6/10/2008							0.750	0.112	0.752	0.117	0.758	0.119	0.788	0.103					0.779	0.141			0.756	0.077
6/11/2008							0.750	0.122	0.752	0.120	0.759	0.134	0.787	0.104					0.779	0.144			0.756	0.080
6/12/2008							0.749	0.130	0.752	0.126	0.784	0.137	0.786	0.106					0.779	0.144			0.755	0.080
6/13/2008							0.750	0.130	0.752	0.126	0.764	0.138	0.786	0.101					0.779	0.132			0.755	0.072
6/14/2008							0.751	0.145	0.752	0.133	0.798	0.151	0.784	0.101					0.779	0.136			0.754	0.074
6/15/2008							0.759	0.172	0.751	0.142	0.831	0.149	0.780	0.096					0.779	0.132			0.753	0.067
6/16/2008							0.761	0.178	0.751	0.145	0.834	0.148	0.780	0.091					0.775	0.120			0.752	0.062
6/17/2008							0.760	0.180	0.751	0.137	0.833	0.148	0.779	0.087					0.767	0.099			0.752	0.055
6/18/2008							0.758	0.180	0.752	0.127	0.829	0.147	0.779	0.084					0.764	0.095			0.752	0.055
6/19/2008							0.757	0.177	0.752	0.119	0.823	0.146	0.779	0.080					0.762	0.083	0.770	0.065	0.752	0.051
6/20/2008							0.755	0.175	0.752	0.116	0.822	0.143	0.780	0.079					0.762	0.080	0.770	0.063	0.752	0.052
6/21/2008							0.755	0.171	0.752	0.113	0.822	0.140	0.780	0.077					0.762	0.074	0.770	0.060	0.752	0.052
6/22/2008							0.754	0.168	0.752	0.111	0.823	0.138	0.780	0.076					0.763	0.068	0.771	0.058	0.752	0.051
6/23/2008							0.754	0.164	0.752	0.108	0.821	0.136	0.781	0.074					0.761	0.059	0.775	0.055	0.752	0.052
6/24/2008							0.754	0.162	0.752	0.106	0.817	0.134	0.782	0.073					0.759	0.049	0.789	0.050	0.753	0.056
6/25/2008							0.754	0.159	0.752	0.104	0.815	0.132	0.783	0.072					0.758	0.048	0.790	0.050	0.753	0.055
6/26/2008							0.751	0.142	0.752	0.097	0.791	0.121	0.783	0.071					0.759	0.049	0.792	0.053	0.753	0.056
6/27/2008							0.749	0.132	0.752	0.098	0.779	0.111	0.784	0.069					0.759	0.050			0.753	0.057
6/28/2008							0.749	0.135	0.752	0.099	0.779	0.113	0.784	0.069					0.759	0.050			0.753	0.059
6/29/2008							0.751	0.112	0.752	0.094	0.755	0.093	0.784	0.067					0.759	0.050			0.753	0.059

Table A-2. Continued.

	T7-145 (20 cm)		T7-145 (40 cm)		T7-145 (67 cm)		T7-90 (23 cm)		T7-90 (40 cm)		T7-90 (66 cm)		T7-25 (23 cm)		T7-25 (46 cm)		T7-25 (66 cm)		T7-2 (16 cm)		T7-2 (32 cm)		T7-2 (48 cm)	
Date	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w
6/30/2008							0.752	0.097	0.752	0.093	0.752	0.094	0.785	0.066					0.761	0.055			0.753	0.062
7/1/2008							0.751	0.096	0.752	0.095	0.760	0.108	0.783	0.065					0.763	0.061			0.753	0.070
7/2/2008							0.755	0.141	0.752	0.118	0.779	0.116	0.777	0.062					0.760	0.063			0.752	0.067
7/3/2008							0.759	0.156	0.752	0.118	0.781	0.123	0.779	0.062					0.759	0.059			0.752	0.064
7/4/2008							0.758	0.158	0.752	0.112	0.784	0.124	0.779	0.060					0.757	0.060			0.752	0.061
7/5/2008							0.759	0.157	0.752	0.107	0.786	0.126	0.779	0.059					0.756	0.055			0.752	0.061
7/6/2008							0.760	0.156	0.752	0.103	0.789	0.126	0.778	0.058					0.755	0.050	0.785	0.062	0.752	0.061
7/7/2008							0.759	0.155	0.752	0.100	0.793	0.127	0.778	0.058					0.755	0.047	0.783	0.055	0.752	0.058
7/8/2008							0.760	0.154	0.752	0.099	0.794	0.131	0.777	0.058	0.774	0.157	0.749	0.052	0.754	0.045	0.781	0.051	0.752	0.059
7/9/2008							0.759	0.155	0.752	0.097	0.795	0.134	0.776	0.059	0.774	0.157	0.749	0.047	0.754	0.044	0.780	0.049	0.752	0.060
7/10/2008							0.759	0.156	0.752	0.098	0.796	0.137	0.776	0.060	0.773	0.157	0.749	0.042	0.754	0.043	0.780	0.047	0.752	0.062
7/11/2008							0.760	0.156	0.752	0.097	0.798	0.140	0.776	0.062	0.773	0.157	0.749	0.038	0.754	0.043	0.780	0.047	0.752	0.063
7/12/2008							0.760	0.158	0.752	0.099	0.802	0.143	0.777	0.063	0.773	0.157	0.749	0.035	0.754	0.044	0.780	0.049	0.752	0.066
7/13/2008							0.760	0.163	0.752	0.101	0.805	0.148	0.777	0.064	0.775	0.157	0.749	0.034	0.755	0.045	0.782	0.050	0.752	0.068
7/14/2008							0.761	0.165	0.752	0.103	0.809	0.148	0.777	0.065	0.775	0.157	0.749	0.033	0.755	0.044	0.782	0.049	0.752	0.065
7/15/2008							0.761	0.168	0.752	0.103	0.811	0.149	0.777	0.064	0.777	0.157	0.749	0.033	0.755	0.045	0.784	0.050	0.752	0.067
7/16/2008							0.763	0.171	0.752	0.103	0.815	0.147	0.777	0.064	0.778	0.157	0.749	0.033	0.755	0.045	0.784	0.051	0.752	0.066
7/17/2008							0.763	0.175	0.752	0.103	0.818	0.145	0.777	0.064	0.778	0.157	0.749	0.033	0.755	0.045	0.785	0.052	0.752	0.066
7/18/2008							0.764	0.175	0.752	0.103	0.818	0.143	0.777	0.062	0.778	0.157	0.749	0.033	0.754	0.041	0.786	0.051	0.752	0.065
7/19/2008							0.765	0.178	0.752	0.103	0.819	0.140	0.778	0.062	0.780	0.157	0.749	0.033	0.754	0.037	0.787	0.053	0.752	0.066
7/20/2008							0.766	0.179	0.752	0.103	0.818	0.139	0.779	0.060	0.780	0.157	0.749	0.033	0.754	0.036	0.788	0.054	0.752	0.067
7/21/2008							0.767	0.178	0.752	0.102	0.818	0.137	0.778	0.059	0.781	0.157	0.749	0.033	0.754	0.036	0.788	0.054	0.752	0.067
7/22/2008							0.769	0.179	0.752	0.102	0.820	0.136	0.777	0.057	0.781	0.157	0.749	0.033	0.755	0.033	0.790	0.054	0.752	0.068
7/23/2008							0.770	0.180	0.752	0.101	0.826	0.135	0.778	0.056	0.782	0.157	0.749	0.033	0.756	0.031	0.793	0.055	0.752	0.072
7/24/2008							0.773	0.179	0.752	0.100	0.828	0.134	0.778	0.055	0.782	0.157	0.749	0.032	0.757	0.030	0.794	0.055	0.752	0.071
7/25/2008							0.773	0.181	0.752	0.100	0.829	0.132	0.778	0.053	0.783	0.157	0.749	0.032	0.756	0.030	0.794	0.053	0.752	0.068
7/26/2008							0.774	0.181	0.752	0.099	0.828	0.132	0.779	0.053	0.783	0.157	0.750	0.031	0.756	0.029	0.794	0.053	0.752	0.067
7/27/2008							0.776	0.182	0.752	0.100	0.830	0.131	0.776	0.052	0.778	0.157	0.749	0.030	0.755	0.028	0.788	0.052	0.751	0.071
7/28/2008							0.772	0.183	0.752	0.117	0.836	0.135	0.768	0.056	0.767	0.157	0.749	0.025	0.753	0.029	0.775	0.048	0.750	0.071
7/29/2008							0.771	0.183	0.752	0.130	0.859	0.152	0.764	0.063	0.765	0.157	0.749	0.022	0.753	0.031	0.774	0.050	0.750	0.073
7/30/2008							0.771	0.184	0.752	0.145	0.836	0.157	0.762	0.068	0.762	0.157	0.749	0.022	0.753	0.035	0.774	0.054	0.750	0.078
7/31/2008							0.771	0.184	0.752	0.157	0.837	0.161	0.760	0.072	0.763	0.157	0.749	0.025	0.753	0.039	0.779	0.061	0.750	0.081
8/1/2008	0.774	0.034	0.756	0.022	0.761	0.000	0.772	0.182	0.752	0.153	0.831	0.154	0.764	0.073	0.769	0.157	0.749	0.031	0.754	0.041	0.789	0.066	0.751	0.081
8/2/2008	0.772	0.032	0.757	0.021	0.761	0.000	0.774	0.180	0.752	0.135	0.831	0.141	0.763	0.068	0.770	0.157	0.749	0.034	0.756	0.040	0.791	0.065	0.751	0.080
8/3/2008	0.770	0.031	0.756	0.021	0.760	0.000	0.774	0.180	0.752	0.122	0.831	0.134	0.764	0.063	0.772	0.157	0.749	0.034	0.756	0.039	0.793	0.067	0.751	0.083
8/4/2008	0.768	0.030	0.757	0.020	0.759	0.000	0.777	0.177	0.752	0.114	0.831	0.130	0.763	0.058	0.773	0.157	0.749	0.033	0.756	0.037	0.793	0.064	0.751	0.079
8/5/2008	0.767	0.029	0.757	0.019	0.759	0.000	0.777	0.177	0.752	0.108	0.830	0.127	0.763	0.055	0.774	0.157	0.749	0.033	0.756	0.036	0.794	0.063	0.751	0.077
8/6/2008	0.765	0.028	0.757	0.018	0.758	0.000	0.778	0.177	0.752	0.105	0.829	0.125	0.763	0.052	0.775	0.157	0.749	0.032	0.756	0.034	0.794	0.062	0.751	0.076
8/7/2008	0.763	0.026	0.758	0.017	0.758	0.000	0.778	0.178	0.752	0.101	0.828	0.124	0.763	0.050	0.776	0.157	0.749	0.031	0.756	0.033	0.794	0.061	0.751	0.073
8/8/2008	0.762	0.025	0.759	0.015	0.759	0.000	0.779	0.178	0.752	0.101	0.828	0.123	0.763	0.049	0.778	0.157	0.749	0.032	0.756	0.033	0.795	0.062	0.752	0.077
8/9/2008	0.761	0.024	0.758	0.015	0.758	0.000	0.778	0.178	0.751	0.100	0.830	0.122	0.763	0.047	0.778	0.157	0.749	0.031	0.757	0.032	0.794	0.060	0.751	0.075
8/10/2008	0.760	0.022	0.758	0.014	0.758	0.000	0.778	0.179	0.752	0.099	0.832	0.121	0.763	0.046	0.779	0.157	0.749	0.030	0.757	0.032	0.794	0.060	0.751	0.074
8/11/2008	0.759	0.022	0.760	0.013	0.758	0.000	0.782	0.178	0.752	0.098	0.832	0.121	0.764	0.045	0.780	0.157	0.749	0.030	0.757	0.031	0.796	0.059	0.752	0.072
8/12/2008	0.758	0.021	0.759	0.013	0.758	0.000	0.782	0.178	0.752	0.096	0.832	0.121	0.764	0.044	0.780	0.157	0.749	0.031	0.757	0.030	0.796	0.059	0.752	0.075
8/13/2008	0.757	0.019	0.759	0.015	0.757	0.000	0.781	0.178	0.752	0.096	0.832	0.120	0.765	0.043	0.782	0.157	0.749	0.030	0.757	0.030	0.795	0.057	0.752	0.071
8/14/2008	0.756	0.018	0.759	0.014	0.756	0.000	0.783	0.178	0.752	0.095	0.834	0.120	0.764	0.042	0.781	0.157	0.749	0.030	0.757	0.029	0.795	0.056	0.751	0.067
8/15/2008	0.756	0.017	0.759	0.014	0.756	0.000	0.784	0.179	0.752	0.095	0.835	0.120	0.764	0.042	0.782	0.157	0.749	0.029	0.757	0.028	0.796	0.057	0.752	0.070
8/16/2008	0.755	0.017	0.759	0.013	0.756	0.000	0.786	0.178	0.752	0.094	0.836	0.120	0.764	0.041	0.783	0.157	0.750	0.029	0.757	0.028	0.796	0.056	0.752	0.070
8/17/2008	0.755	0.017	0.760	0.013	0.756	0.001	0.786	0.178	0.752	0.093	0.836	0.120	0.764	0.040	0.783	0.157	0.750	0.028	0.757	0.028	0.795	0.054	0.752	0.070
8/18/2008	0.755	0.016	0.759	0.013	0.755	0.000	0.787	0.178	0.752	0.093	0.836	0.120	0.764	0.039	0.783	0.157	0.750	0.028	0.757	0.028	0.797	0.056	0.752	0.073

Table A-2. Continued.

	T7-145 (20 cm)		T7-145 (40 cm)		T7-145 (67 cm)		T7-90 (23 cm)		T7-90 (40 cm)		T7-90 (66 cm)		T7-25 (23 cm)		T7-25 (46 cm)		T7-25 (66 cm)		T7-2 (16 cm)		T7-2 (32 cm)		T7-2 (48 cm)	
Date	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w	θ	σ_w
8/19/2008	0.754	0.016	0.759	0.015	0.755	0.000	0.786	0.179	0.751	0.094	0.837	0.121	0.765	0.039	0.784	0.157	0.750	0.028	0.757	0.027	0.798	0.056	0.752	0.069
8/20/2008	0.754	0.015	0.759	0.015	0.754	0.000	0.786	0.179	0.752	0.094	0.838	0.122	0.764	0.039	0.785	0.157	0.750	0.027	0.757	0.027	0.798	0.056	0.752	0.071
8/21/2008	0.753	0.014	0.759	0.015	0.754	0.002	0.787	0.179	0.752	0.092	0.840	0.124	0.763	0.038	0.784	0.157	0.750	0.027	0.757	0.026	0.797	0.055	0.752	0.068
8/22/2008	0.752	0.015	0.759	0.015	0.754	0.004	0.786	0.179	0.752	0.091	0.840	0.126	0.763	0.038	0.786	0.157	0.750	0.027	0.757	0.026	0.798	0.055	0.751	0.053
8/23/2008	0.752	0.014	0.760	0.015	0.754	0.005	0.787	0.179	0.752	0.091	0.844	0.127	0.763	0.038	0.786	0.157	0.750	0.027	0.757	0.026	0.796	0.053	0.751	0.061
8/24/2008	0.752	0.014	0.760	0.015	0.754	0.005	0.789	0.177	0.752	0.092	0.844	0.127	0.763	0.037	0.786	0.157	0.750	0.027	0.757	0.025	0.796	0.052	0.751	0.062
8/25/2008	0.752	0.013	0.759	0.015	0.754	0.005	0.789	0.178	0.752	0.091	0.846	0.127	0.763	0.037	0.787	0.157	0.750	0.027	0.757	0.025	0.796	0.051	0.752	0.064
8/26/2008	0.751	0.013	0.759	0.015	0.753	0.006	0.789	0.178	0.752	0.091	0.847	0.127	0.763	0.037	0.787	0.157	0.750	0.026	0.757	0.025	0.795	0.050	0.752	0.062
8/27/2008	0.751	0.013	0.760	0.015	0.753	0.006	0.788	0.177	0.752	0.090	0.844	0.127	0.763	0.036	0.788	0.157	0.750	0.026	0.757	0.025	0.796	0.050	0.751	0.066
8/28/2008	0.751	0.013	0.759	0.016	0.753	0.006	0.785	0.177	0.752	0.090	0.841	0.127	0.763	0.036	0.787	0.157	0.750	0.026	0.758	0.024	0.796	0.049	0.751	0.066

APPENDIX B
ECOLOX SOURCE CODE

```
      PROGRAM ECOLOX

CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C                                                                     C
C     WRITTEN FOR: Ph.D.dissertation and later modified for distribution C
C     Last Updated: 1 April 2010 v 0.37                               C
C     Written by: David Kaplan, R. Munoz-Carpena                      C
C                 ABE-University of Florida                           C
C                 Gainesville, FL 32611                               C
C                 e-mail: dkaplan@ufl.edu, carpena@ufl.edu            C
C                                                                     C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C                                                                     C
C     PROGRAM CALCULATES LONG-TERM FLOODING, MOISTURE, AND            C
C     SALINITY CONDITIONS IN THE FLOODPLAIN WETLANDS OF THE           C
C     LOXAHATCHEE RIVER (FL,USA) TO ASSESS THE EFFECTS OF             C
C    RESTORATION SCENARIOS ON VEGETATIVE COMMUNITIES                  C
C                                                                     C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC

      IMPLICIT REAL (A-H,O-Z)
      PARAMETER (MAXDREC=14600,MAXYEAR=40,MAXREACH=40,MAXCELL=50000,
     & NumPWSClass=14)
      CHARACTER*75 LISFIL(20)

      COMMON/CELL/CellChar(MAXCELL,2)
      COMMON/ICELL/ICellReach(MAXCELL),ICELLCOUNT,IReach

      COMMON/FLOOD/SWE(MAXDREC,MAXREACH),WaterDepth
      COMMON/IFLOOD/InunRecord(MAXYEAR,366),IDAYREC,IYEARREC,
     & InunDay,IConInunDay

      COMMON/GERM/RAIN(MAXDREC)
      COMMON/GERM1/CritRainDepth,CritMoistureDepth
      COMMON/IGERM/ISeedsAvailable(MAXDREC),ICritConsecGermDays,
     & IMoistDay,IConMoistDay,IGoodGermCond,IGoodGermCount

      COMMON/REPORT/YearlyRecord(MAXYEAR,16),
     & HabitatSuitability(MAXYEAR,8),IBREAK(MAXYEAR)
      COMMON/REPORT1/SWSDsDbRatio,PWSDsDbRatio
      COMMON/IREPORT1/InundationMap(MAXYEAR),
     & IConInundationMap(MAXYEAR),IMoistMap(MAXYEAR),
     & IConMoistMap(MAXYEAR),IGoodGermCondMap(MAXYEAR),
     & IGerminationEventMap(MAXYEAR),IRecruitmentMap(MAXYEAR),
     & ISWSalXMap(MAXYEAR),IConSWSalXMap(MAXYEAR),
     & IPWSalXMap(MAXYEAR),IConPWSalXMap(MAXYEAR)

      COMMON/SALT/SWS(MAXDREC,MAXREACH),CritSal,SWSalXMag,
     & PWSalXMag
      COMMON/ISALT/ISWSalXDay,IConSWSalXDay,ISWSaltyYesterday,
     & ISWSDsCount,ISWSDsRecord(MAXDREC),ISWSDbCount,
     & ISWSDbRecord(MAXDREC),ISWSalBDay,IConSWSalBDay,
     & IPWSalXDay,IConPWSalXDay,IPWSaltyYesterday,
     & IPWSDsCount,IPWSDsRecord(MAXDREC),IPWSDbCount,
     & IPWSDbRecord(MAXDREC),IPWSalBDay,IConPWSalBDay

      COMMON/SEEDLING/Seedlings(MAXDREC,12),VinitialSeedlingHeight,
     & YearZeroGrowthRate(MAXDREC),YearOneGrowthRate(MAXDREC)
      COMMON/SEEDLING1/YearZeroWinterGrowthMin,
     & YearZeroWinterGrowthMax,
     & YearZeroSpringGrowthMin,YearZeroSpringGrowthMax,
     & YearZeroFallGrowthMin, YearZeroFallGrowthMax,
     & YearOneWinterGrowthMin,YearOneWinterGrowthMax,
     & YearOneSpringGrowthMin, YearOneSpringGrowthMax,
     & YearOneFallGrowthMin,YearOneFallGrowthMax
      COMMON/SEEDLING2/vJanSeedIndex,vFebSeedIndex,vMarSeedIndex,
     & vAprSeedIndex,vMaySeedIndex,vJunSeedIndex,vJulSeedIndex,
C    & vAugSeedIndex,vSepSeedIndex,vOctSeedIndex,vNovSeedIndex,
     & vDecSeedIndex
      COMMON/ISEEDLING/ISeedlingsSubmergedDays(4,MAXDREC),
     & IDaysSeedsAvailable,ISeedlingCount, IGermEvents,
     & IYearZeroSeedlingSubmergedCrit, IYearOneSeedlingSubmergedCrit,
     & IYearZeroSeedlingSaltCrit, IYearOneSeedlingSaltCrit,
     & IRecruitmentEvents,IYearOneSaltDaysCrit,IYearZeroSaltDaysCrit

      COMMON/IDAYS/IDAYEND,IDOY,IDAYBEG,INIDAY

C-----Print banner, get I/O filenames and open them ---------------------------

      CALL FINPUT(LISFIL,INARGS,ISCR)

C-----Get inputs and parameters from input files------------------------------

      CALL INPUTS(INARGS,LISFIL,INIYEAR)

C-----Initialize variables----------------------------------------------------

      CALL INI

C-----Perform initial calculations and data processing------------------------

      CALL INICALC

C-----Loop for CELLS, set IDAYBEG to 1 to start time loop for each cell--------

c     DO 100 KCell=27279,27279
```

```
      DO 100 KCell=1, ICELLCOUNT
        PRINT*,'calculating cell',KCELL
        IDAYBEG=1

C-----Loop through YEARS-------------------------------------------------------

c       DO 80 I=1,2
        DO 80 I=1,IYEARREC+1
          CALL NEWYEAR(I,IDAY)
C-----Time loop for days within year-------------------------------------------

          DO 40 J=IDAYBEG,IDAYEND
            IDAY=J
            CALL INUND(I,KCell,IDAY)
            CALL SALINITY(I,KCell,IDAY)
            CALL GERMINATION(I,KCell,IDAY)
            CALL SEEDLINGGROW(I,KCell,IDAY)
            IDOY=IDOY+1
40        CONTINUE

C-----Set beginning day and move to next simulation year----------------------

          IDAYBEG=IBREAK(I)
80        CONTINUE

C-----Output maps of results after all simulation years-----------------------

        CALL OUTMAP(KCELL)

C-----Assigns most likely habitat type based on hydrology during period of-----
C-----record-------------------------------------------------------------------

         CALL HABITAT(KCELL)

C-----Reset variables and move to next cell------------------------------------

        CALL NEWCELL
100   CONTINUE

C-----End of EcoLox------------------------------------------------------------

      CLOSE(1)
      CLOSE(2)
      CLOSE(3)
      CLOSE(7)

      CLOSE(10)
      CLOSE(11)
      CLOSE(12)
      CLOSE(13)
      CLOSE(14)
      CLOSE(15)
      CLOSE(16)
      CLOSE(17)
      CLOSE(18)
      CLOSE(19)
      CLOSE(20)
      CLOSE(21)
      CLOSE(22)
      CLOSE(23)

      STOP
      END
```

SUBROUTINE FINPUT(LISFIL,INARGS,ISCR)

```
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C     Create input and output file names from a command line input string     C
C                                                                             C
C     NOTE: Maximum length of command line string = 25 characters            C
C                                                                             C
C     DESCRIPTION OF FILES:                                                   C
C                                                                             C
C     igp: global parameters                                                  C
C     isw: surface water elevation for each river reach                       C
C     iss: surface water salinity for each river reach                        C
C     icl: cell characteristics                                               C
C     irn: daily rainfall (mm)                                                C
C     osm: Output summary of inputs use in the run                            C
C     om1: Map, total inundation                                              C
C     om2: Map, continuous inundation                                         C
C     om3: Map, moisture conditions                                           C
C     om4: Map, continuous moisture conditions                                C
C     om5: Map, germination conditions                                        C
C     om6: Map, germination events                                            C
C     om7: Map, recruitment conditions                                        C
C     om8: Map, surface water salinity                                        C
C     om9: Map, continuous surface water salinity                             C
C     om10: Map, Ds:Db ratios                                                 C
C     om11: Map, porewater salinity                                           C
C     om12: Map, continuous porewater salinity                                C
C     om13: Map, habitat                                                      C
C     om2: Map, continuous inundation                                         C
C                                                                             C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC

      IMPLICIT REAL (A-H,O-Z)
      PARAMETER (NumFiles=19)
```

```
      CHARACTER*120 FILENM1
      CHARACTER*75 LISFIL(20)
            character*200 linein
            CHARACTER*3,SCOD(NumFiles)
            CHARACTER*1,DUMMY1
            character*1 slash
            DATA(SCOD(I),I=1,NumFiles)/'igp','isw','iss','icl','irn','osm','om1',
     & 'om2','om3','om4','om5','om6','om7','om8','om9','oma','omb',
     & 'omc','omd'/

c*** Command line option to input filename
c*** Comment out the following depending for which system you complile
CDOS        slash='\'
CDOS        INARGS=NARGS()-1
CDOS        IF (INARGS.EQ.1) THEN
CDOS        CALL GETARG(1,FILENM1,FSTATUS)
CUNIX
            slash='/'
CUNIX
            INARGS=IARGC()
CUNIX
            IF (INARGS.EQ.1) THEN
CUNIX
              CALL GETARG(1,FILENM1)
c***End of UNIX/DOS selection**********
       ISCR=0
c-----Write welcome message ------------------------------------
       WRITE(*,160)
       WRITE(*,*)'      ECOLOX 02/2010 - v0.0.0'
       WRITE(*,160)
       WRITE(*,*)'      D. Kaplan and R.Munoz-Carpena'
       WRITE(*,*)'      University of Florida - USA'
       WRITE(*,*)'      dkaplan@ufl.edu, carpena@ufl.edu'
       WRITE(*,160)
       WRITE(*,*)'Program calculates long-term flooding, moisture',
     &   'and salinity conditions in the floodplain wetlands of',
     &   'the Loxahatchee River (FL, USA) to assess the effects',
     &   'of restoration scenarios on vegetative communities'
       WRITE(*,160)
       WRITE(*,*)
      ELSEIF (INARGS.EQ.2) THEN
CDOS        CALL GETARG(1,FILENM1,FSTATUS)
CUNIX
            CALL GETARG(1,FILENM1)
       ISCR=1
             ELSE
        WRITE(*,*)
        WRITE(*,105)
        WRITE(*,110)
        WRITE(*,120)
        WRITE(*,130)
        WRITE(*,140)
        WRITE(*,150)
        WRITE(*,*)
        STOP
      ENDIF
c
C------ create I/O filenames from input string ------------------------
c------   or read filenames from project file  ------------------------

            ilstr=index(FILENM1,'.')
            if (ilstr.gt.0) then
c     *** using project file (.prj) to read filenames
c     ***   mods made 10/24/99, jep - push version to 1.04
c     ***  check for .prj or .lis to make sure this is our file
                ilstr1=index(FILENM1,'.prj')
                ilstr2=index(FILENM1,'.lis')
                if ((ilstr1.gt.0).or.(ilstr2.gt.0)) then
c     *** fill filename array with safe names
          do 11 i=1,NumFiles
                    DUMMY1=SCOD(I)
                        if (dummy1.eq.'i') then
                          WRITE(LISFIL(I),'(5A)')
     1         'inputs',slash,'dummy','.',SCOD(I)
                        else
                          WRITE(LISFIL(I),'(5A)')
     1         'output',slash,'dummy','.',SCOD(I)
                    endif
11                    continue
c
                open (unit=99,file=FILENM1,status='old')
12                    read(99,'(a)',end=18) linein
                      lpos = index(linein,'=')
                lstr = len(linein)
                if ((lpos.gt.0).and.(lstr.gt.0)) then
                            do 14 jj=1,NumFiles
                    lpp=index(linein(1:lpos-1),scod(jj))
                    if (lpp.gt.0) lisfil(jj)=linein(lpos+1:)
14          continue
                      endif
                go to 12
c      **** done
18      continue
       else
        WRITE(*,*)
        WRITE(*,105)
                    WRITE(*,110)
                WRITE(*,120)
        WRITE(*,130)
                WRITE(*,140)
```

```
      WRITE(*,150)
      WRITE(*,*)
      STOP
            endif

          else
c     *** rafa's i/o scheme for filenames
            ILSTR=INDEX(FILENM1,' ')-1
            IF(ILSTR.LT.1)ILSTR=NumFiles
            DO 101 I=1,NumFiles
                  DUMMY1=SCOD(I)
                  IF(DUMMY1.EQ.'i') THEN
                        WRITE(LISFIL(I),'(5A)')
     1      'inputs',slash,FILENM1(:ILSTR),'.',SCOD(I)
                   ELSE
                        WRITE(LISFIL(I),'(5A)')
     1      'output',slash,FILENM1(:ILSTR),'.',SCOD(I)
                  ENDIF
101   CONTINUE
    endif

C---------Open I/O files -------------------------------
    OPEN(1,FILE=LISFIL(1),ERR=1500,STATUS='OLD')
    OPEN(2,FILE=LISFIL(2),ERR=1500,STATUS='OLD')
    OPEN(3,FILE=LISFIL(3),ERR=1500,STATUS='OLD')
    OPEN(7,FILE=LISFIL(4),ERR=1500,STATUS='OLD')
    OPEN(8,FILE=LISFIL(5),ERR=1500,STATUS='OLD')
    OPEN(10,FILE=LISFIL(6),STATUS='UNKNOWN')
    OPEN(11,FILE=LISFIL(7),STATUS='UNKNOWN')
    OPEN(12,FILE=LISFIL(8),STATUS='UNKNOWN')
    OPEN(13,FILE=LISFIL(9),STATUS='UNKNOWN')
    OPEN(14,FILE=LISFIL(10),STATUS='UNKNOWN')
    OPEN(15,FILE=LISFIL(11),STATUS='UNKNOWN')
    OPEN(16,FILE=LISFIL(12),STATUS='UNKNOWN')
    OPEN(17,FILE=LISFIL(13),STATUS='UNKNOWN')
    OPEN(18,FILE=LISFIL(14),STATUS='UNKNOWN')
    OPEN(19,FILE=LISFIL(15),STATUS='UNKNOWN')
    OPEN(20,FILE=LISFIL(16),STATUS='UNKNOWN')
    OPEN(21,FILE=LISFIL(17),STATUS='UNKNOWN')
    OPEN(22,FILE=LISFIL(18),STATUS='UNKNOWN')
    OPEN(23,FILE=LISFIL(19),STATUS='UNKNOWN')

          WRITE(10,220)LISFIL(6)
          WRITE(10,*)
c*** in summary file, put the list of files for this run
          write(10,*) 'Files for this simulation'
          write(10,225) (i,scod(i),lisfil(i),i=1,NumFiles)

105       FORMAT('Name:    ecolox')
110       FORMAT(9x,'(ECOLOX model to calculate long-term flooding and')
120       FORMAT(10x,'salinity conditions in a floodplain wetland)')
130       FORMAT('Usage:   ecolox filename (max 25 characters)')
Cunix
140       FORMAT('Version: 0.0.0 for Unix - 02/2010')
CDOS 140  FORMAT('Version: 0.0.0 for Win32 - 02/2010')
150       FORMAT('Authors: D.Kaplan & R.Munoz-Carpena (U. of Florida)')
160       FORMAT(72('-'))
220       FORMAT('File: ',A40,8x,'ECOLOX v0.0.0 02/2010')
225   format(3x,'File #=',i3,' code:',a3,'=',a)

          RETURN
1500      WRITE(*,1600)'ERROR: Input file(s) missing (check project)'
1600      FORMAT(/,A50,/)

          END
```

SUBROUTINE INPUTS(INARGS,LISFIL,INIYEAR)

```
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C                                                                  C
C     Reads data from input files and writes to .osm file          C
C                                                                  C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC

IMPLICIT REAL (A-H,O-Z)
    PARAMETER (MAXDREC=14600,MAXYEAR=40,MAXREACH=40,MAXCELL=50000,
   & NumPWSClass=14)
    CHARACTER*75 LISFIL(20)

    COMMON/CELL/CellChar(MAXCELL,2)
    COMMON/ICELL/ICellReach(MAXCELL),ICELLCOUNT,IReach

    COMMON/FLOOD/SWE(MAXDREC,MAXREACH),WaterDepth
    COMMON/IFLOOD/InunRecord(MAXYEAR,366),IDAYREC,IYEARREC,
   & InunDay,IConInunDay

    COMMON/GERM/RAIN(MAXDREC)
    COMMON/GERM1/CritRainDepth,CritMoistureDepth
    COMMON/IGERM/ISeedsAvailable(MAXDREC),ICritConsecGermDays,
   & IMoistDay,IConMoistDay,IGoodGermCond,IGoodGermCount

    COMMON/REPORT/YearlyRecord(MAXYEAR,16),
   & HabitatSuitability(MAXYEAR,8),IBREAK(MAXYEAR)
    COMMON/REPORT1/SWSDsDbRatio,PWSDsDbRatio
    COMMON/IREPORT1/InundationMap(MAXYEAR),
   & IConInundationMap(MAXYEAR),IMoistMap(MAXYEAR),
   & IConMoistMap(MAXYEAR),IGoodGermCondMap(MAXYEAR),
   & IGerminationEventMap(MAXYEAR),IRecruitmentMap(MAXYEAR),
   & ISWSalXMap(MAXYEAR),IConSWSalXMap(MAXYEAR),
```

```
     & IPWSalXMap(MAXYEAR),IConPWSalXMap(MAXYEAR)

       COMMON/SALT/SWS(MAXDREC,MAXREACH),CritSal,SWSalXMag,
     & PWSalXMag
       COMMON/ISALT/ISWSalXDay,IConSWSalXDay,ISWSaltyYesterday,
     & ISWSDsCount,ISWSDsRecord(MAXDREC),ISWSDbCount,
     & ISWSDbRecord(MAXDREC),ISWSalBDay,IConSWSalBDay,
     & IPWSalXDay,IConPWSalXDay,IPWSaltyYesterday,
     & IPWSDsCount,IPWSDsRecord(MAXDREC),IPWSDbCount,
     & IPWSDbRecord(MAXDREC),IPWSalBDay,IConPWSalBDay

       COMMON/SEEDLING/Seedlings(MAXDREC,12),VinitialSeedlingHeight,
     & YearZeroGrowthRate(MAXDREC),YearOneGrowthRate(MAXDREC)
       COMMON/SEEDLING1/YearZeroWinterGrowthMin,
     & YearZeroWinterGrowthMax,
     & YearZeroSpringGrowthMin,YearZeroSpringGrowthMax,
     & YearZeroFallGrowthMin, YearZeroFallGrowthMax,
     & YearOneWinterGrowthMin,YearOneWinterGrowthMax,
     & YearOneSpringGrowthMin, YearOneSpringGrowthMax,
     & YearOneFallGrowthMin,YearOneFallGrowthMax
       COMMON/SEEDLING2/vJanSeedIndex,vFebSeedIndex,vMarSeedIndex,
     & vAprSeedIndex,vMaySeedIndex,vJunSeedIndex,vJulSeedIndex,
     & vAugSeedIndex,vSepSeedIndex,vOctSeedIndex,vNovSeedIndex,
     & vDecSeedIndex
       COMMON/ISEEDLING/ISeedlingsSubmergedDays(4,MAXDREC),
     & IDaysSeedsAvailable,ISeedlingCount, IGermEvents,
     & IYearZeroSeedlingSubmergedCrit, IYearOneSeedlingSubmergedCrit,
     & IYearZeroSeedlingSaltCrit, IYearOneSeedlingSaltCrit,
     & IRecruitmentEvents,IYearOneSaltDaysCrit,IYearZeroSaltDaysCrit

       COMMON/IDAYS/IDAYEND,IDOY,IDAYBEG,INIDAY

C-------Read in global parameters of the program (.igp file)--------

       IF(INARGS.EQ.1) THEN
         WRITE(*,'(" ... Reading inputs from: ",A45)')LISFIL(1)
       ENDIF
       READ(1,*)IdayRec, Ireach,IyearRec
       READ(1,*)CritRainDepth,CritMoistureDepth,ICritConsecGermDays,
     &  VinitialSeedlingHeight
       READ(1,*)IYearZeroSeedlingSubmergedCrit,
     &  IYearOneSeedlingSubmergedCrit
       READ(1,*)IYearZeroSeedlingSaltCrit,IYearOneSeedlingSaltCrit
       READ(1,*)IYearZeroSaltDaysCrit,IYearOneSaltDaysCrit
       READ(1,*)YearZeroWinterGrowthMin,YearZeroWinterGrowthMax
       READ(1,*)YearZeroSpringGrowthMin,YearZeroSpringGrowthMax
       READ(1,*)YearZeroFallGrowthMin,YearZeroFallGrowthMax
       READ(1,*)YearOneWinterGrowthMin,YearOneWinterGrowthMax
       READ(1,*)YearOneSpringGrowthMin,YearOneSpringGrowthMax
       READ(1,*)YearOneFallGrowthMin,YearOneFallGrowthMax
       READ(1,*)CritSal
       READ(1,*)vJanSeedIndex
       READ(1,*)vFebSeedIndex
       READ(1,*)vMarSeedIndex
       READ(1,*)vAprSeedIndex
       READ(1,*)vMaySeedIndex
       READ(1,*)vJunSeedIndex
       READ(1,*)vJulSeedIndex
       READ(1,*)vAugSeedIndex
       READ(1,*)vSepSeedIndex
       READ(1,*)vOctSeedIndex
       READ(1,*)vNovSeedIndex
       READ(1,*)vDecSeedIndex

C-------Read in surface water elevation time series (.isw file)--------

             IF(INARGS.EQ.1) THEN
         WRITE(*,'(" ... Reading inputs from: ",A45)')LISFIL(2)
             ENDIF
       DO 10 I=1,IDAYREC
       READ(2,*,END=15)DUMMY0, DUMMY1,(SWE(I,J),J=1,Ireach)
       IF(I.EQ.1) THEN
         INIYEAR=DUMMY0
         INIDAY=DUMMY1
       endif
10     CONTINUE

C-------Read in surface water salinity time series (.iss file)--------

15           IF(INARGS.EQ.1) THEN
       WRITE(*,'(" ... Reading inputs from: ",A45)')LISFIL(3)
             ENDIF
      DO 20 I=1,IDAYREC
       READ(3,*,END=25)DUMMY0, DUMMY1,(SWS(I,J),J=1,Ireach)
20     CONTINUE

C-------Read in cell parameters (.icl file)--------

25           IF(INARGS.EQ.1) THEN
       WRITE(*,'(" ... Reading inputs from: ",A45)')LISFIL(4)
             ENDIF
      DO 30 I=1,MAXCELL
       READ(7,*,END=35)DUMMY1,(CellChar(I,J),J=1,2),
     &    ICellReach(I)
30     CONTINUE
35     ICELLCOUNT=I-1

C-------Read in rain time series (.irn file)--------

             IF(INARGS.EQ.1) THEN
```

```
      WRITE(*,'(" ... Reading inputs from: ",A45)')LISFIL(5)
            ENDIF
      DO 40 I=1,IDAYREC
       READ(8,*,END=45)DUMMY0,DUMMY1,RAIN(I)
40     CONTINUE
45      IRAINCOUNT=I-1

C-------Find break point (January 1) between years--------

            IYEAR=INIYEAR
            DO 50 I=1,MAXYEAR
                  IADD=365
                  IF(ILEAP(IYEAR).EQ.1) IADD=366
                  IF(I.EQ.1) THEN
                        IBREAK(I)=IADD-INIDAY+2
                   ELSE
                        IBREAK(I)=IBREAK(I-1)+IADD
                  ENDIF
                  IYEAR=INIYEAR+I
50          CONTINUE

C-------Print inputs in the output summary file (.osm) --------

      WRITE(10,'(/,"INPUTS:",A45)')
      WRITE(10,1605)
      WRITE(10,'("Global inputs from file: ",A45,/)')LISFIL(1)
      WRITE(10,1608)IdayRec, Ireach,IyearRec
      WRITE(10,1610)CritRainDepth,CritMoistureDepth,ICritConsecGermDays,
     &  VinitialSeedlingHeight
      WRITE(10,1615)IYearZeroSeedlingSubmergedCrit,
     &  IYearOneSeedlingSubmergedCrit
      WRITE(10,1615)IYearZeroSeedlingSaltCrit,IYearOneSeedlingSaltCrit
      WRITE(10,1615)IYearZeroSaltDaysCrit,IYearOneSaltDaysCrit
      WRITE(10,1620)YearZeroWinterGrowthMin,YearZeroWinterGrowthMax
      WRITE(10,1620)YearZeroSpringGrowthMin,YearZeroSpringGrowthMax
      WRITE(10,1620)YearZeroFallGrowthMin,YearZeroFallGrowthMax
      WRITE(10,1620)YearOneWinterGrowthMin,YearOneWinterGrowthMax
      WRITE(10,1620)YearOneSpringGrowthMin,YearOneSpringGrowthMax
      WRITE(10,1620)YearOneFallGrowthMin,YearOneFallGrowthMax
      WRITE(10,1620)CritSal
      WRITE(10,1620)vJanSeedIndex
      WRITE(10,1620)vFebSeedIndex
      WRITE(10,1620)vMarSeedIndex
      WRITE(10,1620)vAprSeedIndex
      WRITE(10,1620)vMaySeedIndex
      WRITE(10,1620)vJunSeedIndex
      WRITE(10,1620)vJulSeedIndex
      WRITE(10,1620)vAugSeedIndex
      WRITE(10,1620)vSepSeedIndex
      WRITE(10,1620)vOctSeedIndex
      WRITE(10,1620)vNovSeedIndex
      WRITE(10,1620)vDecSeedIndex

      WRITE(10,1605)
      WRITE(10,'("Surface water level from file: ",A45,/)')LISFIL(2)
      DO 100 I=1,IDAYREC
       WRITE(10,1630)I,(SWE(I,J),J=1,Ireach)
100    CONTINUE

      WRITE(10,1605)
      WRITE(10,'("Surface water salinity from: ",A45,/)')LISFIL(3)
      DO 110 I=1,IDAYREC
       WRITE(10,1630)I,(SWS(I,J),J=1,Ireach)
110    CONTINUE

      WRITE(10,1605)
      WRITE(10,'("Cell characteristics from: ",A45,/)')LISFIL(4)
      DO 120 I=1,ICELLCOUNT
       WRITE(10,1640)I,(CellChar(I,J),J=1,2),ICellReach(I)
120    CONTINUE

      WRITE(10,1605)
      WRITE(10,'("Rain time series from: ",A45,/)')LISFIL(5)
      DO 130 I=1,IRAINCOUNT
       WRITE(10,1630)I,RAIN(I)
130    CONTINUE

            RETURN

1500        WRITE(*,1600)'ERROR: Input file missing (check project)'
1600        FORMAT(/,A50,/)
1605        FORMAT(10('-'))
1608        FORMAT(4i12)
1610        FORMAT(2f12.4,i12,f12.4)
1615  FORMAT(2i12)
1620        FORMAT(5f12.4)
1630        FORMAT(I12,40f12.4)
1640        FORMAT(I12,2f12.4,i12)

            END

      FUNCTION ILEAP(IYEAR)

            IA=MOD(IYEAR,4)
            IB=MOD(IYEAR,100)
            IC=MOD(IYEAR,400)

            IF((IA.EQ.0.AND.IB.GT.0).OR.(IA.EQ.0.AND.IB.EQ.0.AND.IC.EQ.0)) THEN
                  ILEAP=1
             ELSE
```

```
            ILEAP=0
          ENDIF
          RETURN
          END
```

SUBROUTINE INI

```
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C                                                                  C
C     Sets initial variable and parameter values                   C
C                                                                  C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC

      IMPLICIT REAL (A-H,O-Z)
      PARAMETER (MAXDREC=14600,MAXYEAR=40,MAXREACH=40,MAXCELL=50000,
     & NumPWSClass=14)

      COMMON/CELL/CellChar(MAXCELL,2)
      COMMON/ICELL/ICellReach(MAXCELL),ICELLCOUNT,IReach

      COMMON/IFLOOD/InunRecord(MAXYEAR,366),IDAYREC,IYEARREC,
     & InunDay,IConInunDay

      COMMON/SALT/SWS(MAXDREC,MAXREACH),CritSal,SWSalXMag,
     & PWSalXMag
      COMMON/ISALT/ISWSalXDay,IConSWSalXDay,ISWSaltyYesterday,
     & ISWSDsCount,ISWSDsRecord(MAXDREC),ISWSDbCount,
     & ISWSDbRecord(MAXDREC),ISWSalBDay,IConSWSalBDay,
     & IPWSalXDay,IConPWSalXDay,IPWSaltyYesterday,
     & IPWSDsCount,IPWSDsRecord(MAXDREC),IPWSDbCount,
     & IPWSDbRecord(MAXDREC),IPWSalBDay,IConPWSalBDay

      COMMON/GERM1/CritRainDepth,CritMoistureDepth
      COMMON/IGERM/ISeedsAvailable(MAXDREC),ICritConsecGermDays,
     & IMoistDay,IConMoistDay,IGoodGermCond,IGoodGermCount

      COMMON/SEEDLING1/YearZeroWinterGrowthMin,
     & YearZeroWinterGrowthMax,
     & YearZeroSpringGrowthMin,YearZeroSpringGrowthMax,
     & YearZeroFallGrowthMin, YearZeroFallGrowthMax,
     & YearOneWinterGrowthMin,YearOneWinterGrowthMax,
     & YearOneSpringGrowthMin, YearOneSpringGrowthMax,
     & YearOneFallGrowthMin,YearOneFallGrowthMax
      COMMON/ISEEDLING/ISeedlingsSubmergedDays(4,MAXDREC),
     & IDaysSeedsAvailable,ISeedlingCount, IGermEvents,
     & IYearZeroSeedlingSubmergedCrit, IYearOneSeedlingSubmergedCrit,
     & IYearZeroSeedlingSaltCrit, IYearOneSeedlingSaltCrit,
     & IRecruitmentEvents,IYearOneSaltDaysCrit,IYearZeroSaltDaysCrit

C------Set appropriate variables to their initial values (usually 0)----------

      InunDay=0
      IConInunDay=0

      IMoistDay=0
      IConMoistDay=0

      IDAY=1

      ISeedlingCount=0
      IGoodGermCon=0
      IGoodGermCount=0
      IDaysSeedsAvailable=0
      IGermEvents=0
      IRecruitmentEvents=0

      SWSalXMag=0
      ISWSalXDay=0
      IConSWSalXDay=0
      ISWSalBDay=0
            IConSWSalBDay=0
      ISWSaltyYesterday=0
      ISWSDsCount=0
      ISWSDbCount=0

      PWSalXMag=0
      IPWSalXDay=0
      IConPWSalXDay=0
      IPWSalBDay=0
      IConPWSalBDay=0
      IPWSaltyYesterday=0
      IPWSDsCount=0
      IPWSDbCount=0

C-------Return to main program-----------------------------------------------

      RETURN
      END
```

SUBROUTINE INICALC

```
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C                                                                  C
C     Performs initial calculations and data processing            C
C                                                                  C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC

      IMPLICIT REAL (A-H,O-Z)
```

```
      PARAMETER (MAXDREC=14600,MAXYEAR=40,MAXREACH=40,MAXCELL=50000,
     & NumPWSClass=14)

      COMMON/CELL/CellChar(MAXCELL,2)
      COMMON/ICELL/ICellReach(MAXCELL),ICELLCOUNT,IReach

      COMMON/IFLOOD/InunRecord(MAXYEAR,366),IDAYREC,IYEARREC,
     & InunDay,IConInunDay

      COMMON/IGERM/ISeedsAvailable(MAXDREC),ICritConsecGermDays,
     & IMoistDay,IConMoistDay,IGoodGermCond,IGoodGermCount

      COMMON/SALT/SWS(MAXDREC,MAXREACH),CritSal,SWSalXMag,
     & PWSalXMag

      COMMON/POREWATER/PWS(MAXDREC,MAXREACH*NumPWSClass)

      COMMON/SEEDLING/Seedlings(MAXDREC,12),VinitialSeedlingHeight,
     & YearZeroGrowthRate(MAXDREC),YearOneGrowthRate(MAXDREC)
      COMMON/SEEDLING1/YearZeroWinterGrowthMin,
     & YearZeroWinterGrowthMax,
     & YearZeroSpringGrowthMin,YearZeroSpringGrowthMax,
     & YearZeroFallGrowthMin, YearZeroFallGrowthMax,
     & YearOneWinterGrowthMin,YearOneWinterGrowthMax,
     & YearOneSpringGrowthMin, YearOneSpringGrowthMax,
     & YearOneFallGrowthMin,YearOneFallGrowthMax
      COMMON/SEEDLING2/vJanSeedIndex,vFebSeedIndex,vMarSeedIndex,
     & vAprSeedIndex,vMaySeedIndex,vJunSeedIndex,vJulSeedIndex,
     & vAugSeedIndex,vSepSeedIndex,vOctSeedIndex,vNovSeedIndex,
     & vDecSeedIndex
      COMMON/ISEEDLING/ISeedlingsSubmergedDays(4,MAXDREC),
     & IDaysSeedsAvailable,ISeedlingCount, IGermEvents,
     & IYearZeroSeedlingSubmergedCrit, IYearOneSeedlingSubmergedCrit,
     & IYearZeroSeedlingSaltCrit, IYearOneSeedlingSaltCrit,
     & IRecruitmentEvents,IYearOneSaltDaysCrit,IYearZeroSaltDaysCrit

      COMMON/REPORT/YearlyRecord(MAXYEAR,16),
     & HabitatSuitability(MAXYEAR,8),IBREAK(MAXYEAR)

      COMMON/IDAYS/IDAYEND,IDOY,IDAYBEG,INIDAY

C------Set seedling growth parameters----------------------------------------

      IDAYBEG=1
      DO 75 I=1,IYEARREC+1
        IDAYEND=IBREAK(I)-1
        IF(I.EQ.IYEARREC+1) IDAYEND=IDAYREC
        IF(I.EQ.1) THEN
          IDOY=INIDAY
        ELSE
          IDOY=1
        END IF

        a=YearZeroWinterGrowthMin
        b=YearZeroWinterGrowthMax
        YearZeroWinterGrowthRate=(rand(0)*(b-a))+a

        a=YearZeroSpringGrowthMin
        b=YearZeroSpringGrowthMax
        YearZeroSpringGrowthRate=(rand(0)*(b-a))+a

        a=YearZeroFallGrowthMin
        b=YearZeroFallGrowthMax
        YearZeroFallGrowthRate=(rand(0)*(b-a))+a

        a=YearOneWinterGrowthMin
        b=YearOneWinterGrowthMax
        YearOneWinterGrowthRate=(rand(0)*(b-a))+a

        a=YearOneSpringGrowthMin
        b=YearOneSpringGrowthMax
        YearOneSpringGrowthRate=(rand(0)*(b-a))+a

        a=YearOneFallGrowthMin
        b=YearOneFallGrowthMax
        YearOneFallGrowthRate=(rand(0)*(b-a))+a

        DO 50 J=IDAYBEG,IDAYEND
          IF(IDOY.LT.60) THEN
            YearZeroGrowthRate(J)=YearZeroWinterGrowthRate
            YearOneGrowthRate(J)=YearOneWinterGrowthRate
          ELSE IF(IDOY.LT.182) THEN
            YearZeroGrowthRate(J)=YearZeroSpringGrowthRate
            YearOneGrowthRate(J)=YearOneSpringGrowthRate
          ELSE
            YearZeroGrowthRate(J)=YearZeroFallGrowthRate
            YearOneGrowthRate(J)=YearOneFallGrowthRate
          END IF
          IDOY=IDOY+1
50      CONTINUE
        IDAYBEG=IBREAK(I)
c       PRINT*,I,YearZeroWinterGrowthRate,YearZeroSpringGrowthRate
75    CONTINUE

C------Set seed availability based on month-----------------------------------

      IDAYBEG=1
      DO 150 I=1,IYEARREC+1
        IDAYEND=IBREAK(I)-1
        IF(I.EQ.IYEARREC+1) IDAYEND=IDAYREC
```

```
IF(I.EQ.1) THEN
  IDOY=INIDAY
ELSE
  IDOY=1
END IF

DiceRoll=rand(0)

IF(vJanSeedIndex.GT.DiceRoll) THEN
  vJanAvail=1
ELSE
  vJanAvail=0
END IF
IF(vFebSeedIndex.GT.DiceRoll) THEN
  vFebAvail=1
ELSE
  vFebAvail=0
END IF
IF(vMarSeedIndex.GT.DiceRoll) THEN
  vMarAvail=1
ELSE
  vMarAvail=0
END IF
IF(vAprSeedIndex.GT.DiceRoll) THEN
  vAprAvail=1
ELSE
  vAprAvail=0
END IF
IF(vMaySeedIndex.GT.DiceRoll) THEN
  vMayAvail=1
ELSE
  vMayAvail=0
END IF
IF(vJunSeedIndex.GT.DiceRoll) THEN
  vJunAvail=1
ELSE
  vJunAvail=0
END IF
IF(vJulSeedIndex.GT.DiceRoll) THEN
  vJulAvail=1
ELSE
  vJulAvail=0
END IF
IF(vAugSeedIndex.GT.DiceRoll) THEN
  vAugAvail=1
ELSE
  vAugAvail=0
END IF
IF(vSepSeedIndex.GT.DiceRoll) THEN
  vSepAvail=1
ELSE
  vSepAvail=0
END IF
IF(vOctSeedIndex.GT.DiceRoll) THEN
  vOctAvail=1
ELSE
  vOctAvail=0
END IF
IF(vNovSeedIndex.GT.DiceRoll) THEN
  vNovAvail=1
ELSE
  vNovAvail=0
END IF
IF(vDecSeedIndex.GT.DiceRoll) THEN
  vDecAvail=1
ELSE
  vDecAvail=0
END IF

DO 100 J=IDAYBEG,IDAYEND
  IF(IDOY.LT.32) THEN
    ISeedsAvailable(J)=vJanAvail
  ELSE IF(IDOY.LT.60) THEN
    ISeedsAvailable(J)=vFebAvail
  ELSE IF(IDOY.LT.91) THEN
    ISeedsAvailable(J)=vMarAvail
  ELSE IF(IDOY.LT.121) THEN
    ISeedsAvailable(J)=vAprAvail
  ELSE IF(IDOY.LT.152) THEN
    ISeedsAvailable(J)=vMayAvail
  ELSE IF(IDOY.LT.182) THEN
    ISeedsAvailable(J)=vJunAvail
  ELSE IF(IDOY.LT.213) THEN
    ISeedsAvailable(J)=vJulAvail
  ELSE IF(IDOY.LT.244) THEN
    ISeedsAvailable(J)=vAugAvail
  ELSE IF(IDOY.LT.274) THEN
    ISeedsAvailable(J)=vSepAvail
  ELSE IF(IDOY.LT.305) THEN
    ISeedsAvailable(J)=vOctAvail
  ELSE IF(IDOY.LT.335) THEN
    ISeedsAvailable(J)=vNovAvail
  ELSE
    ISeedsAvailable(J)=vDecAvail
  END IF
  IDOY=IDOY+1
c       PRINT*,I,J,ISeedsAvailable(J)
100   CONTINUE
  IDAYBEG=IBREAK(I)
150  CONTINUE
```

```
C------Calculates porewater salinity (PWS) time series-------------------------

C------Loop for reaches-----------------------------------------------------------

      DO 300 I=1,IReach

C------Loop for classes of distance from river. Sets a and b parameters for----
C------relationship between SWS and PWS. Sets L=second PWS matrix index--------

        DO 250 J=1,NumPWSClass

          IF(J.EQ.1) THEN
            a=0.006685043
            b=-0.000263779
            lag=12
          ELSE IF(J.EQ.2) THEN
            a=0.008780662
            b=-0.000305542
            lag=13
          ELSE IF(J.EQ.3) THEN
            a=0.010876281
            b=-0.000347305
            lag=13
          ELSE IF(J.EQ.4) THEN
            a=0.009763568
            b=-0.000253685
            lag=16
          ELSE IF(J.EQ.5) THEN
            a=0.008650854
            b=-0.000160064
            lag=18
          ELSE IF(J.EQ.6) THEN
            a=0.007538141
            b=-6.64436E-05
            lag=21
          ELSE IF(J.EQ.7) THEN
            a=0.006425427
            b=2.71769E-05
            lag=23
          ELSE IF(J.EQ.8) THEN
            a=0.005312714
            b=0.000120797
            lag=26
          ELSE IF(J.EQ.9) THEN
            a=0.0042
            b=0.000214418
            lag=28
          ELSE IF(J.EQ.10) THEN
            a=0.00463139
            b=-0.000466456
            lag=25
          ELSE IF(J.EQ.11) THEN
            a=0.00506278
            b=-0.001147329
            lag=21
          ELSE IF(J.EQ.12) THEN
            a=0.00549417
            b=-0.001828202
            lag=18
          ELSE IF(J.EQ.13) THEN
            a=0.00592556
            b=-0.002509076
            lag=14
          ELSE
            a=0.00635695
            b=-0.003189949
            lag=11
          END IF

          L=(I-1)*NumPWSClass+J

C------Loop for days---------------------------------------------------------

          DO 200 K=1,IDAYREC

C------Initial PWS values set 0.1 ppt for first 30 days then calculates--------
C------remaining values based on lagged surface water time series and classed--
C------distance from the river (each 10 m) for each reach. If calculated PWS---
C------is negative, sets value to 0-----------------------------------------

            IF(K.LE.30) THEN
              PWS(K,L)=0.1
            ELSE IF((PWS(K-1,L)+a*(SWS(K-lag,I)-PWS(K-1,L))+b)
     &          .LT.0) THEN
              PWS(K,L)=0
            ELSE
              PWS(K,L)=PWS(K-1,L)+a*(SWS(K-lag,I)-PWS(K-1,L))+b
            END IF
200         CONTINUE

C-----Move to next class of distance from river-----------------------------

250       CONTINUE

C-----Move to next reach-----------------------------------------------------

300     CONTINUE

C-------Return to main program-----------------------------------------------
```

```
      RETURN
      END
```

```
      SUBROUTINE NEWYEAR(I,IDAY)

CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C                                                                   C
C     Resets appropriate variables and arrays at beginning of a new year   C
C                                                                   C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC

      IMPLICIT REAL (A-H,O-Z)
      PARAMETER (MAXDREC=14600,MAXYEAR=40,MAXREACH=40,MAXCELL=50000,
     & NumPWSClass=14)

      COMMON/IFLOOD/InunRecord(MAXYEAR,366),IDAYREC,IYEARREC,
     & InunDay,IConInunDay

      COMMON/GERM1/CritRainDepth,CritMoistureDepth
      COMMON/IGERM/ISeedsAvailable(MAXDREC),ICritConsecGermDays,
     & IMoistDay,IConMoistDay,IGoodGermCond,IGoodGermCount

      COMMON/SEEDLING/Seedlings(MAXDREC,12),VinitialSeedlingHeight,
     & YearZeroGrowthRate(MAXDREC),YearOneGrowthRate(MAXDREC)
      COMMON/ISEEDLING/ISeedlingsSubmergedDays(4,MAXDREC),
     & IDaysSeedsAvailable,ISeedlingCount, IGermEvents,
     & IYearZeroSeedlingSubmergedCrit, IYearOneSeedlingSubmergedCrit,
     & IYearZeroSeedlingSaltCrit, IYearOneSeedlingSaltCrit,
     & IRecruitmentEvents,IYearOneSaltDaysCrit,IYearZeroSaltDaysCrit

      COMMON/SALT/SWS(MAXDREC,MAXREACH),CritSal,SWSalXMag,
     & PWSalXMag
      COMMON/ISALT/ISWSalXDay,IConSWSalXDay,ISWSaltyYesterday,
     & ISWSDsCount,ISWSDsRecord(MAXDREC),ISWSDbCount,
     & ISWSDbRecord(MAXDREC),ISWSalBDay,IConSWSalBDay,
     & IPWSalXDay,IConPWSalXDay,IPWSaltyYesterday,
     & IPWSDsCount,IPWSDsRecord(MAXDREC),IPWSDbCount,
     & IPWSDbRecord(MAXDREC),IPWSalBDay,IConPWSalBDay

      COMMON/REPORT/YearlyRecord(MAXYEAR,16),
     & HabitatSuitability(MAXYEAR,8),IBREAK(MAXYEAR)
      COMMON/REPORT1/SWSDsDbRatio,PWSDsDbRatio
      COMMON/IREPORT1/InundationMap(MAXYEAR),
     & IConInundationMap(MAXYEAR),IMoistMap(MAXYEAR),
     & IConMoistMap(MAXYEAR),IGoodGermCondMap(MAXYEAR),
     & IGerminationEventMap(MAXYEAR),IRecruitmentMap(MAXYEAR),
     & ISWSalXMap(MAXYEAR),IConSWSalXMap(MAXYEAR),
     & IPWSalXMap(MAXYEAR),IConPWSalXMap(MAXYEAR)
      COMMON/IDAYS/IDAYEND,IDOY,IDAYBEG,INIDAY

C------Sets IDAYEND to next years limit, calculates day of year (IDOY)---------

      IDAYEND=IBREAK(I)-1
      IF(I.EQ.IYEARREC+1) IDAYEND=IDAYREC
      IF(I.EQ.1) THEN
        IDAY=1
        IDOY=IDAY+INIDAY-1
      ELSE
        IDOY=1
      END IF

C------Resets variables between simulation years-----------------------------

      InunDay=0
c     IConInunDay=0

      IMoistDay=0
      IConMoistDay=0
      IConMoistMap(I)=0
      IGoodGermCount=0
      IGoodGermCon=0
      IDaysSeedsAvailable=0
      IGermEvents=0
      IRecruitmentEvents=0
      IRecruitmentMap(I)=0

      ISWSalXDay=0
c     IConSWSalXDay=0
      ISWSalBDay=0
c     IConSWSalBDay=0
      IConSWSalXMap(I)=0
      SWSalXMag=0

      IPWSalXDay=0
c     IConPWSalXDay=0
      IPWSalBDay=0
c     IConPWSalBDay=0
      IConPWSalXMap(I)=0
      PWSalXMag=0

C------Return to main program-----------------------------------------------

      RETURN
      END
```

```
      SUBROUTINE INUND(I,KCELL,IDAY)

CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C                                                                     C
C     Read data from input file *.isw and calculate the following for each  C
C     model cell:                                                     C
C                                                                     C
C     1. Whether cell is inuated or not (0=FALSE, 1=TRUE)             C
C     2. Number of inundated days in the current year (InunDay)       C
C     3. Number of consecutive inundated days (ConInunDay)            C
C                                                                     C
C     If cell goes from inundated to non-inundated state, and current C
C     value of ConInunDay is longest in current simulation year, writes C
C     ConInunDay to IConInundationMap()                               C
C                                                                     C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC

      IMPLICIT REAL (A-H,O-Z)
      PARAMETER (MAXDREC=14600,MAXYEAR=40,MAXREACH=40,MAXCELL=50000,
     & NumPWSClass=14)

      COMMON/CELL/CellChar(MAXCELL,2)
      COMMON/ICELL/ICellReach(MAXCELL),ICELLCOUNT,IReach
      COMMON/FLOOD/SWE(MAXDREC,MAXREACH),WaterDepth
      COMMON/IFLOOD/InunRecord(MAXYEAR,366),IDAYREC,IYEARREC,
     & InunDay,IConInunDay

          COMMON/REPORT/YearlyRecord(MAXYEAR,16),
     & HabitatSuitability(MAXYEAR,8),IBREAK(MAXYEAR)
      COMMON/REPORT1/SWSDsDbRatio,PWSDsDbRatio
      COMMON/IREPORT1/InundationMap(MAXYEAR),
     & IConInundationMap(MAXYEAR),IMoistMap(MAXYEAR),
     & IConMoistMap(MAXYEAR),IGoodGermCondMap(MAXYEAR),
     & IGerminationEventMap(MAXYEAR),IRecruitmentMap(MAXYEAR),
     & ISWSalXMap(MAXYEAR),IConSWSalXMap(MAXYEAR),
     & IPWSalXMap(MAXYEAR),IConPWSalXMap(MAXYEAR)

C-------Calculates water depth-----------------------------------------------

      WaterDepth=SWE(IDAY,ICellReach(KCELL))-CellChar(KCELL,1)

C-------Set cell to inundated (1) or non-inundated (0)-------------------------

      IF(WaterDepth.GT.0)THEN
        InundatedToday=1
      ELSE
        InundatedToday=0
      ENDIF

C-------If inundated, increments count of inundated and consecutively----------
C-------inundated days. If not, sets count of consecutively inundated---------
C-------days to zero----------------------------------------------------------

      IF(InundatedToday.EQ.1) THEN
        InunDay=InunDay+1
        IConInunDay=IConInunDay+1
      ELSE
        IConInunDay=0
      END IF

C-------Stores current value of InunDay to InundationMap for current year------
C-------If number of consecutivley inundated days is longest in current--------
C-------simulation year, writes IConInunDay to IConInundationMap---------------

      InundationMap(I)=InunDay
      IF(IConInunDay.GT.IConInundationMap(I)) THEN
        IConInundationMap(I)=IConInunDay
      END IF

C-------Return to main program-------------------------------------------------

      RETURN
      END
```

```
      SUBROUTINE SALINITY(I,KCell,IDAY)

CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C                                                                     C
C     Reads current value of surface water salinity data from input file  C
C      *.iss and calcualtes porewater salinity. Calculates the following:  C
C                                                                     C
C     1. Number of days/consecutive days that surface water and porewater C
C        salinities are above the critical salinity threshold         C
C     2. The cumulative magnitude of surface water and porewater salinity C
C        exceedances in the current simulation year                   C
C     3. The cumulative number of days when surface water and porewater C
C        salinities are below the critical salinity threshold         C
C                                                                     C
C     Stores consecutive days above (Ds) and below (Db) the critical  C
C     salinity threshold for calculation of the characteristic salinity C
C     ratio (Ds/Db) in the Report subroutine. If number of consecutive C
C     days above or below the critical salinity threshoold is the greatest C
C     in the current simulation year, writes record to YearlyRecord()  C
C                                                                     C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
      IMPLICIT REAL (A-H,O-Z)
      PARAMETER (MAXDREC=14600,MAXYEAR=40,MAXREACH=40,MAXCELL=50000,
     & NumPWSClass=14)
```

```
      COMMON/IFLOOD/InunRecord(MAXYEAR,366),IDAYREC,IYEARREC,
     & InunDay,IConInunDay

      COMMON/SALT/SWS(MAXDREC,MAXREACH),CritSal,SWSalXMag,
     & PWSalXMag
      COMMON/ISALT/ISWSalXDay,IConSWSalXDay,ISWSaltyYesterday,
     & ISWSDsCount,ISWSDsRecord(MAXDREC),ISWSDbCount,
     & ISWSDbRecord(MAXDREC),ISWSalBDay,IConSWSalBDay,
     & IPWSalXDay,IConPWSalXDay,IPWSaltyYesterday,
     & IPWSDsCount,IPWSDsRecord(MAXDREC),IPWSDbCount,
     & IPWSDbRecord(MAXDREC),IPWSalBDay,IConPWSalBDay

      COMMON/POREWATER/PWS(MAXDREC,MAXREACH*NumPWSClass)

      COMMON/CELL/CellChar(MAXCELL,2)
      COMMON/ICELL/ICellReach(MAXCELL),ICELLCOUNT,IReach

      COMMON/REPORT/YearlyRecord(MAXYEAR,16),
     & HabitatSuitability(MAXYEAR,8),IBREAK(MAXYEAR)
      COMMON/REPORT1/SWSDsDbRatio,PWSDsDbRatio
      COMMON/IREPORT1/InundationMap(MAXYEAR),
     & IConInundationMap(MAXYEAR),IMoistMap(MAXYEAR),
     & IConMoistMap(MAXYEAR),IGoodGermCondMap(MAXYEAR),
     & IGerminationEventMap(MAXYEAR),IRecruitmentMap(MAXYEAR),
     & ISWSalXMap(MAXYEAR),IConSWSalXMap(MAXYEAR),
     & IPWSalXMap(MAXYEAR),IConPWSalXMap(MAXYEAR)


CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
CCCCCCCCCCCCCCCCCCCCC.....SURFACE WATER.....CCCCCCCCCCCCC
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC

C-------Sets SURFACE water to salty (1) or not salty (0)----------------------

      IF(SWS(IDAY,ICellReach(KCell)).GT.CritSal)THEN
                  ISWSaltyToday=1
      ELSE
                  ISWSaltyToday=0
      END IF

C-------If salty, increments count of salty and consecutively salty days and----
C-------cumulates surface water exceedance magnitude. If not, increments count--
C-------of consecutive days with SURFACE water salinity below CritSal-----------

      IF(ISWSaltyToday.EQ.1) THEN
                  ISWSalXDay=ISWSalXDay+1
                  IConSWSalXDay=IConSWSalXDay+1
        SWSalXMag=SWSalXMag+(SWS(IDAY,ICellReach(KCell))-CritSal)
      ELSE
            ISWSalBDay=ISWSalBDay+1
                  IConSWSalBDay=IConSWSalBDay+1
      END IF

C------Stores current value of ISWSalXDays to ISWSalXDaysMap for current year--
C------If number of consecutivley salty days is longest in current-------------
C------simulation year, writes IConSWSalXDay to IConSWSSalXMap-----------------

      ISWSalXMap(I)=ISWSalXDay
      IF(IConSWSalXDay.GT.IConSWSalXMap(I)) THEN
        IConSWSalXMap(I)=IConSWSalXDay
      END IF

C------If cell goes from SALTY TO NOT SALTY increments count of SURFACE--------
C------water salinity exceedance events and writes duration of event to--------
C------ISWSDsRecord. Resets IConSWSalXDays to 0--------------------------------

      IF(((ISWSaltyToday.EQ.0).AND.(ISWSaltyYesterday.EQ.1))) THEN
        ISWSDsCount=ISWSDsCount+1
        ISWSDsRecord(ISWSDsCount)=IConSWSalXDay
        IConSWSalXDay=0
      END IF

C------If cell goes from NOT SALTY TO SALTY increments count of days between---
C------SURFACE water salinity exceedance events and writes duration to---------
C------ISWSDbRecord.

      IF(((ISWSaltyToday.EQ.1).AND.(ISWSaltyYesterday.EQ.0))) THEN
        ISWSDbCount=ISWSDbCount+1
        ISWSDbRecord(ISWSDbCount)=IConSWSalBDay
        IConSWSalBDay=0
      END IF

C-----If last day of simulation, calculates the SURFACE water Ds/Db ratio-----

      IF(IDAY.EQ.IDAYREC) THEN
        IF(ISWSDsCount.EQ.0) THEN
          SWSDsDbRatio=0
        ELSE IF(ISWSDbCount.EQ.0) THEN
          SWSDsDbRatio=-999
        ELSE
          SWSDsSum=0
          SWSDbSum=0
          DO 50 N=1,ISWSDsCount
            SWSDsSum=SWSDsSum+ISWSDsRecord(N)
50        CONTINUE
          DO 100 N=1,ISWSDbCount
            SWSDbSum=SWSDbSum+ISWSDbRecord(N)
100       CONTINUE
          a=SWSDsSum/ISWSDsCount
```

```
          b=SWSDbSum/ISWSDbCount
          SWSDsDbRatio=a/b
        END IF
      END IF


CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
CCCCCCCCCCCCCCCCCCCC.....POREWATER.....CCCCCCCCCCCCCCCC
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC

C-------Determines which class of PWS to read from PWS matrix as a function----
C-------of cell's distance from river (i.e., 0-10, 11-20, etc.) and sets-------
C-------value to PWSToday. Sets PWS to salty or not based on CritSal-----------

      IPWSClass=MIN(INT(CellChar(KCell,2)/10)+1,NumPWSClass)
      PWSToday=PWS(IDAY,NumPWSClass*(ICellReach(KCell)-1)+IPWSClass)
      IF(PWSToday.GT.CritSal) THEN
        IPWSaltyToday=1
      ELSE
              IPWSaltyToday=0
      END IF

C-------If salty, increments count of salty and consecutively salty days and----
C-------cumulates surface water exceedance magnitude. If not, increments count--
C-------of consecutive days with PORE water salinity below CritSal-----------

      IF(IPWSaltyToday.EQ.1) THEN
        IPWSalXDay=IPWSalXDay+1
        IConPWSalXDay=IConPWSalXDay+1
        PWSalXMag=PWSalXMag+(PWSToday-CritSal)
      ELSE
        IPWSalBDay=IPWSalBDay+1
              IConPWSalBDay=IConPWSalBDay+1
        IPWSalXDay=IPWSalXDay
      END IF

C------Stores current value of IPWSalXDays to IPWSalXDaysMap for current year--
C------If number of consecutivley salty days is longest in current------------
C------simulation year, writes IConPWSalXDay to IConPWSSalXMap-----------------

      IPWSalXMap(I)=IPWSalXDay
      IF(IConPWSalXDay.GT.IConPWSalXMap(I)) THEN
        IConPWSalXMap(I)=IConPWSalXDay
      END IF

C------If cell goes from SALTY TO NOT SALTY increments count of PORE--------
C------water salinity exceedance events and writes duration of event to--------
C------ISWSDsRecord. Resets IConSWSalXDays to 0-------------------------------

      IF(((IPWSaltyToday.EQ.0).AND.(IPWSaltyYesterday.EQ.1))) THEN
        IPWSDsCount=IPWSDsCount+1
        IPWSDsRecord(IPWSDsCount)=IConPWSalXDay
        IConPWSalXDay=0
      END IF

C------If cell goes from NOT SALTY TO SALTY increments count of days between---
C------PORE water salinity exceedance events and writes duration to---------
C------ISWSDbRecord.

      IF(((IPWSaltyToday.EQ.1).AND.(IPWSaltyYesterday.EQ.0))) THEN
        IPWSDbCount=IPWSDbCount+1
        IPWSDbRecord(IPWSDbCount)=IConPWSalBDay
        IConPWSalBDay=0
      END IF

C-----If last day of simulation, calculates the PORE water Ds/Db ratio--------
C-----Writes record of SURFACE and POREWATER Ds:Db ratio to file 20-----------

      IF(IDAY.EQ.IDAYREC) THEN
        IF(IPWSDsCount.EQ.0) THEN
          IF(IPWSDbCount.EQ.1) THEN
            PWSDsDbRatio=600
          ELSE
            PWSDsDbRatio=0
          END IF
        ELSE
          PWSDsSum=0
          PWSDbSum=0
          DO 150 M=1,IPWSDsCount
            PWSDsSum=PWSDsSum+IPWSDsRecord(M)
150         CONTINUE
          DO 200 M=1,IPWSDbCount
            PWSDbSum=PWSDbSum+IPWSDbRecord(M)
200         CONTINUE
          a=PWSDsSum/IPWSDsCount
          b=PWSDbSum/IPWSDbCount
          PWSDsDbRatio=a/b
        END IF
        write(20,1000)KCELL,SWSDsDbRatio,PWSDsDbRatio
      END IF

C-------Sets today's SURFACE and POREWATER salinity statuses to Yesterday's---
C-------for next day's calculations--------------------------------------------

              ISWSaltyYesterday=ISWSaltyToday
              IPWSaltyYesterday=IPWSaltyToday

C-------Return to main program-----------------------------------------------

      RETURN
```

```
1000        FORMAT(i6,2f12.4)

      END
```

SUBROUTINE GERMINATION(I,KCell,IDAY)

```
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C                                                                  C
C     Receives data from subroutine inund and input file *.isw and C
C     calculates the following:                                    C
C                                                                  C
C     1. Whether cell has appropriate moisture conditions for germination C
C        and sets MoistToday to TRUE(1) or FALSE (0)               C
C     2. Number of germination days in the current year (GermDay)  C
C     3. Number of consecutive germination days (ConGermDay)       C
C                                                                  C
C     If cell goes from moist to non-moist state, and current value of C
C     ConGermDay is longest in current simulation year, writes ConInunDay C
C     to YearlyRecord(). If ConGermDay is equal to or greater than C
C     critical number of days required for germination (CritConsecGermDays) C
C     GoodGermCon is set to TRUE (1), otherwise it is set to FALSE (0). C
C                                                                  C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
      IMPLICIT REAL (A-H,O-Z)
      PARAMETER (MAXDREC=14600,MAXYEAR=40,MAXREACH=40,MAXCELL=50000,
     & NumPWSClass=14)

      COMMON/ICELL/ICellReach(MAXCELL),ICELLCOUNT,IReach

      COMMON/FLOOD/SWE(MAXDREC,MAXREACH),WaterDepth

      COMMON/GERM/RAIN(MAXDREC)
      COMMON/GERM1/CritRainDepth,CritMoistureDepth
      COMMON/IGERM/ISeedsAvailable(MAXDREC),ICritConsecGermDays,
     & IMoistDay,IConMoistDay,IGoodGermCond,IGoodGermCount

      COMMON/SALT/SWS(MAXDREC,MAXREACH),CritSal,SWSalXMag,
     & PWSalXMag

      COMMON/REPORT/YearlyRecord(MAXYEAR,16),
     & HabitatSuitability(MAXYEAR,8),IBREAK(MAXYEAR)
      COMMON/REPORT1/SWSDsDbRatio,PWSDsDbRatio
      COMMON/IREPORT1/InundationMap(MAXYEAR),
     & IConInundationMap(MAXYEAR),IMoistMap(MAXYEAR),
     & IConMoistMap(MAXYEAR),IGoodGermCondMap(MAXYEAR),
     & IGerminationEventMap(MAXYEAR),IRecruitmentMap(MAXYEAR),
     & ISWSalXMap(MAXYEAR),IConSWSalXMap(MAXYEAR),
     & IPWSalXMap(MAXYEAR),IConPWSalXMap(MAXYEAR)

C------Determines soil moisture conditions-----------------------------------

      IMoistToday=0
      IF(Rain(IDAY).GE.CritRainDepth) IMoistToday=1
      IF(WaterDepth.GE.(-1*CritMoistureDepth)) IMoistToday=1
      IF(WaterDepth.GT.0) IMoistToday=0

C------If moist today, increments count of moist and consecutively moist ------
C------days-------------------------------------------------------------------

      IF(IMoistToday.EQ.1) THEN
                        IMoistDay=IMoistDay+1
                        IConMoistDay=IConMoistDay+1
      ELSE
        IConMoistDay=0
      END IF

C------Stores current value of IMoistDay to IMoistMap for current year----------
C------If number of consecutivley moist days is longest in current--------------
C------simulation year, writes IConMoistDay to IConMoistMap---------------------

      IMoistMap(I)=IMoistDay
      IF(IConMoistDay.GT.IConMoistMap(I)) THEN
        IConMoistMap(I)=IConMoistDay
      END IF

C------Checks surface watrer salinity and sets likelihood of germination based--
C------on salinity conditions against a random dice roll-----------------------

      IF(SWS(IDAY,ICellReach(KCell)).LE.1) THEN
        SalGermMod=1
      ELSE IF(SWS(IDAY,ICellReach(KCell)).LE.3) THEN
        SalGermMod=0.87
      ELSE IF(SWS(IDAY,ICellReach(KCell)).LE.5) THEN
        SalGermMod=0.59
      ELSE IF(SWS(IDAY,ICellReach(KCell)).LE.7) THEN
        SalGermMod=0.39
      ELSE IF(SWS(IDAY,ICellReach(KCell)).LE.8) THEN
        SalGermMod=0.20
      ELSE
        SalGermMod=0
      END IF

      DiceRoll=rand(0)
      IF(SalGermMod.GT.DiceRoll) THEN
        ISalGermStaus=1
      ELSE
        ISalGermStaus=0
      END IF
```

```
C------If soil has been moist for a number of days equal to or greater than----
C------then critical number of days for germination, and germination is not----
C------prevented by high salinity, sets germination condition to good (1) and--
C------increments count of days with good germination conditions. Writes-------
C------IGoodGermCount to IGoodGermCountMap for cell/year----------------------

      If((IConMoistDay.GE.ICritConsecGermDays).AND.
     &       (ISalGermStaus.EQ.1)) THEN
        IGoodGermCond=1
        IGoodGermCount=IGoodGermCount+1
      ELSE
        IGoodGermCond=0
      END IF
      IGoodGermCondMap(I)=IGoodGermCount

C-------Return to main program-----------------------------------------------

      RETURN
      END
```

SUBROUTINE SEEDLINGGROW(I,KCell,IDAY)

```
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C                                                                       C
C     Takes germination conditions from germination subroutine and seed C
C     availability(IDAY) to determine if seedling growth is initiated.  C
C     Performs the following:                                           C
C                                                                       C
C     1. Updates current number of days seeds have been avaialble in    C
C        current SimYear                                                C
C     2. Adds age and height to all seedlings                           C
C     3. Checks whether seedlings are submerged and increments submerged C
C        days in year zero/one                                          C
C     4. If any seedlings reach 2 years (730 days) without having been  C
C        overtopped longer than the critical limits in EITHER year (i.e.,C
C        a recruitment event), increments number of recruitment events. C
C        Writes this value to IRecruitmentMap for the current year/cell C
C                                                                       C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC

      IMPLICIT REAL (A-H,O-Z)
      PARAMETER (MAXDREC=14600,MAXYEAR=40,MAXREACH=40,MAXCELL=50000,
     & NumPWSClass=14)

      COMMON/FLOOD/SWE(MAXDREC,MAXREACH),WaterDepth

      COMMON/IGERM/ISeedsAvailable(MAXDREC),ICritConsecGermDays,
     & IMoistDay,IConMoistDay,IGoodGermCond,IGoodGermCount

      COMMON/SEEDLING/Seedlings(MAXDREC,12),VinitialSeedlingHeight,
     & YearZeroGrowthRate(MAXDREC),YearOneGrowthRate(MAXDREC)
      COMMON/ISEEDLING/ISeedlingsSubmergedDays(4,MAXDREC),
     & IDaysSeedsAvailable,ISeedlingCount, IGermEvents,
     & IYearZeroSeedlingSubmergedCrit, IYearOneSeedlingSubmergedCrit,
     & IYearZeroSeedlingSaltCrit, IYearOneSeedlingSaltCrit,
     & IRecruitmentEvents,IYearOneSaltDaysCrit,IYearZeroSaltDaysCrit

      COMMON/REPORT/YearlyRecord(MAXYEAR,16),
     & HabitatSuitability(MAXYEAR,8),IBREAK(MAXYEAR)
      COMMON/REPORT1/SWSDsDbRatio,PWSDsDbRatio
      COMMON/IREPORT1/InundationMap(MAXYEAR),
     & IConInundationMap(MAXYEAR),IMoistMap(MAXYEAR),
     & IConMoistMap(MAXYEAR),IGoodGermCondMap(MAXYEAR),
     & IGerminationEventMap(MAXYEAR),IRecruitmentMap(MAXYEAR),
     & ISWSalXMap(MAXYEAR),IConSWSalXMap(MAXYEAR),
     & IPWSalXMap(MAXYEAR),IConPWSalXMap(MAXYEAR)

      COMMON/POREWATER/PWS(MAXDREC,MAXREACH*NumPWSClass)
      COMMON/SALT/SWS(MAXDREC,MAXREACH),CritSal,SWSalXMag,
     & PWSalXMag

      COMMON/CELL/CellChar(MAXCELL,2)
      COMMON/ICELL/ICellReach(MAXCELL),ICELLCOUNT,IReach

      COMMON/IDAYS/IDAYEND,IDOY,IDAYBEG,INIDAY

C-------Resets IFirstSeedling to 1 for current day----------------------------

      IFirstSeedling=1

C-------If seeds are available, increments counter of days seeds available-----
C-------need to actual set this at some point---------------------------------

      IF(ISeedsAvailable(IDAY).EQ.1) THEN
                IDaysSeedsAvailable=IDaysSeedsAvailable+1
      END IF

C-------If seeds are available and germination conditions are met, initiates---
C-------seedling growth (age starts at 0, increments to 1 below), increments---
C-------seedling counter, and writes to IGerminationEventMap for current year--

      IF((ISeedsAvailable(IDAY).EQ.1).AND.(IGoodGermCond.EQ.1)) THEN
        ISeedlingCount=ISeedlingCount+1
        IGermEvents=IGermEvents+1
        Seedlings(ISeedlingCount,1)=0
        Seedlings(ISeedlingCount,2)=VinitialSeedlingHeight
      END IF
      IGerminationEventMap(I)=IGermEvents
```

```
C-------Checks to see how far back in Seedlings matrix the subroutine must go--
C-------Does not perform any calculations on seedlings older than 730 days-----

      DO 30 L=1,ISeedlingCount
        IF(Seedlings(L,1).GE.730) IFirstSeedling=IFirstSeedling+1
30    CONTINUE

C------Internal loop runs for for all seedlings less than 2 years old----------

      DO 50 N=IFirstSeedling,ISeedlingCount

C------Increments seedlings age and grows all seedlings according to seasonal--
C------growth rate for current year-----------------------------------------

        Seedlings(N,1)=Seedlings(N,1)+1
        IF(Seedlings(N,1).LE.365) THEN
          Seedlings(N,2)=Seedlings(N,2)+YearZeroGrowthRate(IDAY)
        ELSE
          Seedlings(N,2)=Seedlings(N,2)+YearOneGrowthRate(IDAY)
        END IF

C------Checks whether seedlings are submerged (water depth converted from cm---
C------to m). If so, increments number of consecutive days submerged in year---
C------zero/one (columns 3 and 5). Stores max number of days submerged in year-
C------zero/one in columns 4/6. Resets consecutive days submerged to 0---------

        IF(WaterDepth*100.GT.Seedlings(N,2)) THEN
          IF(Seedlings(N,1).LE.365) THEN
            Seedlings(N,3)=Seedlings(N,3)+1
          ELSE
            Seedlings(N,5)=Seedlings(N,5)+1
          END IF
          IF(Seedlings(N,3).GT.Seedlings(N,4)) THEN
            Seedlings(N,4)=Seedlings(N,3)
          END IF
          IF(Seedlings(N,5).GT.Seedlings(N,6)) THEN
            Seedlings(N,6)=Seedlings(N,5)
          END IF
        ELSE
          Seedlings(N,3)=0
          Seedlings(N,5)=0
        END IF

C------Checks whether PWS is greater than CritSal. If so, increments number----
C------of consecutive days seedling is subject to high salinity conditions-----
C------in year zero/one (columns 7 and 9). Stores max number of days above-----
C------threshold in year zero/one in columns 8/10. Resets counters to zero if--
C------Not above threshold.  Calculates the cumulative salt.days seedling is---
C------exposed to in year zero/one and stores in columns 11 and 12. Does not---
C------reset SaltDays (until next cell)---------------------------------------

        IPWSClass=MIN(INT(CellChar(KCell,2)/10)+1,NumPWSClass)
        PWSToday=PWS(IDAY,NumPWSClass*(ICellReach(KCell)-1)+IPWSClass)
        IF(PWSToday.GT.CritSal) THEN
          IF(Seedlings(N,1).LE.365) THEN
            Seedlings(N,7)=Seedlings(N,7)+1
            Seedlings(N,11)=Seedlings(N,11)+PWSToday-CritSal
          ELSE
            Seedlings(N,9)=Seedlings(N,9)+1
            Seedlings(N,12)=Seedlings(N,12)+PWSToday-CritSal
          END IF
          IF(Seedlings(N,7).GT.Seedlings(N,8)) THEN
            Seedlings(N,8)=Seedlings(N,7)
          END IF
          IF(Seedlings(N,9).GT.Seedlings(N,10)) THEN
            Seedlings(N,10)=Seedlings(N,9)
          END IF
        ELSE
          Seedlings(N,7)=0
          Seedlings(N,9)=0
        END IF

C------If less than 2 years from model start, sets IRecruitmentMap to 0--------
C------Otherwise, if any seedling survives 2 years (730 days) without being---
C------overtopped longer than the critical submergence values and without------
C------being subject to high salinity longer than the critical threshold, sets-
C------IRecruitmentMap to 1 for current cell/year------------------------------

        IF(IDAY.LT.730) THEN
          IRecruitmentMap(I)=0
        ELSE IF(Seedlings(N,1).EQ.730) THEN
          IF(Seedlings(N,4).LT.IYearZeroSeedlingSubmergedCrit) THEN
          IF(Seedlings(N,6).LT.IYearOneSeedlingSubmergedCrit) THEN
c           IF(Seedlings(N,8).LT.IYearZeroSeedlingSaltCrit) THEN
c           IF(Seedlings(N,10).LT.IYearOneSeedlingSaltCrit) THEN
c           IF(Seedlings(N,11).LT.IYearZeroSaltDaysCrit) THEN
c           IF(Seedlings(N,12).LT.IYearOneSaltDaysCrit) THEN
             IRecruitmentEvents=IRecruitmentEvents+1
             IRecruitmentMap(I)=IRecruitmentEvents
          END IF
c           END IF
c           END IF
c           END IF
c           END IF
        END IF
        END IF

C------End of internal seedling loop--------------------------------------------

50    CONTINUE
```

```
1000   FORMAT(i8,12f12.4)

C-------Return to main program----------------------------------------------

      RETURN
      END
```

SUBROUTINE NEWCELL

```
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C                                                                     C
C      Resets variables between cells                                 C
C                                                                     C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC

      IMPLICIT REAL (A-H,O-Z)
      PARAMETER (MAXDREC=14600,MAXYEAR=40,MAXREACH=40,MAXCELL=50000,
     & NumPWSClass=14)

      COMMON/IFLOOD/InunRecord(MAXYEAR,366),IDAYREC,IYEARREC,
     & InunDay,IConInunDay

      COMMON/SALT/SWS(MAXDREC,MAXREACH),CritSal,SWSalXMag,
     & PWSalXMag
      COMMON/ISALT/ISWSalXDay,IConSWSalXDay,ISWSaltyYesterday,
     & ISWSDsCount,ISWSDsRecord(MAXDREC),ISWSDbCount,
     & ISWSDbRecord(MAXDREC),ISWSalBDay,IConSWSalBDay,
     & IPWSalXDay,IConPWSalXDay,IPWSaltyYesterday,
     & IPWSDsCount,IPWSDsRecord(MAXDREC),IPWSDbCount,
     & IPWSDbRecord(MAXDREC),IPWSalBDay,IConPWSalBDay
           COMMON/IGERM/ISeedsAvailable(MAXDREC),ICritConsecGermDays,
     & IMoistDay,IConMoistDay,IGoodGermCond,IGoodGermCount

      COMMON/SEEDLING/Seedlings(MAXDREC,12),VinitialSeedlingHeight,
     & YearZeroGrowthRate(MAXDREC),YearOneGrowthRate(MAXDREC)
      COMMON/ISEEDLING/ISeedlingsSubmergedDays(4,MAXDREC),
     & IDaysSeedsAvailable,ISeedlingCount, IGermEvents,
     & IYearZeroSeedlingSubmergedCrit, IYearOneSeedlingSubmergedCrit,
     & IYearZeroSeedlingSaltCrit, IYearOneSeedlingSaltCrit,
     & IRecruitmentEvents,IYearOneSaltDaysCrit,IYearZeroSaltDaysCrit

C------Resets seedling matrix-------------------------------------------------

      DO 100 J=1,ISeedlingCount
        DO 50 K=1,12
          Seedlings(J,K)=0
50      CONTINUE
100   CONTINUE

C------Resets surface water salinity exceedance records-----------------------

      DO 150 J=1,ISWSDsCount+1
        ISWSDsRecord(J)=0
        ISWSDbRecord(J)=0
150   CONTINUE

C------Resets porewater water salinity exceedance records---------------------

      DO 200 J=1,PSWSDsCount+1
        IPWSDsRecord(J)=0
        IPWSDbRecord(J)=0
200   CONTINUE

C------Resets appropriate variables to their initial values (usually 0)---------

      InunDay=0
      IConInunDay=0

      MoistDay=0
      IConMoistDay=0
      IGoodGermCount=0
      IGoodGermCon=0
      IGoodGermCount=0

      ISeedlingCount=0
      IDaysSeedsAvailable=0
      IGermEvents=0
      IRecruitmentEvents=0
      IDAY=1

      SWSalXMag=0
      ISWSalXDay=0
      IConSWSalXDay=0
      ISWSaltyYesterday=0
      ISWSDsCount=0
      ISWSDbCount=0

      PWSalXMag=0
      IPWSalXDay=0
      IConPWSalXDay=0
      IPWSaltyYesterday=0
      IPWSDsCount=0
      IPWSDbCount=0

C-------Return to main program----------------------------------------------

      RETURN
      END
```

```
SUBROUTINE OUTMAP(KCELL)

CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C                                                                     C
C     Writes yearly output for each cell to "map" with Cell ID (post-processed in ArcGIS) C
C                                                                     C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC

      IMPLICIT REAL (A-H,O-Z)
      PARAMETER (MAXDREC=14600,MAXYEAR=40,MAXREACH=40,MAXCELL=50000,
     & NumPWSClass=14)

      COMMON/IFLOOD/InunRecord(MAXYEAR,366),IDAYREC,IYEARREC,
     & InunDay,IConInunDay

      COMMON/REPORT/YearlyRecord(MAXYEAR,16),
     & HabitatSuitability(MAXYEAR,8),IBREAK(MAXYEAR)
      COMMON/REPORT1/SWSDsDbRatio,PWSDsDbRatio
      COMMON/IREPORT1/InundationMap(MAXYEAR),
     & IConInundationMap(MAXYEAR),IMoistMap(MAXYEAR),
     & IConMoistMap(MAXYEAR),IGoodGermCondMap(MAXYEAR),
     & IGerminationEventMap(MAXYEAR),IRecruitmentMap(MAXYEAR),
     & ISWSalXMap(MAXYEAR),IConSWSalXMap(MAXYEAR),
     & IPWSalXMap(MAXYEAR),IConPWSalXMap(MAXYEAR)

C------Writes model output to files-----------------------------------------

      write(11,100)KCELL,(InundationMap(INU),INU=1,IYEARREC+1)
      write(12,100)KCELL,(IConInundationMap(INU),INU=1,IYEARREC+1)
      write(13,100)KCELL,(IMoistMap(INU),INU=1,IYEARREC+1)
      write(14,100)KCELL,(IConMoistMap(INU),INU=1,IYEARREC+1)
      write(15,100)KCELL,(IGoodGermCondMap(INU),INU=1,IYEARREC+1)
      write(16,100)KCELL,(IGerminationEventMap(INU),INU=1,IYEARREC+1)
      write(17,100)KCELL,(IRecruitmentMap(INU),INU=1,IYEARREC+1)
      write(18,100)KCELL,(ISWSalXMap(INU),INU=1,IYEARREC+1)
      write(19,100)KCELL,(IConSWSalXMap(INU),INU=1,IYEARREC+1)
      write(21,100)KCELL,(IPWSalXMap(INU),INU=1,IYEARREC+1)
      write(22,100)KCELL,(IConPWSalXMap(INU),INU=1,IYEARREC+1)

C------Return to main program----------------------------------------------

      RETURN

100           FORMAT(i6,40i8)

       END

_____________________________________________________________________________

SUBROUTINE HABITAT(KCELL)

CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C                                                                     C
C     Determines the most likely habitat type in each cell            C
C                                                                     C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC

      IMPLICIT REAL (A-H,O-Z)
      PARAMETER (MAXDREC=14600,MAXYEAR=40,MAXREACH=40,MAXCELL=50000,
     & NumPWSClass=14)

      COMMON/IFLOOD/InunRecord(MAXYEAR,366),IDAYREC,IYEARREC,
     & InunDay,IConInunDay

      COMMON/REPORT/YearlyRecord(MAXYEAR,16),
     & HabitatSuitability(MAXYEAR,8),IBREAK(MAXYEAR)
      COMMON/REPORT1/SWSDsDbRatio,PWSDsDbRatio
      COMMON/IREPORT1/InundationMap(MAXYEAR),
     & IConInundationMap(MAXYEAR),IMoistMap(MAXYEAR),
     & IConMoistMap(MAXYEAR),IGoodGermCondMap(MAXYEAR),
     & IGerminationEventMap(MAXYEAR),IRecruitmentMap(MAXYEAR),
     & ISWSalXMap(MAXYEAR),IConSWSalXMap(MAXYEAR),
     & IPWSalXMap(MAXYEAR),IConPWSalXMap(MAXYEAR)

      DIMENSION ICellHabitat(IYEARREC+1),ICellHab(MAXCELL),
     & IYearlyCellHabitat(MAXCELL)

C------Sets likely habitat type for each year based on yearly inundation-------
C------using the following codes: 1=upland; 2=freshwater hydric hammock;-------
C------3=freshwater bottomland hardwood forest (low and high); 4=bald cypress--
C------swamp. These are modified by recruitment and salinity information in----
C------subsequent steps (below). Determines most common habitat type (mode)----
C------over period of record and stores in TempCellHab(I)----------------------

      IUpland=0
      IHydHam=0
      IBLHFor=0
      IBldCyp=0

      DO 50 I=1,IYEARREC+1
        IF(InundationMap(I).LT.30) THEN
          IYearlyCellHabitat(I)=1
          IUpland=IUpland+1
        ELSE IF(InundationMap(I).LE.60) THEN
          IYearlyCellHabitat(I)=2
          IHydHam=IHydHam+1
        ELSE IF(InundationMap(I).LE.180) THEN
          IYearlyCellHabitat(I)=3
          IBLHFor=IBLHFor+1
        ELSE
          IYearlyCellHabitat(I)=4
```

```
          IBldCyp=IBldCyp+1
        END IF
50     CONTINUE

      IF(MAX(IBldCyp,IBLHFor,IHydHam,IUpland).EQ.IUpland) THEN
        ICellHab(KCELL)=1
      ELSE IF(MAX(IBldCyp,IBLHFor,IHydHam,IUpland).EQ.IHydHam) THEN
        ICellHab(KCELL)=2
      ELSE IF(MAX(IBldCyp,IBLHFor,IHydHam,IUpland).EQ.IBLHFor) THEN
        ICellHab(KCELL)=3
      ELSE IF(MAX(IBldCyp,IBLHFor,IHydHam,IUpland).EQ.IBldCyp) THEN
        ICellHab(KCELL)=4
      END IF

C------THE CHARACTERISTIC SALINITY REGIME PATH---------------------------------
C------Modifies above by PWS Ds:Db ratio such that for salty cells, bald-------
C------cypress are modified to mangroves (5)-----------------------------------

      IF((ICellHab(KCELL).EQ.4).AND.(PWSDsDbRatio.GT.0.12)) THEN
        ICellHab(KCELL)=5
      END IF

C------For cells that are predicted to have bald cypress habitat, checks-------
C------IRecruitmentMap(I) to see how many germination and recruitment events---
C------took place in the cell over the period of record. Writes results of-----
C------this and previous step to file 23. For non-cypress cells, writes -699---
C------germination and recruitment columns-------------------------------------

      IGerminationYears=-699
      IRecruitmentYears=-699
      IF(ICellHab(KCELL).EQ.4) THEN
        IGerminationYears=0
        IRecruitmentYears=0
        DO 100 I=1,IYEARREC+1
          IF(IRecruitmentMap(I).GT.0) THEN
            IRecruitmentYears=IRecruitmentYears+1
          END IF
          IF(IGerminationEventMap(I).GT.0) THEN
            IGerminationYears=IGerminationYears+1
          END IF
100       CONTINUE
      END IF
      write(23,1000) KCELL,ICellHab(KCELL),IGerminationYears,
     & IRecruitmentYears

C------Return to main program--------------------------------------------------
       RETURN
1000   FORMAT(4i8)
       END
```

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BIOGRAPHICAL SKETCH

David Kaplan was born in Baltimore, MD and received a B.S. in agricultural and biological engineering from Cornell University in 2000. He worked on grant-funded ecological research and restoration projects for the New York City Department of Parks and Recreation Natural Resources Group from 2001 to 2005 before pursuing his Ph.D. in agricultural and biological engineering at the University of Florida. He is a founding member of the Gainesville band Tanks in Series.