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ESTIMATING EVAPOTRANSPIRATION AND SEEPAGE FOR A SINKHOLE WETLAND FROM DIURNAL SURFACE-WATER CYCLES[1]

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ABSTRACT: This study used measured diurnal surface-water cycles to estimate daily evapotranspiration (ET) and seepage for a seasonally flooded sinkhole wetland. Diurnal surface-water cycles were classified into five categories based on the relationship between the surface-water body and the surrounding ground-water system (i.e., recharge/discharge). Only one class of diurnal cycles was found to be suitable for application of this method. This subset of diurnal cycles was used to estimate ET and seepage and the relative importance of each transfer process to the overall water budget. The method has limited utility for wetlands with erratic hydrologic regimes (e.g., wetlands in urban environments). This is due to violation of the critical assumption that the inflow/outflow rate remains constant throughout the day. For application to surface-water systems, the method is typically applied with an assumed specific yield of 1.0. This assumption was found to be invalid for application to surface-water systems with a noncylindrical pond geometry. An overestimation of ET by as much as 60% was found to occur under conditions of low pond stage and high water loss. The results demonstrate the high ET rates that can occur in isolated wetlands due to contrasting roughness and moisture conditions (oasis and clothesline effects). Estimated ET rates ranged from 4.1 to 18.7 mm/day during the growing season. Despite these large ET rates, seepage (recharge) was found to be the dominant water loss mechanism for the wetland.

(KEY TERMS: evapotranspiration; karst hydrology; wetlands; surface-water/ground-water interactions; urbanization; ground-water hydrology.)

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INTRODUCTION

Evapotranspiration (ET), the combined loss of water to the atmosphere through evaporation and transpiration, is an important component of the water budget for many wetland environments (Abtew, 1996; Lott and Hunt, 2001; Mao *et al.*, 2002). ET estimation in wetland environments is particularly challenging because of their transitional nature between terrestrial and aquatic systems. As noted by Drexler *et al.* (2004), many wetland environments are a complex mixture of bare soil, vegetated, and open water areas. For many wetland types including vernal pools, cypress domes, prairie potholes, and sinkholes, the depth, duration, and expanse of open water areas varies greatly throughout the year.

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Drexler *et al.* (2004) recently reviewed several micrometeorological methods available for the measurement of wetland ET, including the Bowen ratio energy balance method, eddy covariance method, surface renewal method, and light detection and ranging (LIDAR) and other laser-based techniques. Unfortunately, these methods require a substantial investment in equipment (sensors, etc.), making them impractical for routine applications. Models of ET ranging in complexity from the temperature-based Thornwhaite equation to the physically based Penman-Monteith equation have been applied with limited success to wetland environments, mainly due to the lack of site specific information on aerodynamic and surface resistances (Drexler *et al.*, 2004). Lysimeters can be used to directly measure ET, but are expensive and difficult to construct in certain environments (e.g., forests).

Observations of diurnal cycles of surface and ground water have been used extensively to estimate ET (White, 1932; Troxell, 1936; Meyboom, 1967; Johansson, 1986, Gerla, 1992; Rushton, 1996; Bauer *et al.*, 2004; Loheide *et al.*, 2005). The presence of diurnal cycles is a direct result of temporal variability in consumptive water use by plants and open water and/or bare soil evaporation. A typical diurnal cycle is shown in Figure 1. At night, when ET can be assumed negligible, the rate of water level increase provides an integrated measure of the net inflow of water. During the daytime, a larger rate of decline occurs due to the contribution of ET. At two points during the cycle, the net inflow is exactly balanced by the net outflow. White (1932) developed a technique for ET estimation based on similar observations at arid wetlands in the Escalante Valley of Utah. The expression for ET is

$$\mathrm{ET} = S_y(24h \pm s), \qquad (1)$$

where S_y is the specific yield (dimensionless), h is the net inflow rate (hourly), and s is the net fall (+) or net rise (−) in water level over one day.

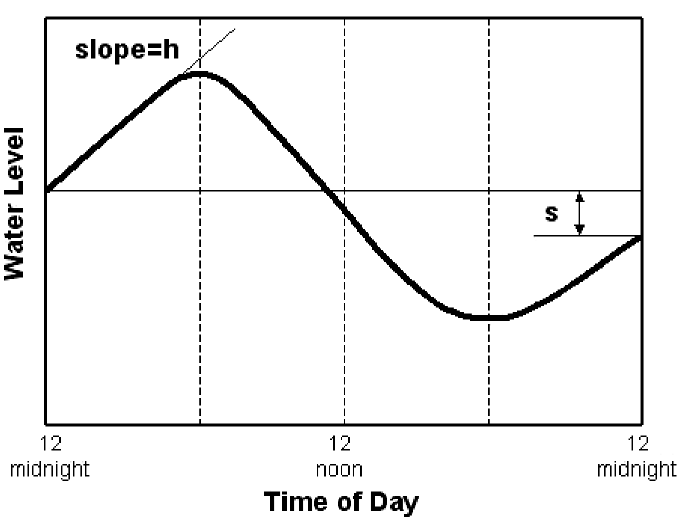

FIGURE 1. Typical Diurnal Cycle.

The primary assumptions of the White (1932) method include: (1) ET is negligible during the nighttime period used to calculate h and (2) the rate of stage increase (h) remains constant throughout the day. The assumption of negligible nighttime ET is generally valid. However, Tolk *et al.* (2006) noted that nighttime ET can be an important part of total ET for irrigated crops in a semiarid environment. They reported measured ratios of nighttime ET to total ET ranging from an average of 3-7.2% for dryland cotton and irrigated alfalfa, respectively. The largest ratio of 12% resulted in a nighttime ET approaching 2 mm. The assumption of constant inflow/outflow restricts the use of the method to periods with no precipitation or other transient effects (e.g., pumping). Loheide *et al.* (2005) stated an additional assumption that "diurnal water table fluctuations are a product of plant water use." This assumption is restricted to ground-water systems, where the water table is below the ground surface. For this condition, Loheide *et al.* (2005) found the White (1932) method to quantify water extracted from the water table and capillary fringe. Water removed from the vadose zone above the capillary fringe is not included. Under conditions of ponded surface water, diurnal water table fluctuations may result from transpiration and open water and/or bare soil evaporation.

Excessive ET estimates have been obtained using Equation (1) and researchers have attributed this overestimation to uncertainty in estimating the specific yield term, S_y (Gerla, 1992; Loheide *et al.*, 2005). Gerla (1992) recommended the use of air-filled porosity instead of S_y and approximated it by the ratio of infiltrated rainfall to the resulting rise of the water table. Loheide *et al.* (2005) utilized the concept of "readily available specific yield," which considers only the water released from storage during the time frame of a diurnal cycle. For a silty clay loam sediment texture, Loheide *et al.* (2005) estimated the specific yield to be over 28 times the readily available specific yield. Nachabe *et al.* (2005) developed a method to estimate ET that uses diurnal variations in total soil moisture and does not require estimation of specific yield.

Given the preceding discussion concerning S_y, two distinct modes of application are relevant for Equation (1): (1) application to ground-water systems,

where the water table is below the ground surface, and (2) application to surface-water systems where flooded conditions prevail. For application to ground-water systems, the readily available specific yield, following Loheide *et al.* (2005), should be used. For application to surface-water systems, a value of 1.0 is typically recommended for the specific yield (e.g., Mitsch and Gosselink, 2000).

For application to surface-water systems, the specific yield is only strictly equal to 1.0 for a cylindrical pond geometry, where the surface area of ponded water is not a function of stage. Use of a specific yield of 1.0 will lead to overestimation of ET for most small natural depressional wetlands, where the surface area of ponded water decreases rapidly at low stages. As illustrated in Figure 2, a noncylindrical pond geometry results in a specific yield less than 1.0 due to the contribution of sediment. This reduction in specific yield will depend on the pond geometry, the water-level change (as shown in Figure 2), and the properties of the sediment.

The primary objective of this paper was to evaluate the adequacy of the White (1932) method for obtaining daily ET estimates at a sinkhole wetland on the Tennessee Highland Rim (THR). The wetland is typical of other seasonally inundated sinkhole wetlands on the THR. Finally, daily estimates of net seepage are computed in conjunction with daily ET estimates, and the relative importance of each transfer process to the overall water budget is compared.

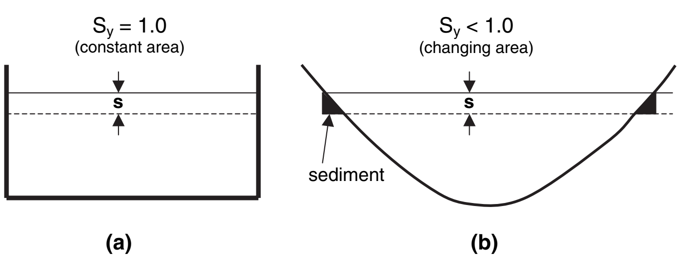

FIGURE 2. Effect of Pond Geometry on Specific Yield (S_y) for (a) Cylindrical Pond Geometry and (b) Noncylindrical Pond Geometry.

STUDY SITE

The wetland selected for this study is a 0.93-ha forested sinkhole wetland located in Algood, Tennessee (36°10′53″N and 85°27′21″W) (Figure 3). The Algood wetland was initially selected for detailed study due in part to its pristine condition. However, during the summer of 2003, approximately 13% of the watershed was converted to commercial land use, increasing the surface-runoff contribution to the water budget of the site. The Algood wetland is located in the headwaters of Burtons Branch watershed (Figure 3) and is typical of other sinkhole wetlands distributed throughout the THR (Wolfe, 1996). The maximum depth of the depression is 0.4 meter and is seasonally inundated, ponding water from December through late spring (May-June).

Dominant vegetation at the site includes red maple *Acer rubra* L., black gum *Nyssa sylvatica* L., and willow oak *Quercus phellos* L. in the overstory, *A. rubra* and Virginia willow *Itea virginiana* L. in the midstory and shrub layers, and various herbaceous *Carex* species in the understory. The spatial arrangement of plant community species is closely related to the hydroperiod and an individual species tolerance to inundation and saturation. As is typical of depression wetlands in middle Tennessee, trees, shrubs, and herbaceous vegetation are found throughout the wetland, although densities tend to be lower in the center and increase towards the edge.

INSTRUMENTATION AND MONITORING

The site was instrumented with an automated water level sensor, a weather station, and a network of monitoring wells. Meteorological conditions, including temperature, solar radiation, humidity, atmospheric pressure, and precipitation, were measured with a Davis GroWeather weather station located 55 meter southeast of the wetland in an open area (Figure 3). A water level sensor (model WL15) from Global Water Instrumentation, Inc. (Gold River, California) was installed in the deepest part of the depression to measure surface-water levels (Figure 3). Both meteorological variables and surface-water level were measured at 15-minute time intervals.

Ground-water monitoring wells were installed at 11 locations throughout the wetland and adjacent upland to monitor ground-water levels (Figure 3). The wells were located along east-west and north-south transects. Wells SC, SP, and NC form one north-south transect and Wells 1, CW, 2, and 3 form another. Wells W, 4, 5, and 6 form the east-west transect. Wells were constructed and installed following Sprecher (2000), using 5.1 cm (2 in) polyvinyl chloride pipe. Ground-water levels were measured manually using a Heron water level indicator accurate to the nearest 0.25 mm (0.01 in). The sampling interval ranged from one day to one week.

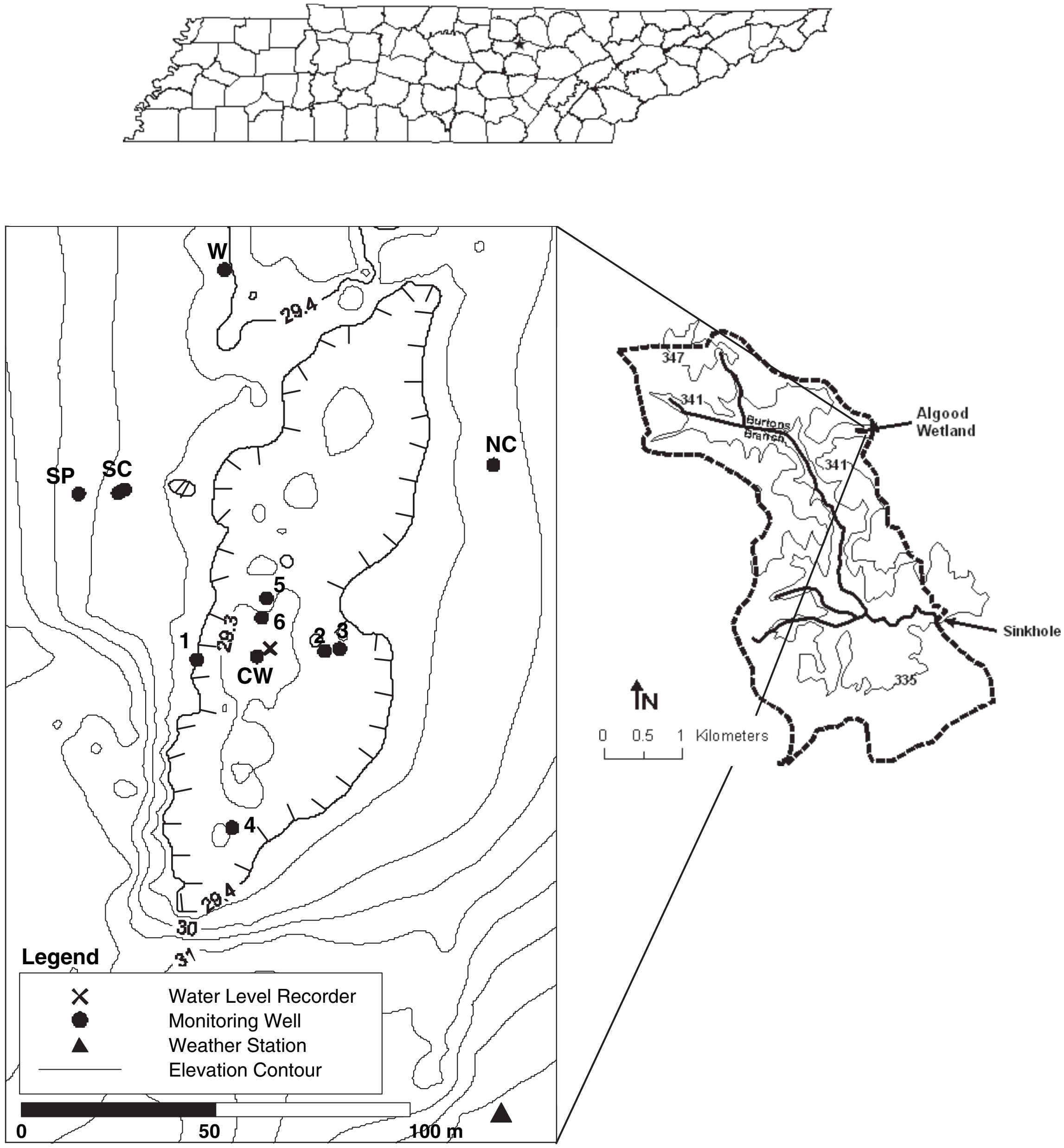

FIGURE 3. Location and Site Map for the Algood Wetland.

METHODS

Diurnal Cycle Classification

Previous studies using diurnal cycles to estimate ET have focused primarily on ground-water systems, where the diurnal pattern shown in Figure 1 is most common. For surface-water systems, a more dynamic diurnal pattern is expected due to a more rapid run-off response. The diurnal pattern reflects the prevailing relationship of the surface-water body to the ground-water system (i.e., discharge/recharge), which is known to vary both spatially and temporally in some wetlands.

Five distinct types of diurnal cycles were observed throughout the study period, as indicated in Figure 4. Type A (Figure 4a) corresponds to the typical diurnal cycle of Figure 1, where net inflow exists during the nighttime (postive h). This corresponds to a ground-water discharge condition, where the water table elevation in the perimeter wells is greater than the surface-water elevation. A Type B diurnal cycle (Figure 4b) displays a negative nighttime recession slope (h). This corresponds to a ground-water recharge condition, where the surface-water elevation

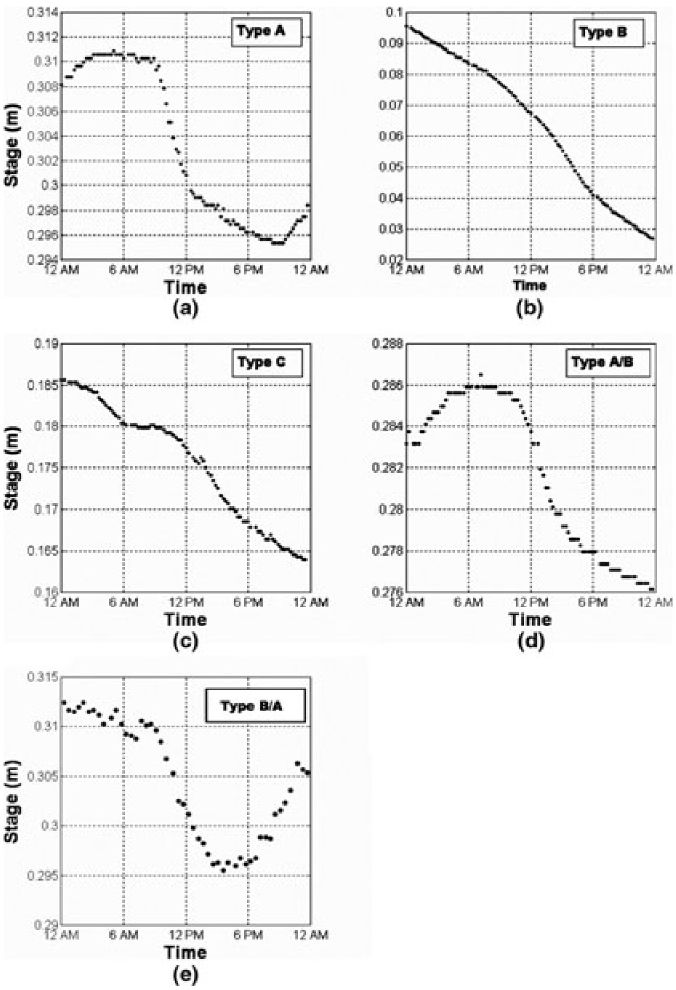

FIGURE 4. Classification of Diurnal Surface-Water Cycles for Algood Wetland: (a) Type A Discharge Condition, (b) Type B Recharge Condition, (c) Type C, (d) Type A/B Transitional Cycle, and (e) Type B/A Transitional Cycle.

is greater than the water table elevation in the perimeter wells. The Type C cycle (Figure 4c) is a variation of the Type B, where a period of zero net inflow/outflow occurs between the hours of 6 AM and 12 PM. Two diurnal cycles were observed that are transitional between Type A and Type B (Figures 4d and 3e). The Type A/B cycle displays a discharge condition in the AM and a recharge condition in the PM, whereas the B/A cycle displays a recharge condition in the AM and a discharge condition in the PM.

A typical sequence of diurnal cycles for the Algood wetland is shown in Figure 5 for April of 2005. During a precipitation event, the shallow water table is recharged, creating a ground-water discharge condition (Type A diurnal cycle). This condition persists for several days and is followed by a transitional Type A/B diurnal cycle that lasts for one to two days. During this period, the wetland transitions from a discharge condition to a recharge condition over the course of a day. This flow reversal is attributed to water table decline due to transpiration losses around the perimeter of the surface-water body. A Type B recharge condition ends the sequence and continues until the next recharge event.

Evapotranspiration and Seepage Calculations From Diurnal Cycles

The complete stage record for the Algood wetland includes a continuous record of pond stage for 2004-2005 and a discontinuous record for 2002-2003. Each day of the stage record was examined and classified according to Figure 4. Diurnal cycles classified as transitional (Type A/B or B/A) were excluded from the analysis, as ET estimates cannot be obtained without making an assumption about the duration of recharge and discharge conditions throughout the day. Type C cycles were also excluded for this reason. Additionally, we excluded the days where the water surface elevation exceeded the invert elevation of the surface outlet. As a result, the seepage estimates represent ground-water seepage and do not include surface-water outflow. Surface-water outflow occurred infrequently at the site due to the high invert elevation in relation to the mean surface-water elevation.

A total of 53 diurnal cycles classified as Type A or B and judged to be high quality were selected for calculation of ET and seepage. Diurnal cycles displaying the characteristic form as displayed in Figure 4b were found to occur only when preceded by a significant period without precipitation. Due to the terminal position in the sequence (Figure 5), the majority of the 53 diurnal cycles were Type B. These 53 diurnal cycles also cover a wide range of climatic conditions with average daily temperatures ranging from 3.3 to 25.6°C.

Equation (1) was used to estimate ET for each of the 53 diurnal cycles. An average value ($h_1 + h_2/2$) was used for the net inflow/outflow term (h). A composite specific yield was computed that weights the relative contribution of sediment and air. The expression used was

$$S_{yc} = S_{ys}\left(\frac{V_s}{\Delta V_c}\right) + S_{ya}\left(1 - \frac{V_s}{\Delta V_c}\right), \tag{2}$$

where S_{yc} is the composite specific yield, S_{ys} is the specific yield of sediment, S_{ya} is the specific yield of air (equal to one), V_s is the sediment volume, and ΔV_c is the volume change for a cylindrical pond geometry. Equation (2) approaches 1.0 as the pond geometry becomes cylindrical (Figure 2a).

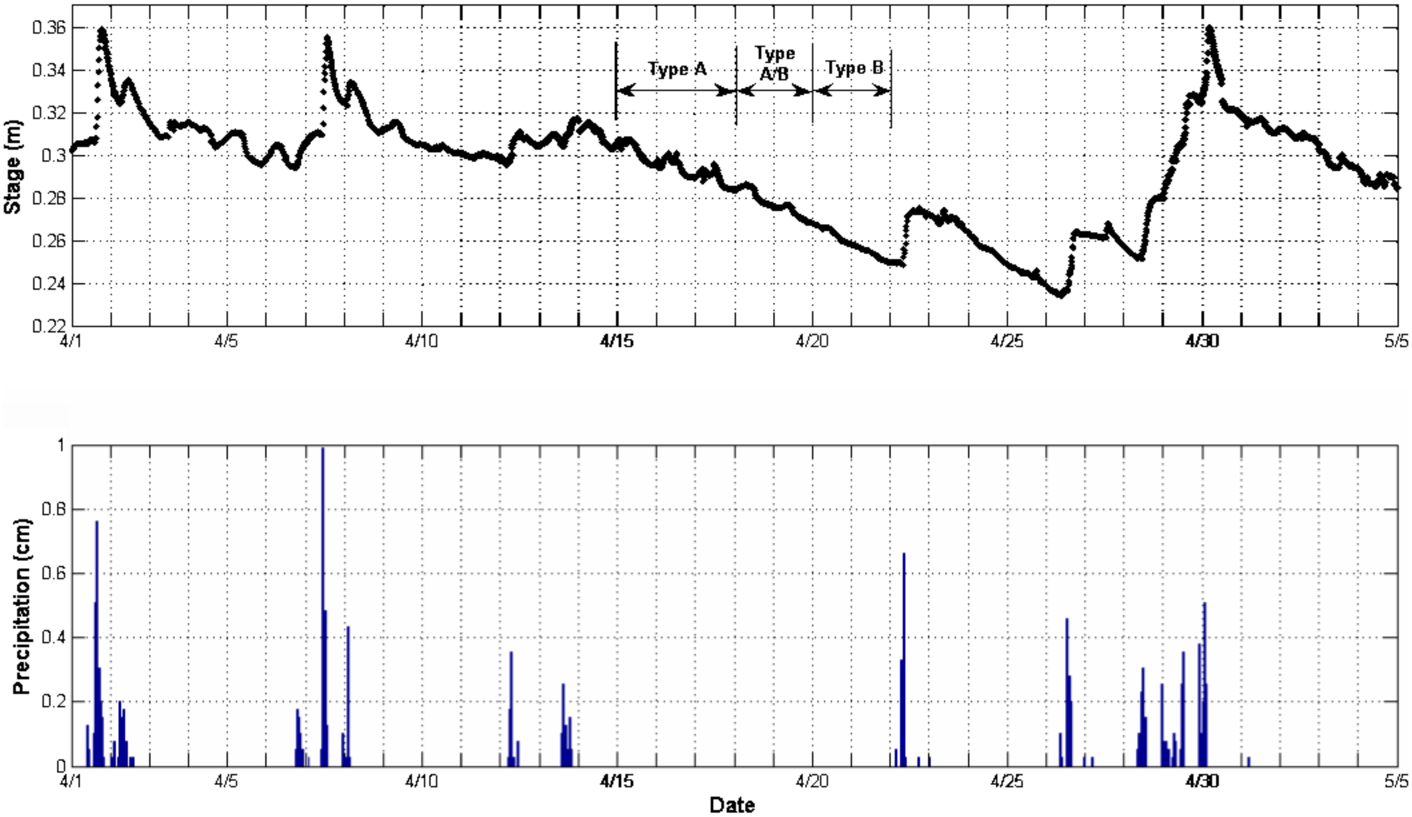

FIGURE 5. Typical Sequence of Diurnal Cycles for the Algood Wetland During April 2005.

The surface soil horizon at the Algood wetland has a silt loam texture, for which Loheide *et al.* (2005) reported a readily available specific yield of 0.037. Although this value is expected to vary significantly with site conditions, we expect 0.037 to be on the lower range of values due to the presence of organic matter in the surface horizon. Detailed topographic data of the Algood wetland was used to develop analytical relationships for estimation of V_s and ΔV_c in Equation (2). The resulting expressions for area (A in m^2) and volume (V in m^3) as a function of stage (h in meter) are

$$A(h) = 45654h^{1.45} \tag{3}$$

$$V(h) = 18640h^{2.45}. \tag{4}$$

The sediment volume is given by

$$V_s = \Delta V_c - \Delta V_{sw} = A(h_i)(h_i - h_f) - [V(h_i) - V(h_f)], \tag{5}$$

where ΔV_{sw} is the change in surface-water volume, h_i is the initial stage, and h_f is the final stage. The first term in Equation (5) represents the volume change for a cylindrical pond geometry and the second terms represent the actual volume change. The ratio of sediment volume to cylindrical volume is given by

$$\frac{V_s}{\Delta V_c} = 1 - \frac{V(h_i) - V(h_f)}{A(h_i)(h_i - h_f)}. \tag{6}$$

Equations (3-6) were used to compute a composite specific yield for each of the 53 diurnal cycles.

Seepage was computed as the difference in the total volume change (ΔV_t) and ET (computed with Equation 1), or

$$\text{Seepage} = \frac{\Delta V_t}{A(h_i)} - \text{ET}, \tag{7}$$

where the total volume change is given by

$$\Delta V_t = \Delta V_c - (n - S_{ys})V_s, \tag{8}$$

where n is the sediment porosity. The second term in Equation (8) represents the water retained in the sediments as the pond stage changes from h_i to h_f. A typical porosity for a silt loam of 0.501 was used for

all calculations. The equations developed in this section are valid only for a Type B diurnal cycle (Figure 4). As will be demonstrated, Type A diurnal cycles that occur less frequently are less amenable to application of the White (1932) method.

Sample Calculations

A sample diurnal cycle (Type B) for June 21, 2004, is shown in Figure 6. The net outflow rate (*h* in Equation 1) varied from 2.08 to 2.10 mm/h with an average of 2.09 mm/h. Stage decreased from 0.143 to 0.064 meter, a total change of 79 mm. Equations (9-13) present the calculation of ET and seepage for this day.

$$\frac{V_s}{\Delta V_c} = 1 - \frac{18640(0.143)^{2.45} - 18640(0.064)^{2.45}}{45654(0.143)^{1.45}(0.143 - 0.064)} = 0.36 \tag{9}$$

$$S_{yc} = 0.037(0.36) + 1.0(1 - 0.36) = 0.65 \tag{10}$$

$$\mathrm{ET} = 0.65(24(-2.09) + 79) = 18.7\,\mathrm{mm} \tag{11}$$

$$\begin{aligned}\Delta V_t =& \Delta V_c - (n - S_{ys})V_s = 215 \\ & - (0.501 - 0.037)(0.36)(215) = 179\,\mathrm{m}^3\end{aligned} \tag{12}$$

$$\mathrm{Seepage} = \left(\frac{179}{2721}\right)1000 - 18.7 = 65.8 - 18.7 = 47.1\,\mathrm{mm} \tag{13}$$

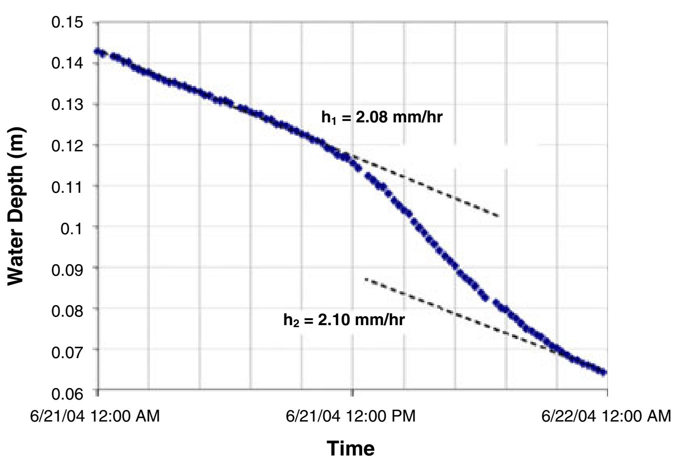

FIGURE 6. Diurnal Surface-Water Cycle (Type B) for June 21, 2004.

RESULTS AND DISCUSSION

Diurnal Curve Estimates of Evapotranspiration and Seepage

The ET estimates for each selected diurnal cycle are shown in Figure 7 plotted against wetland stage (water depth at location of water level recorder in Figure 3). Figure 7 indicates a moderately strong linear relationship between ET and depth, with ET increasing with decreasing stage. Four estimates in Figure 7 (enclosed by dashed rectangle) deviate from this trend. All four were classified as Type A diurnal cycles (Figure 4a). It is not evident why the outliers are all based on Type A diurnal cycles, although the proximity to the precipitation event in the typical sequence (Figure 5) may influence the ET estimates. A critical assumption of the White (1932) method is that the rate that stage increases or decreases remains constant throughout the day. For the period immediately following a precipitation event, where Type A diurnal curves are found to occur, this assumption is less likely to be valid. Upon closer examination, the inflow rate (*h*) was found to vary more significantly for the Type A diurnal cycles than for the Type B. Additionally, the outliers occurred during the nongrowing season, where smaller ET rates are expected. Excluding these values, the ET estimates range from a minimum of 1.08 mm/day to a maximum of 18.7 mm/day.

The negative correlation between ET and stage shown in Figure 7 suggests a possible oasis effect (Allen *et al.*, 1998). Pond stage is directly proportional to the surface area of the water body. As the stage

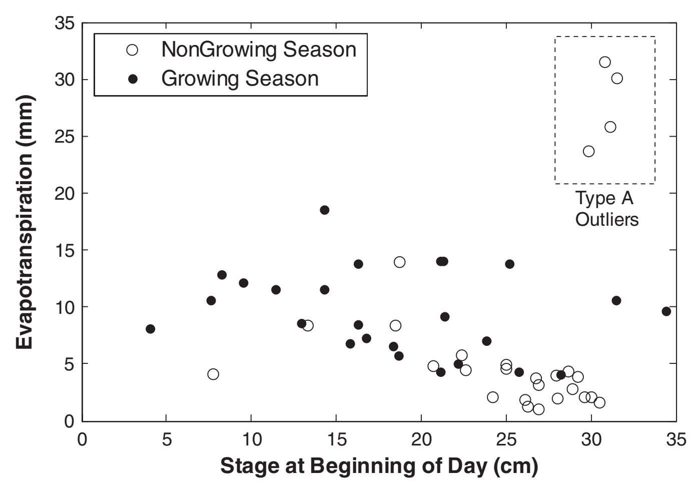

FIGURE 7. Relationship Between Wetland Stage and Total Daily Evapotranspiration. The growing season is assumed to occur between the months of May and September.

decreases, the surface area of open water decreases and the exposed bare soil begins to dry. This creates three distinct moisture regimes as you move from the dry upland pasture and urban areas to open water. Similar elevated evaporation rates are well known to occur from shallow evaporation pans. Grouping the data by season (growing/nongrowing) illustrates the influence of meteorological conditions on ET (Figure 7). As illustrated in Figure 8, the temporal distribution of the ET rates are consistent with the known regional distribution and the expected positive correlation with average daily temperature is present.

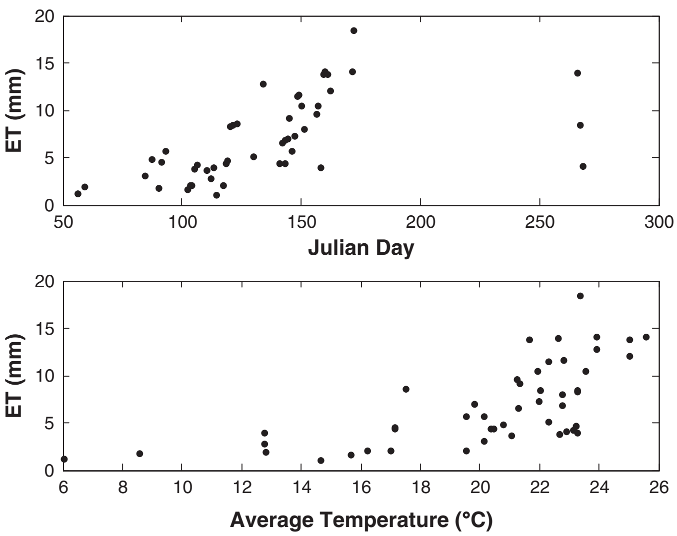

FIGURE 8. Relationship Between Total Daily Evapotranspiration and (top) Julian Day and (bottom) Average Daily Temperature.

The ET rates at low stage and during the growing season exceed 5 mm/day and approach 20 mm/day (Figure 7, excluding Type A estimates). Daily ET rates reported by Abtew (1996) for three wetland plant communities (cattail, mixed marsh, and open water/algae) in a subtropical climate (Florida) never exceeded 9 mm/day. Moro *et al.* (2004) reported transpiration rates of about 23 mm/day during the growing season for a reed bed in semi-arid Spain, which exceeds the maximum of 18.5 mm/day estimated for the Algood wetland. The abnormally high ET rates estimated for the Algood wetland could also be enhanced by a clothesline effect (Allen *et al.*, 1998). Although the plant community within the Algood wetland is pristine, the watershed is composed of short grass and two urban developments that comprise approximately 10% of the watershed. Additional urban areas are located in close proximity to the wetland. An access road for the urban developments was constructed during the summer of 2003 near the wetland on the southeast side. Trees around the perimeter that act as a wind barrier were removed. As a result, the horizontal advection of sensible heat from the urban and drier upland areas was enhanced. The combined effects of the contrasting roughness (clothesline) and moisture conditions (oasis) appear to be significant.

The composite specific yield values computed for 49 of the 53 diurnal cycles (excluding Type A cycles) are shown in Figure 9 as a function of stage. The values range from 0.43 to 0.99 with the lower values occurring at low stages. This is attributed to greater deviation from a cylindrical pond geometry at low stages as indicated by Equations (3) and (4). The magnitude of the stage decrease is also an important factor as large decreases are likely to coincide with low stages. Computed values of the composite specific yield were found to be relatively insensitive to changes in the specific yield of sediment (S_{ys}). The maximum ET of 18.7 mm/day increased to only 22 mm/day with a tenfold increase in S_{ys}.

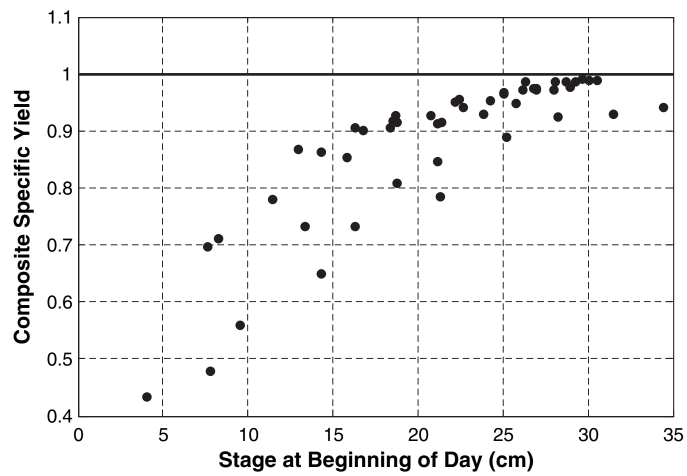

FIGURE 9. Relationship Between Composite Specific Yield and Stage for 49 of the 53 Diurnal Cycles Evaluated for the Algood Wetland.

The net seepage estimates are shown in Figure 10 plotted against wetland stage. Net seepage estimates range from 1.2 to 48.2 mm/day. Figure 10 indicates increased seepage during the growing season. During the growing season, the hydraulic gradient is increased due to large transpiration losses at the edge of the seasonal extent of the surface-water body. A distinct trend of increasing seepage with decreasing stage is also evident in Figure 10. Seepage is directly proportional to hydraulic gradient. The measured hydraulic gradient along the E-W and N-S transects is shown in Figure 11 as a function of stage. A strong linear relationship exists between stage and hydraulic gradient. A positive hydraulic gradient indicates a recharge condition (i.e., flow out of wetland). The largest hydraulic gradient occurs at Wells

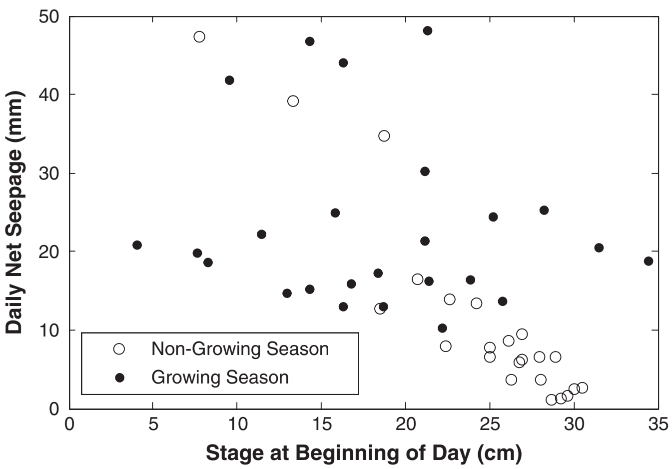

FIGURE 10. Relationship Between Wetland Stage and Net Seepage. The growing season is assumed to occur between the months of May and September.

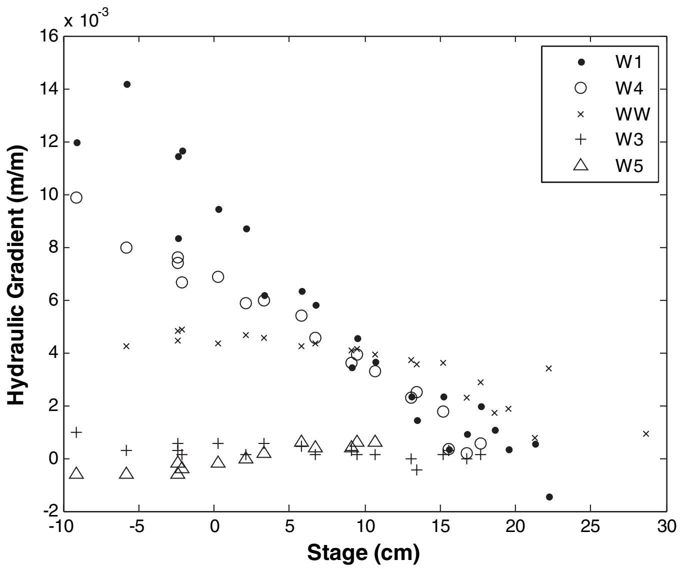

FIGURE 11. Relationship Between Wetland Stage and Hydraulic Gradient for Five Wells. Refer to Figure 2 for well locations. Stage values are measured at well CW in Figure 2. Negative values of stage indicate the water table is below the ground surface. Negative values for hydraulic gradient indicate discharge conditions.

1 and 4 (W1 and W4 in Figure 3) along the south and east directions. Small hydraulic gradients occur at Wells 3 and 5 and alternate between discharge and recharge conditions. Overall, Figure 11 indicates that recharge conditions are dominant and provides support for the accuracy of the seepage estimates shown in Figure 10.

Figure 12 indicates that despite the large ET rates estimated at the Algood wetland, seepage is the dominant water loss mechanism. The ratio of daily seepage to daily ET exceeds 1.0 for all but 3 of the

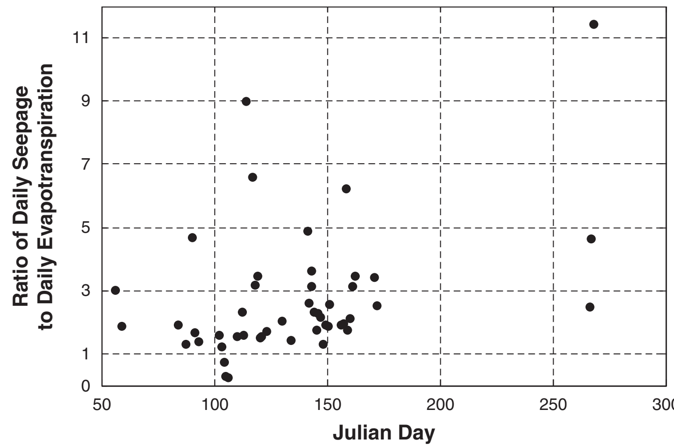

FIGURE 12. Relationship Between the Ratio of Daily Seepage to Daily Evapotranspiration and Julian Day.

49 days included in Figure 12. It is suspected that the recharged water moves laterally and is eventually transpired by the denser plant community around the seasonal surface-water body margins. Deep infiltration is impeded by a shallow fragipan soil horizon.

CONCLUSIONS

This study used the White (1932) method to obtain daily estimates of ET and seepage for a seasonally flooded sinkhole wetland. Diurnal surface-water cycles were classified into five categories based on the relationship between the surface-water body and the surrounding ground-water system (i.e., recharge/discharge). Only one class of diurnal cycles was found to be suitable for application of the White (1932) method. This subset of diurnal cycles was used to estimate ET and seepage and to estimate the relative importance of each transfer process to the overall water budget. The White (1932) method has limited utility for wetlands with erratic hydrologic regimes due to the long hydrologic records needed to extract a meaningful sample size. Inflow/outlow rates rarely remain constant throughout the day, hence violating the critical assumption of the White (1932) method. High-resolution observations of diurnal surface-water cycles can, however, provide important information about the hydrologic regime (i.e., temporal distribution of recharge/discharge conditions) without requiring the installation of ground-water monitoring wells and piezometers.

The results demonstrate that high ET rates can occur in isolated wetlands due to contrasting roughness and moisture conditions (oasis and clothesline

effects). Estimated ET rates ranged from 4.1 to 18.7 mm/day during the growing season. Despite these large ET rates, seepage (recharge) was found to be the dominant water loss mechanism for the wetland.

The current study applied the White (1932) method to a surface-water system, where the specific yield term is typically assumed to equal 1.0 in applications. This assumption was found to be invalid for application to surface-water systems with a noncylindrical pond geometry. An overestimation of ET by as much as 60% was found to occur under conditions of low pond stage and high water loss. Future studies should combine observations of the surface-water body and shallow ground-water table to estimate ET at the site-level. This would require extensive soil sampling and laboratory testing to accurately characterize the specific yield.

The use of diurnal surface water cycles to estimate ET and seepage is an attractive low-cost alternative to other methods (e.g., Penman-Monteith equation). Historically, the technique was developed and applied to ground-water systems that exhibit the classic type A diurnal cycle shown in Figure 4a. This study demonstrated that surface water systems exhibit a wider range of diurnal cycles, which reflect the relationship between the surface water body and the local ground-water system. A direct measurement of ET at the Algood wetland would be valuable, given the unique site conditions and elevated ET rates. Additional work is needed to characterize the error introduced into the estimates of seepage and ET by a variable rate of stage increase or decrease throughout the day.

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