CUMBERLAND ISLAND NATIONAL SEASHORE: LINKING OFFSHORE IMPACTS TO MAINLAND WITHDRAWALS FROM A REGIONAL KARST AQUIFER

Sydney T. Bacchus

AUTHOR: Institute of Ecology, University of Georgia, Athens, Georgia 30602-2202, E-mail: sbacchus@arches.uga.edu.
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Abstract: Unsustainable withdrawals from the Floridan aquifer on the mainland of southeast Georgia have resulted in an estimated decline in the potentiometric surface of approximately 9 m (30 ft) in the location of Cumberland Island. The majority of this largest, most southerly barrier island off the coast of Georgia was designated as a National Seashore in 1972. Ten years later, Congress designated 3,600 ha (9,000 ac) of the 14,560 ha (36,400 ac) federally-owned tract as a "Wilderness Area", to "preserve the scenic, scientific, and historical values" of this natural resource. Unsustainable withdrawals from this regional karst aquifer are known to result in adverse impacts to surface resources beyond the point of withdrawals. However, no record could be found of attempts to determine whether any damage to the National Seashore might have occurred due to the large declines in potentiometric surface of the Floridan aquifer. A ground reconnaissance was conducted in the vicinity of the interior, "Wilderness Area" wetlands, where the greatest potential for adverse impacts related to groundwater withdrawals was predicted to occur. Environmental damage of the nature and magnitude associated with wellfields in Florida was documented in this area. A detailed investigation is recommended to determine the extent of the damage, and the role of past and present groundwater mining on the mainland.

INTRODUCTION

Damage from Regional Groundwater Mining in Florida

The Floridan aquifer is the major source of ground water for Florida and south Georgia, and extends north and west into South Carolina and Mississippi, respectively. This regional aquifer does not halt abruptly at the coastline, but continues offshore (Miller, 1992), extending under barrier islands such as Cumberland Island. Municipal, agricultural, industrial, and residential uses of ground water have increased in both Florida and Georgia since the early 1900s. However, monitoring the impacts on the surficial aquifer of these withdrawals from this regional water resource was not initiated until much later. The United States Geological Survey (USGS) began producing contour maps of the potentiometric surface of the upper Floridan aquifer in the west-central Florida area in 1964, more than 60 years after the withdrawals were initiated. Regulation of groundwater withdrawals in Florida did not begin until 1972, with the adoption of Chapter 373, Florida Statutes, so a more detailed monitoring of groundwater response was delayed until that time. This legislation directed the five regional Water Management Districts to manage the state's water resources. The Southwest Florida Water Management District (SWFWMD) regulates groundwater withdrawals in the west-central Florida region (SWFWMD, 1993).

In 1994 and 1995, a multitude of legal actions were initiated against the SWFWMD in response to their management of groundwater resources. The groundwater withdrawal issues that prompted these legal actions are summarized in the Orders that were issued on March 26, 1997 (Menton, 1997) and May 1997 (Quattlebaum, 1997). A significant conclusion of these hearings was that the major cause of environmental damage in the areas addressed by the cases, including natural lakes and wetlands, is "related to the withdrawal by the permittees of substantial quantities of water from the Floridan aquifer", rather than to other factors such as recent low levels of rainfall, and area drainage projects. After initiation of these cases, the SWFWMD (1996) published an extensive report documenting the environmental damage to wetlands, natural lakes, streams, and groundwater discharge through springs that had occurred as a result of groundwater mining in their District.

Aquifer characteristics vary dramatically from the shallow, semiconfined hydrogeologic system in the north Tampa Bay area, to a system described by the SWFWMD as a "well-confined, multi-layered aquifer system" southwest of Tampa Bay. However, similar damage to private property and natural resources has been observed and reported at both locations (Menton, 1997; Quattlebaum, 1997). These similar responses probably can be attributed to the common characteristics of secondary porosity and preferential flow that govern hydrologic responses in karst aquifers (Ford and Williams, 1989).

The House Committee on Natural Resources (1994) concluded that unsustainable groundwater withdrawals from the Floridan aquifer in a single west-central Florida county resulted in destruction of approximately 6,880 hectares (17,000 acres) of wetlands in addition to private property damage, including failure of private wells. Costs of repairing and replacing private wells damaged from these withdrawals have exceeded $4 million, and estimates of additional damage to private property have not been completed. These estimates did not include damages incurred to public property, such as the J. B. Starkey Wilderness Park (SWP), where one of the municipal wellfields was constructed.

Additional economic losses incurred by private property owners included loss of timber, devalued lakefront property as lakes receded, and costs of removing water-stressed trees that become diseased, including oaks and pines (Bacchus, unpub.; Kenneth Webber, Florida Division of Forestry, pers. comm.). Timber losses have extended to stands on public property at SWP, and may be contributing to loss of long leaf pines at the Myakka River State Park (MRSP). Additional timber loss is predicted in areas of excessive groundwater withdrawals due to problems associated with prescribed burning of pine stands with reduced tissue moisture content (Bacchus, 1995).

Hydrogeologic Characteristics of the Regional Aquifer

Presently, the main water source for the southeastern Coastal Plain (SCP) of Georgia is ground water from the upper Floridan aquifer, the same regional groundwater resource involved in previously described problems. Estimated withdrawals in southeast Georgia for 1995 were 359 mgd, a conservative figure since the amount of water withdrawn for agricultural use cannot be determined. This regional burden has resulted in saltwater intrusion into the aquifer offshore from Tybee Island, in addition to upconing of buried brines in Brunswick (Environmental Protection Department, 1997). Although similar monitoring of Floridan aquifer wells occurs in south Georgia, a monitoring program comparable to that established by the SWFWMD in Florida has not been established. Longterm monitoring of the surficial aquifer, including monitoring wells located in depressional wetlands, and vegetation sensitive to alterations in hydroperiod does not appear to be implemented in Georgia.

Contour maps produced by USGS for south Georgia suggest that a burden at least comparable to that observed in west-central Florida has been imposed on the regional aquifer in south Georgia. For example, the estimated potentiometric surface prior to development (mining of the aquifer) for Cumberland Island was between 18 and 21 m (60 and 70 ft) above mean sea level (Johnston *et al.*, 1980). The potentiometric surface for the same area in May 1980 was estimated to be approximately 9 to 12 m (30 to 40 ft) above mean sea level (Johnston *et al.*, 1981). Cones of depression on the 1980 contour map occur both north (Brunswick, Georgia) and south (Fernandina Beach, Florida) of Cumberland Island.

Widespread disruptions in the integrity of the semiconfining unit separating the regional aquifer from overlying surficial aquifers have been documented throughout Florida and Georgia, extending from inland to offshore (Bacchus and Brook, 1996; Bacchus, 1998; Field *et al.*, 1997; Popenoe *et al.*, 1984; Snyder *et al.*, 1989; Spechler, 1994; Spechler and Phelps, 1997; Spechler and Wilson, 1997; Stewart and Stedje, 1990; Warner, 1997; Watson *et al.*, 1990). These discontinuities include horizontal and vertical fractures, in addition to solution/collapse features. Documentation also exists regarding preferential flow in the aquifer associated with these discontinuities in Florida and Georgia (Brook and Sun, 1982; Brook, 1985; Brook and Allison, 1986; Brook *et al.*, 1988; Stewart and Stedje, 1990; Warner, 1997; Watson *et al.*, 1990). Recent findings provide additional support that depressional wetlands and some tree species throughout the SCP may respond similarly to groundwater mining. For example, direct hydrologic connections between the surficial and Floridan aquifers were documented in some depressional wetlands evaluated in the central Dougherty Plain of southwest Georgia (Blood *et al.*, 1997), and premature decline and death of trees in that area associated with groundwater withdrawals was similar to responses in areas of west-central Florida with unsustainable groundwater withdrawals (Bacchus, 1997). Similar hydraulic evidence suggests that vertical flow occurs from the Okefenokee Swamp to the underlying Floridan aquifer in southeast Georgia (Kitchens and Rasmussen, 1995).

Hydrologic models generally are based on assumptions of homogeneous, isotropic aquifer conditions. However, preferential flow through the dynamic fracture systems and solution/collapse features of the Floridan aquifer invalidates these assumptions and makes it extremely difficult to develop hydrologic models that can predict accurately the location and severity of impacts from groundwater withdrawals. The use of hydro-ecological indicators has been proposed to identify the location and evaluate the magnitude of impacts due to unsustainable groundwater withdrawals from the regional Floridan aquifer (Bacchus *et al.*, 1997). The objectives of this project were to use the hydroecological approach to predict the location where surface manifestation of groundwater mining would be most likely to occur, and conduct a preliminary investigation of the identified area.

METHODS

A review was conducted of 1:24,000 USGS topographic quadrangle maps (Cumberland Island North, GA; Cumberland Island South, GA; and Fernandina Beach, FL), aerial photographs (1-26-53 DSH-3L-105 ASC 1:4,000 and NASA 4/1974 1-65, 1:77,000 IR flown 4/19/74), and related literature to identify areas of high potential for exhibiting surface expressions of groundwater mining from the Floridan aquifer on the mainland. The area in proximity to Willow Pond Trail, Yankee Paradise Trail, and Duck House Road Trail, with the associated interior wetland, was selected for ground reconnaissance. The wetland is oriented in a general north/south direction between the main road and Yankee Paradise Trail, and extends south of Willow Pond Trail. The target area is included in the Wilderness Area. Ground reconnaissance was conducted on April 27 and 28, 1997, during a time of the year when the condition of vegetation should be vigorous, supporting new growth, and not exhibiting seasonal transpiration stress that may be associated with high summer temperatures.

DISCUSSION

Empirical Evidence

During the ground reconnaissance, several shallow, sinkhole-like depressions were observed clustered between the wetland and the southern portion of Yankee Paradise Trail. These depressions were similar to the shallow sinkholes that have been appearing near the west-central Florida wellfields. An example of one sinkhole-like depression in the reconnaissance area is shown in Figure 1. The arrows delineate the apparent rim of the depression, which is approximately 10 m (33 ft) in diameter. The live oak (*Quercus virginiana*) trees surrounding these depressions exhibit signs of premature decline, including thinning canopies with large quantities of Spanish moss.

The eastern perimeter of the wetland, in the vicinity of these sinkhole-like depressions, has a wide zone of disturbance-induced vegetation. This vegetation suggests that the historic level of the surface water in the wetland has receded, and re-established at a new, lower level. The eastern boundary of this zone exhibits a band of large-diameter wax myrtle's (*Myrica cerifera*) that have attained subcanopy status. Generally these plants occur as shrubs. The diameter and height of this outer band of wax myrtle's suggest that they are relatively old.

Wax myrtle characteristically become established along the edge of the water when they are associated with water bodies. They also invade and flourish in depressional wetlands in the SCP where groundwater mining is occurring, and the natural hydroperiod is depressed for prolonged periods. The presence of smaller, presumably younger, wax myrtles toward the center of this zone suggests that the water level of the wetland dropped in at least two stages, with an intermediate level maintained for a period of years prior to establishment of the present, low level. The most recent drop in the surface water level occurred in an area of the zone that currently supports a thick growth of disturbance vegetation, composed predominantly of blackberry (*Rubus* sp.).

The approximate timing of the drops in the surface water could be determined. The time period that the water was maintained at the highest level and mid level in this zone can be estimated by cutting down several of the wax myrtles at the base and determining the number of annual growth rings. The average number of rings for the wax myrtles in each band can be subtracted from the year in which the trees are cut to estimate the date that the surface water was at that level. However, cutting the wax myrtle's requires special Federal permits since this area is part of the Wilderness Area of Cumberland National Seashore, where all plant and animal life are protected.

Further north along Yankee Paradise Trail, pockets of prematurely dead and declining trees in the canopy and subcanopy were observed on both the east and west sides of the trail, as represented in Figure 2. Most of the dead trees were live oaks. Symptoms of decline included leaves that were chlorotic, reduced, or malformed; thinning canopy vegetation of individual trees; and Spanish moss. These symptoms correspond with vegetative responses observed in depressional wetlands and uplands in other areas of Georgia (Bacchus, 1997) and Florida (Bacchus, 1998;

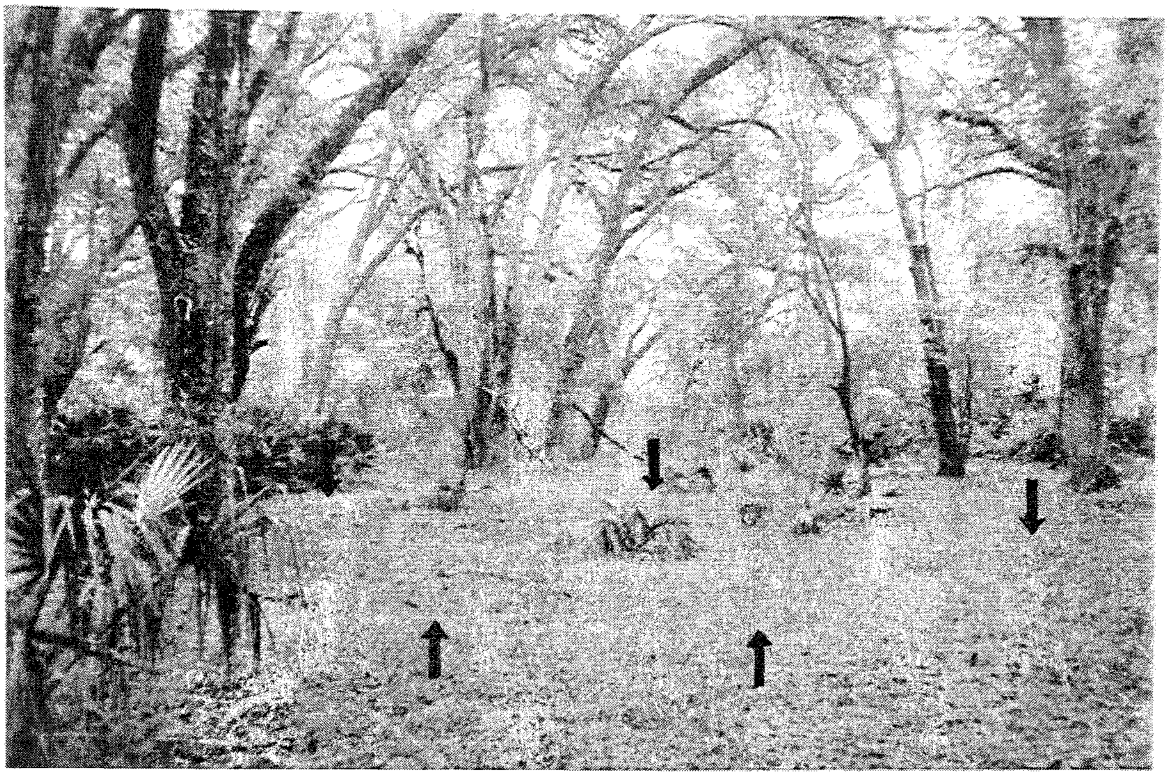

Figure 1. Example of sinkhole-like depressions in the vicinity of Yankee Paradise Trail, Cumberland Island National Seashore Wilderness Area, Georgia, USA (arrows and live oak trees exhibiting signs of premature decline delineate the apparent rim of the depression).

Figure 2. Prematurely dead and declining live oak trees representative of canopy and subcanopy condition on the east and west sides of Yankee Paradise Trail, Cumberland Island National Seashore Wilderness Area, Georgia, USA.

Figure 3. Large black gum (*Nyssa sylvatica* var. *biflora*) with extensive basal decay south of Yankee Paradise Trail, Cumberland Island National Seashore Wilderness Area, Georgia, USA.

Menton, 1997; Quattlebaum, 1997; Rochow, 1994; Rochow and Rhinesmith, 1991) where perturbations of the surficial aquifer and associated surface water have occurred as a result of unsustainable withdrawals from the Floridan aquifer.

Reduction in the size of a tree's canopy is a common adaptation of plants subjected to water stress and is reported extensively throughout the literature. Canopy reduction can occur via reduction in leaf size, leaf number, or both the size and number of leaves. Reduction in leaf size and number was observed in pondcypress (*Taxodium ascendens*) saplings subjected to controlled water stress under growth chamber conditions for a year (Bacchus et al., 1999). Pondcypress trees commonly occur in forested depressional wetlands throughout the SCP.

Longterm reduction in leaf size, without a concomitant increase in leaf number, reduces the total leaf surface available to produce carbohydrates. Carbohydrates are the energy source necessary for the growth and maintenance of health for plants. Reduced growth and vigor due to abnormal stresses can result in premature death and decline of trees, including windthrow, and predisposition to disease from aggressive invasion and colonization by fungi (Bertrand and Hadden, 1992; Hendrix, Jr. and Campbell, 1990; Manion and Lachance, 1992; Schoeneweiss, 1981; 1986; Sinclair *et al.*, 1987).

Windthrow is a pathological term applied to trees that lean and fall because the roots or base of the trees have been decayed by fungi. Windthrow frequently occurs in specific areas associated with groundwater mining where perturbations of the surficial aquifer may be most pronounced because of more direct connection between the surficial aquifer and underlying, production aquifer (Bacchus, 1997; 1998; Bacchus *et al.*, 1997; Menton, 1997; Quattlebaum, 1997; Rochow, 1994; Rochow and Rhinesmith, 1991). Windthrow also can occur as the result of subsidence of organic soils around the roots. The influence of groundwater withdrawals on subsidence of soils, and subsequent impact on associated trees is summarized by Bacchus (1994; 1995). Subsidence of soils was observed south of Willow Pond Trail in the vicinity of the spur trail referenced above. Windthrow of shrubs, such as *Vaccinium* sp., and several species of trees was observed in the vicinity of Yankee Paradise Trail.

A large black gum (*Nyssa sylvatica* var. *biflora*) south of Yankee Paradise Trail fell during the reconnaissance period. That tree had extensive basal decay, as shown in Figure 3. Additional examples of canopy and subcanopy species are shown in Figure 4, with soil subsidence evident in the upper photograph. The responses described above also were observed north of Willow Pond Trail, in the vicinity of the spur trail extending from the central portion of Yankee Paradise Trail southeast to the Willow Pond Trail.

The final observations during the ground reconnaissance were south of Willow Pond Trail and west of the intersection of that trail with Yankee Paradise Trail. Sinkhole-like depressions similar to those described previously, north of Willow Pond Trail also occur south of Willow Pond Trail. The apparent rim of one of these sinkhole-like depressions was approximately 7 m (23 ft) in diameter. Symptoms of decline discussed above also were observed in the trees and shrubs at this location.

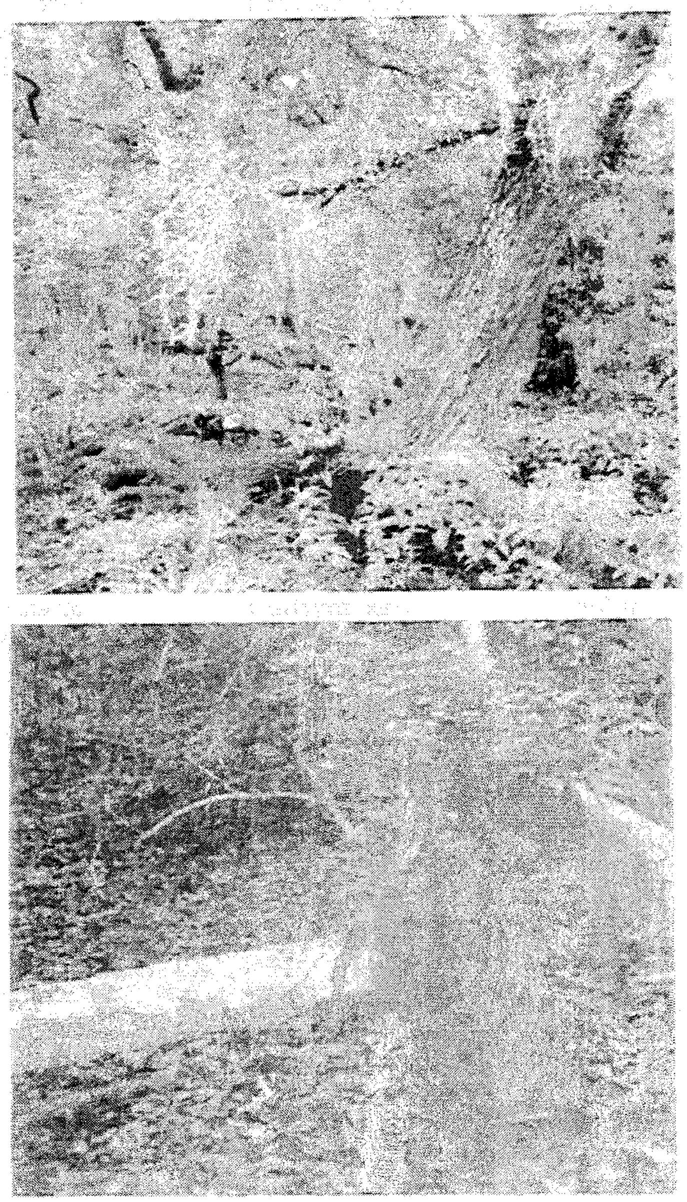

Figure 4. Example of subsidence in canopy trees (upper) and windthrow in subcanopy trees (lower) in the Yankee Paradise Trail/Willow Pond Trail area, Cumberland Island National Seashore Wilderness Area, Georgia, USA.

Potential Causal Factors

Ditching. A network of ditches was excavated through the interior wetland of interest, between the main road and Yankee Paradise Trail, at some time prior to establishment of the Cumberland Island National Seashore in 1972. It is possible that these ditches could have caused the permanent lowering of the water table that was observed along the eastern perimeter of the wetland, as described above. Information regarding the depth of the ditches was not available at the time the reconnaissance was conducted. However, the ditches are presumed to be shallow and although excavation of the ditches may have been capable of lowering the water table, it is unlikely that they would have been responsible for the wide-spread premature death and decline of surrounding upland canopy and subcanopy trees, and associated sinkhole-like depressions.

Available evidence suggests that the ditches within the wetland of interest are not responsible for the water level declines, sinkhole-like depressions, and premature death and decline of the trees described above. Although the exact date that the ditches were excavated could not be determined from the aerial photography available or other accessible records, the ditches were present on the 1953 ASC aerial photograph referenced above. The ditches in that photograph appear to be well-established, suggesting that they may have been constructed at least several years prior to 1953. Based on that information, the wax myrtle trees along the eastern margin of the disturbance would be expected to be more than 45 years old. It is possible, but not likely that the wax myrtles are this old. Unfortunately, collection of any type of sample (particularly those from living organisms) from the Wilderness Area requires federal permits. Cores from trees subjected to anthropogenic groundwater perturbations contain growth ring aberations that prevent accurate aging (Bacchus and Young, unpub. data), requiring comparisons of cross-sections at multiple intervals, which destroys the tree.

The age of the ditches also does not coincide with the appearance of the sinkhole-like depressions, or the symptoms of premature death and decline of the trees. No sinkhole-like depressions or pronounced symptoms of premature death and decline of the trees were observed by the author or Courtney Pape (UGA Chemistry Dept., pers. comm., May 1, 1997) during unrelated trips to this area conducted approximately ten years prior . Therefore, the sinkhole-like depressions, and dead trees in this area apparently have appeared within the last ten years. It is unlikely that ditches excavated in the interior wetland approximately 45 years ago would have resulted in a lagged response time of approximately 35 years.

Excavated Ship Channel. The Cumberland River forms the western shoreline of Cumberland Island, separating the barrier island from the mainland. The St. Marys Inlet, located at the southern end of the island between Georgia and Florida, is a federally maintained entrance channel to the Intracoastal Waterway, ports at Fernandina, Florida, and St. Marys, Georgia, and the U. S. Naval Submarine Base at Kings Bay. The channel has been maintained by dredging for at least 100 years. After King's Bay was selected as the home port for the Navy's new class of Trident submarines in the mid-1970's it was necessary to deepen (12.7 m to 15.5 m), widen, and lengthen the entrance channel to Kings Bay (Herndon, 1991).

Four aquifer systems underlie Cumberland Island. From the uppermost system they include the surficial aquifer, the Pliocene-Miocene aquifer, the Miocene sand aquifers and the Floridan aquifer systems. The surficial aquifer extends throughout the island (Wilson *et al.*, 1991a). The deepening of the channel excavated into the semi-confining bed separating the surficial and Pliocene-Miocene aquifers. This semi-confining unit was not penetrated except in the most southern portion of the island where the semi-confining unit is approximately 6 m (20 ft) thinner than further north (Wilson, 1990). Saltwater was identified in several Pliocene-Miocene observation wells in the southern tip of the island during a study to evaluate the possible impacts of the channel enlargement project. Wilson (1990) and Wilson *et al.* (1991a) concluded that the saltwater intrusion into the Pliocene-Miocene aquifer system may be the result of the dredging of the navigation channel, natural exposure, or some combination of the two. However, Herndon (1991) concluded that hydraulic data suggested that intrusion of seawater from the channel into the Pliocene-Miocene aquifer was insignificant.

Saltwater also was present in Miocene observation wells (Wilson, 1990; Wilson *et al.* 1991a), despite the fact that channel excavations did not extend to the thick semiconfining unit above the Miocene aquifer. This led these researchers to conclude that saltwater intrusion into the Miocene sand aquifer may have important implications regarding the source of the saltwater in the overlying aquifer.

The focal point of the studies conducted to evaluate potential adverse impacts to groundwater due to the deepening of the channel (Herndon, 1991; Herndon and Cofer-Shabica, 1991; Wilson, 1990; Wilson *et al.*, 1991a and b) appeared to be whether groundwater quality would be affected by breaching the uppermost semiconfining zone, rather than whether the excavation would alter hydroperiods of the surficial aquifer (e.g., lower groundwater levels) within specific locations in the island. None of the observation wells or other boreholes excavated on Cumberland Island in conjunction with those studies were located in the Yankee Paradise Trail area. No data appear to be available regarding historic and present levels of the surficial aquifer on Cumberland Island, particularly with regard to the wetland and surrounding area of interest. However, the mechanism by which the deepened channel would result in the observations made during the referenced reconnaissance and described above is unknown at this time.

Cyclical Periods of Drought. Natural vegetation is adapted to the cyclical periods of below-average rainfall that occur in their native region. Long-lived trees, such as live oaks and pondcypress, can thrive for hundreds of years in the absence of significant anthropogenic interference. Trees that are capable of living several hundreds of years, could experience 50 or more periods of drought during their lifetime. If cyclical periods of drought, in the absence of anthropogenic stresses, resulted in premature death and decline of trees these species would be extinct.

Premature death and decline of trees similar to that observed during the referenced reconnaissance and described above are associated with areas of groundwater mining in Florida, and have been attributed to natural periods of below-average rainfall. However, the preponderance of scientific evidence in legal proceedings in Florida supported conclusions that periods of drought had not resulted in the documented damage to the vegetation. These findings also concluded that excessive withdrawals of ground water from the Floridan aquifer had resulted in the extensive damage to vegetation in the areas where the groundwater was being mined (Quattlebaum, 1997; SWFWMD, 1996). Similar conclusions were reached in SCP case studies on the Savannah River Site in South Carolina (Bacchus, 1994), and near Albany, Georgia (Bacchus, 1997).

Finally, if the premature decline and death of trees observed on Cumberland National Seashore were due to drought, the response by those species to the natural shortage of rainfall would be expected to occur uniformly throughout the island, or concentrated along the seaward side of the island where salt spray should be most intense and further increase water stress. The observed pattern of premature decline and death of trees was far from uniform, and was associated with interior wetlands in the Wilderness Area. This pattern, in addition to the sinkhole-like depressions, is consistent with responses to unsustainable groundwater withdrawals.

Groundwater Withdrawals. Apparently there is no historic or present day record of the quantity of groundwater withdrawals on Cumberland Island. However, no records were found to indicate that large quantities of groundwater have been extracted on Cumberland Island for industrial, residential, or agricultural use. The Wilderness Area comprises approximately one-third of the National Seashore tract. The privately-owned land on the island is sparsely inhabited. It is unlikely that groundwater withdrawals on Cumberland since establishment of the National Seashore in 1972 have resulted in the effects described above. However, the historic population of Cumberland was considerably larger than the present population. Additional information is needed to determine the role that historic use of groundwater on Cumberland may have played in the effects described above.

Extensive mining of ground water near Cumberland, along the mainland of south Georgia (Savannah and Brunswick) and north Florida (Fernandina Beach/Jacksonville) predates both monitoring and regulation of groundwater withdrawals. As indicated previously, the primary source for this water is the regional Floridan aquifer. The total volume of ground water withdrawn from this regional aquifer is not known because self-supplied domestic uses and agricultural uses are not metered and must be estimated. Additionally, not all users in the remaining categories (public supply, commercial, industrial, mining, and power generation) are metered (Marella and Fanning, 1996).

In 1990, USGS compiled data for a newly defined study area, the Georgia-Florida Coastal Plain, that extended from the west-central Florida area discussed in the Introduction, throughout Georgia's Coastal Plain. Based on estimates and metered withdrawals, groundwater use in this area was determined to be approximately 2,888 million gallons per day (mgd), with 91% of this groundwater withdrawn from the Floridan aquifer. However, water use estimates are the average daily quantities derived from annual data (Marella and Fanning, 1996). This is another reason that these estimates should be considered conservative, since withdrawals may vary considerably on a seasonal basis and in response to periods of reduced rainfall.

Likewise, data regarding the response of the potentiometric surface to groundwater mining in the north Florida/south Georgia area also are limited. Based on available data, a decline in the potentiometric surface for this Tertiary limestone aquifer after development was estimated to be approximately 9 m (30 ft) in the Cumberland Island area (Johnston *et al.*, 1980; 1981). A reduction of this magnitude has had significant impacts from the standpoint of saltwater contamination in certain locations of the Floridan aquifer. Certainly a reduction of this magnitude in the potentiometric surface of the Floridan aquifer could have had equally significant environmental impacts in locations of greatest surficial aquifer susceptibility. The potential of related impacts is stronger here than in Florida, considering that similar environmental impacts have occurred in Florida in the absence of equivalent permanent declines in the potentiometric surface.

SUMMARY

Aerial photographs and USGS topographic quadrangles of Cumberland Island were used to identify the area of greatest potential for surface expression of long-term groundwater mining on the mainland of southeast Georgia, prior to ground reconnaissance. The identified area was an interior wetland and adjacent uplands in the vicinity of the Yankee Paradise Trail, within the designated Wilderness Area of the Cumberland Island National Seashore. Ground reconnaissance conducted on April 27 and 28, 1997, revealed 1) a permanent reduction in the level of the surface water in the central wetland; 2) premature decline and death of canopy and subcanopy trees in the adjacent uplands; and 3) sinkhole-like depressions similar to those associated with areas of unsustainable groundwater withdrawals in Florida. Potential causal factors considered and rejected included ditching and cyclical periods of drought. Potential causal factors considered, with additional information needed, included deepening of the excavated channel to the U. S. Naval Submarine Base at Kings Bay, and long-term groundwater mining on the mainland. Of the causal factors considered, unsustainable groundwater withdrawals on the mainland appeared to be the most plausible cause. Additional research should be conducted to determine the onset and cause of the damage. If additional research supports the groundwater mining scenario, the ability to "preserve the scenic, scientific, historical values" in the Wilderness Area may continue to be jeopardized.

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