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# History and Hydrology: Engineering Canoe Canals in the Estuaries of the Gulf of Mexico

Gregory A. Waselkov <sup>a</sup>, Donald A. Beebe <sup>a</sup>, Howard Cyr <sup>b</sup>, Elizabeth L. Chamberlain <sup>c</sup>, Jayur Madhusudan Mehta <sup>d</sup>, and Erin S. Nelson <sup>a</sup>

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## ABSTRACT

Local lore has long identified an entrenched feature crossing Fort Morgan peninsula on Alabama's Gulf of Mexico coast (USA) as an ancient canoe canal, a folk identification now confirmed by archival, artifactual, geochronological, geoarchaeological, and hydrological evidence. A 1.39 km canal (site 1BA709) linked two estuaries, Oyster Bay and Little Lagoon, connecting Mobile Bay to the Gulf of Mexico late in the Middle Woodland period, ca. A.D. 600. Construction of such a large hydraulic engineering feature by a non-agricultural, non-hierarchical society seems unusual but not inconsistent with the sorts of monumental landscape alterations accomplished more routinely by other Woodland populations in eastern North America. Although such canals certainly expedited local travel, communication, and transport, their construction and use had broader social ramifications.

## KEYWORDS

coastal; lidar; soil stratigraphy; shell midden; Middle Woodland; Alabama

## Introduction

Canals implicated in agricultural intensification have figured prominently in archaeological theory and practice for at least a century. Whether designed for irrigation or drainage, canals skillfully engineered for pre-industrial water management have played significant roles in the development of many of the world's hierarchically organized agricultural societies (e.g., Dillehay, Eling, and Rossen 2005; Huckleberry, Caramanica, and Quilter 2018; Neely and Lancaster 2019; Stoner et al. 2021). Most canals designed principally for navigation and transportation are likewise attributable to complex hierarchical societies, including several associated with the socially stratified, non-agricultural Calusas of southern Florida, in southeastern North America (Luer 1989; Marquardt and Walker 2013; Thompson, Marquardt, and Walker 2014; also see Bond 2007; Ortloff 2009; Sulas and Pikirayi 2018).

Archaeologists have devoted far less attention to canal-building and use by non-hierarchical, non-agricultural societies. We discuss our observations of one such long-distance canoe canal on the Alabama coast of the Gulf of Mexico created during the Porter phase of the late Middle Woodland period, ca. A.D. 600, well prior to the earliest evidence for cultivation of plant domesticates on the north-central Gulf coast (Gremillion 2018, 36, 136; Price 2008, 306–307). Establishing dates of construction and abandonment of canoe canals has been problematic in this part of the world. We present our approaches to canal dating, as well as our interpretations of canal sediments, hydrology, construction, and abandonment in the hope of raising awareness of this rarely recognized form of hydraulic engineering and monumentality.

## Long-Distance Canoe Canals in Southeastern North America

Transportation and communication throughout southeastern Native North America depended for millennia upon dugout canoe travel on the region's waterways, documented by oral and written accounts from the last five centuries and by discoveries of hundreds of dugout canoes. Extensive systems of footpaths, recorded on maps and in travelers' reports (or modeled from settlement locations and terrain constraints), interconnected with water routes. The two systems—trails and rivers—complemented each other and were so thoroughly intermeshed, with river fords and crossings connecting land routes and overland portages linking discontinuous waterways, as to form a single expansive system of dry and wet paths (Carr 2012, 100; Cobb and Ransley 2019; Duggins 2019, 91; Rodning 2003; Tanner 2006).

One little-known element of these ancient networks is still visible at a few places in southeastern North America. 19th century A.D. archaeologists first documented canals created centuries earlier, apparently to accommodate dugout canoe traffic (in contrast to canals for water control, storage, management, and drainage, all generally for agricultural purposes, which are common in other parts of the world [Ortloff 2009; Sulas and Pikirayi 2018]). However, recognition of additional canoe canals and the roles they played in Indigenous southeastern Native American transportation and communication networks has been hampered by archaeologists' general unfamiliarity with canoe canals and how they worked.

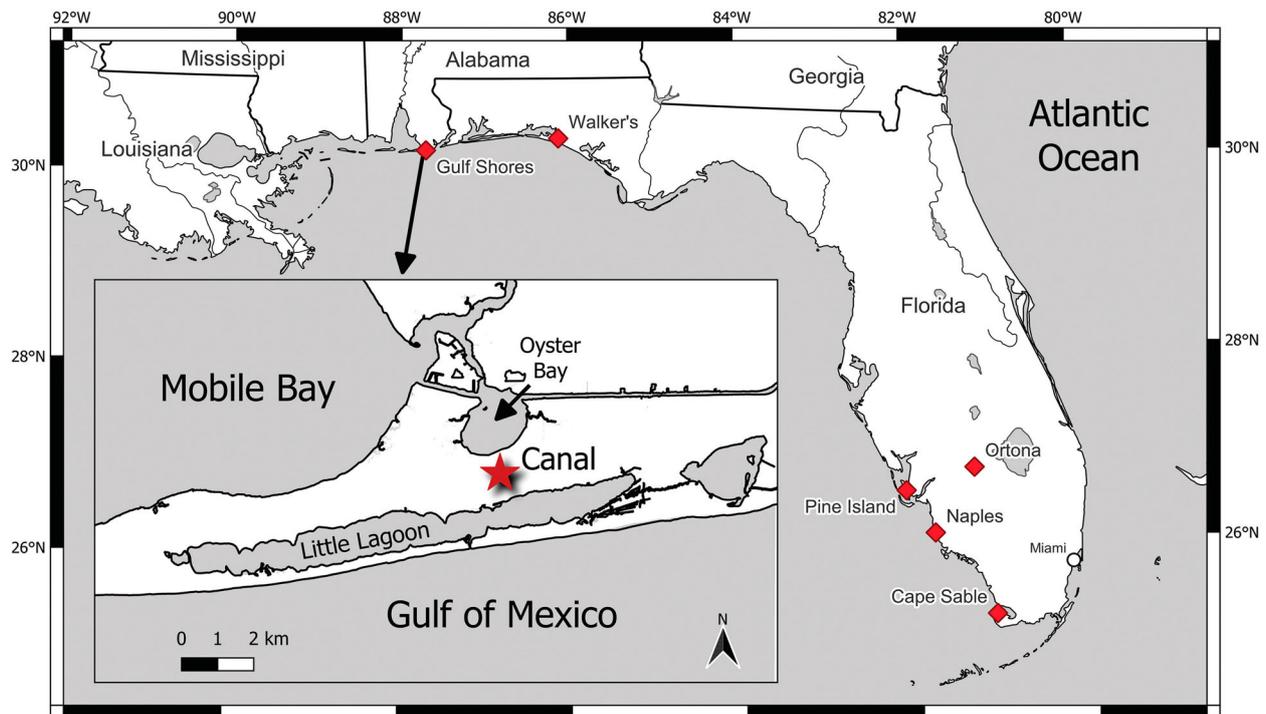
One form of canoe canal found in southeastern North America consists of relatively short (< 1 km long), intra-community, sea-level channels found within large mound

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**Figure 1.** Native American long-distance canals in Florida and Alabama, USA (D. Beebe, University of South Alabama).

sites in coastal peninsular Florida. The Grand Canal that bisects Mound Key (8LL2) and a similar community-centered great canal at Big Mound Key (8CH10), both on the Gulf of Mexico coast, are the best-known canals of this type (Cushing 1896, 329–347; Marquardt and Walker 2013, 847–857; Thompson et al. 2020, 8375).

There is another distinct form of artificial waterway represented by at least six longer and more complex canals, heretofore known only from Florida (Carr, Dickel, and Masson 1995; Douglass 1885; Luer 1989, 1998; Wheeler 1995, 1998a, 1998b) (Figure 1). Each of these specialized canals had a length exceeding 1 km, on a route engineered to enable seasonal canoe travel from one body of water to another, across a topographic divide meters higher than the canal's entrances.

While long canals share some design characteristics, they differ in their relationships to specific landscapes. Most are inter-estuarine and coastal, although one connects bodies of freshwater far inland. Some writers have suggested they functioned as inter-village canals (Luer 1989; Marquardt and Walker 2013, 881), but several exceptions lack contemporaneous settlements at both ends. All appear to traverse watershed boundaries. However, in places along the Gulf coast with sandy soils, where precipitation infiltrates the ground quickly and surface drainages are poorly developed, most drainage and flow occur subsurface, so topographic divides do not, strictly speaking, delimit watersheds in these environments. Consequently, terms such as inter-watershed, inter-estuarine, and intra-coastal are inappropriate as general descriptors. We refer to them simply as long-distance canals (*sensu* Wheeler 1998a, 15; 2005, 4).

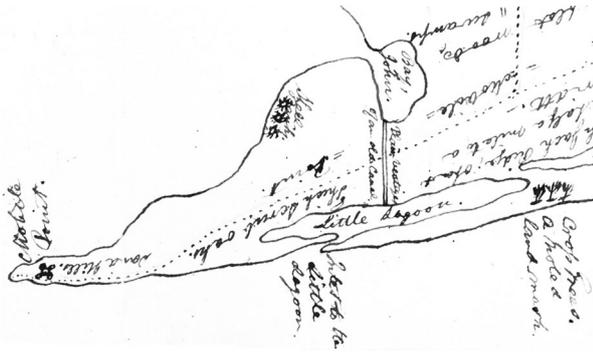
Canals have long been reported in Florida (Cushing 1896, 342–348; Douglass 1885; Kenworthy 1883; Small 1924, 83), although scientific studies have appeared only recently. The six Florida long-distance canoe canals include Walker's Canal (8WL344) in the Florida panhandle and the Pine Island (8LL34), Naples (8CR59), Ortona (8GL4A/B), and

Cape Sable canals—Mud Lake (8MO32) and Snake Bight (8MO29)—in southwestern Florida.

All six Florida canals connected substantial bodies of water and crossed intervening landforms ranging from 2–6 m above mean sea level (AMSL). None were dug deep enough along their entire length to function as level-water canals. Instead, each one depended for navigability on a seasonally high water table. They ranged from 1.2–6.9 km in length, with beds 3.0–8.8 m wide and 0.6–2.4 m deep. Excavations in four revealed canal beds with abruptly sloping sides, two with flat bottoms and two with V-shaped central channels. Luer and Wheeler (1997, 122–124) have argued that sections of canals with steep gradients had dams and impoundments at intervals to maintain enough water for navigability, although this is still unconfirmed by archaeology. They described the Pine Island Canal as “an engineered waterway... not a simple or casually dug ‘ditch.’ Careful planning went into its placement on the landscape and intensive effort went into its construction and maintenance” (Luer and Wheeler 1997, 130). That assessment applies equally to the Alabama example and to the other Florida canals.

### “Discovering” the Gulf Shores Long-Distance Canoe Canal

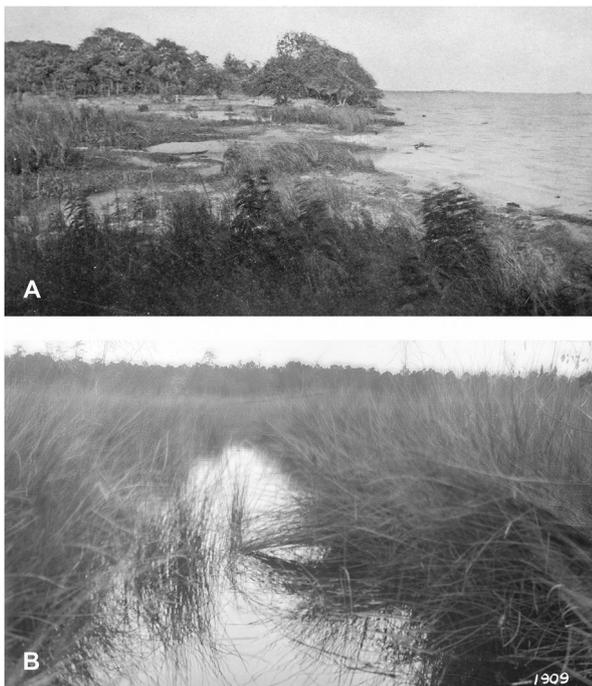
Earliest documentation of an ancient canal on the Alabama coast appeared in an 1828 report to Congress by Captain Daniel Burch (Carter 1958, 1042). General Thomas Jessup, US Army Quartermaster General, had dispatched Burch two years earlier to scout promising routes for road and canal enhancements to transportation around the north-central Gulf coast. To his surprise, Burch learned of a canal that once linked Oyster Bay (then called Bay John), an estuary of Mobile Bay, to Little Lagoon on the Gulf coast. A sketch map appended to his report notes “Plain vestiges of an old canal” crossing Fort Morgan peninsula (Figure 2).



**Figure 2.** “Plain vestiges of an old canal” connecting Bay John and Little Lagoon (Burch 1828, National Archives and Records Administration).

“This canal,” Burch informed Jessup, “has never to my knowledge been spoken of before.” Because “old residents of the Country” knew nothing of its origin, Burch guessed it pre-dated “the present race of white Inhabitants” (Carter 1958, 1042), thereby acknowledging the mysterious canal’s function and antiquity, without explicitly crediting Native Americans with its construction. “The timber has grown up in it as large as elsewhere,” Burch observed, “and where it passed across the Black Jack Ridge, the sand has nearly filled it up, though it is very plain even there; in the Marsh on the Margin of the Bay John, it is more plain; and in the Hammock on the margin of the Lagoon it is some five or six feet in depth” (Carter 1958, 1042).

Antiquarian interest in the old canal included a story published in a Spring Hill College student magazine in 1899, with a photograph of the canal’s southern end looking much as it does today (Villamil 1899) (Figure 3A). In the 1930s, Walter B. Jones, Alabama’s State Geologist, also documented the canal (Jones 1934, 1935), which he considered “quite well preserved” at both extremities, in Oyster Bay



**Figure 3.** A) “Entrance to Indian Canal from Little Lagoon,” visible mid-frame (Villamil 1899, 71); B) “near the north terminus of the canal” in Oyster Bay marsh, 1934 (photograph 3A-1909, Walter B. Jones Collection, University of Alabama Museums, Tuscaloosa).

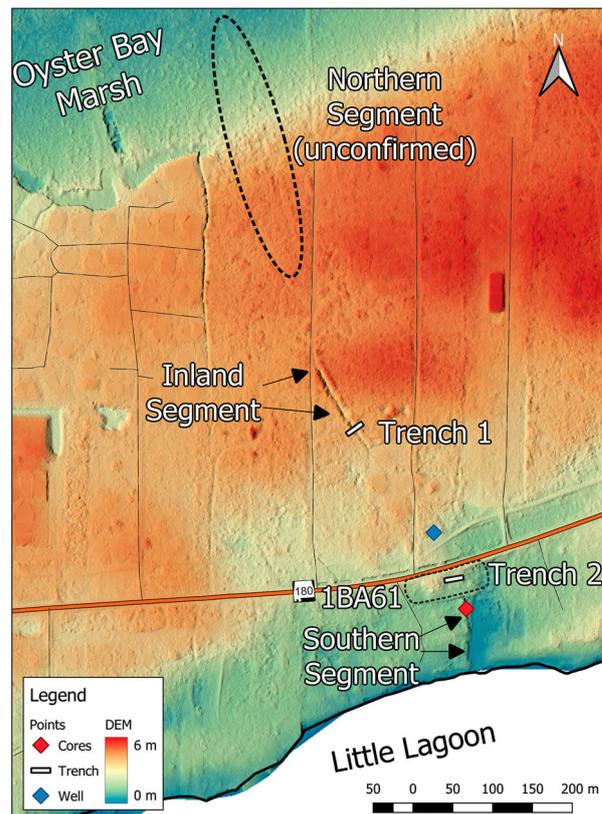
marsh to the north (Figure 3B) and at its intersection with Little Lagoon to the south, although “drifting sands have completely obliterated the middle portion” (Jones 1939, 4).

Longtime residents of Gulf Shores recall how Fort Morgan Road once crossed a feature known locally as the “Indian Ditch,” until that section of canal was leveled by mid-20th century road realignment. Since the 1950s, construction of private homes and unimproved roads has further obscured the canal’s path across the peninsula.

### Field Investigations

Our study of the Gulf Shores canal began in 2017 at the prompting of Gulf Shores resident Harry King, who has long led efforts to raise public awareness of the canal and protect its remaining segments. From an estimated original 1.39 km length, only two segments are readily apparent: a 95 m long section at the canal’s southern end on Little Lagoon and an inland segment 118 m long; the canal comprises site 1BA709. A 7 dm resolution digital elevation model (8.2 cm vertical accuracy), constructed from 2017 lidar data, depicts those two segments of the canal, along with an unconfirmed northern segment leading into Oyster Bay, and site 1BA61 on two small midden-topped relict sand dunes, straddling the canal (Figure 4). Our fieldwork has focused on the two well-preserved canal segments, presently 9 m wide (between outer berm edges) and up to 1 m deep, and on site 1BA61. Investigations included a geophysical survey of the area between the two visible canal segments, geoprobe coring, two hand-dug trenches across the canal, and test excavations at 1BA61.

Geophysical survey thus far has not provided subsurface evidence of the canal. The area between the two extant



**Figure 4.** Digital elevation model illustrating visible canal depressions and fieldwork locations (D. Beebe, University of South Alabama).

canal segments is crisscrossed by modern buried utilities—including a high-pressure gas pipeline and a sewer main serving the Little Lagoon community—that render magnetic gradiometry ineffective. A survey team from the University of Mississippi's Center for Archaeological Research, using a GSSI SIR-3000 ground penetrating radar with 400 MHz and 270 MHz antennas, easily detected radar anomalies from the buried utility lines and the shallow shell midden deposits in 1BA61 but failed to detect anomalies where subsequent excavation pinpointed low-contrast soil-on-soil canal features.

Two 1 m wide trenches have been hand excavated across the canal. Trench 1 exposed a 9.5 m profile of the canal's interior segment, and Trench 2 uncovered the western edge of the canal within site 1BA61, where the canal's remains have been truncated by the modern sewer main.

### Canal Soils and Sediments

Geoarchaeological investigation focused on the two well-preserved canal segments. On-site field examination was followed by laboratory analysis of sediment cores sampled across the southern canal segment. Descriptions of sedimentary deposits, buried soils and surfaces, and cultural horizons follow standard terminology outlined by the Soil Science Division Staff (SSDS 1993) and Birkeland (1999). Soil horizon delineations follow SSDS (1993) nomenclature: A (surface horizon), B (zone of illuviation), and C (unmodified sedimentary material).

Field investigation confirmed the two segments are part of a single linear feature, a canal. Morphological characteristics (i.e., relative depth, angle of canal sides, linearity, and presence of berms) are consistent within each segment and between segments, although heavily weathered and densely vegetated in places. Similarities in form within and between individual segments are supported by stratigraphic examinations.

Sediment cores were taken from the southern canal segment at a point 80 m north of the canal mouth on Little

Lagoon (Supplemental Material 1). A Geoprobe hydraulic corer, using 6.35 cm diameter acetate liners, reached depths of 2.45 m below ground surface. Figure 5 illustrates the soil and sediment stratigraphy revealed in cores collected from the canal's western berm (Core 2) and across the canal bed (Cores 3–5). Particle size analysis results are illustrated in Figure 6.

At the base of the berm in Core 2 is a moderately developed soil horizon, 3Ab, formed within sand-rich subsoil (horizon 3C). Grain size distribution within 3Ab and 3C is dominated by fine to coarse sand; a small increase in silt within 3Ab represents soil formation in the sand-rich matrix. Overlying horizon 3Ab is horizon 2C, a thin layer of mottled dark grayish brown sand, the dark color and mottled nature of which suggest that 2C represents redeposited soil removed during construction of the canal and placed along the margin to form the base of the berm.

Overlying 2C is horizon C, a massive layer of white sand with grain size and color resembling the basal subsoil, horizon 3C, and likely representing subsoil removed during canal construction to form the berm. Although horizon C is a massive layer with no internal stratification, grain size distribution contains variable concentrations of fine, medium, and coarse sand corresponding to isolated peds of redeposited subsoil identified throughout the sandy matrix of horizon C. Preservation of intact yet disorganized subsoil peds of varying stages of soil development, coupled with placement immediately outside the excavated feature atop a buried surface, suggests horizon C is an anthropogenic mix of subsoil collected at varying depths across the canal path and not a natural (storm) deposit. The latter are massive and coarse in terms of grain size, due to the high water velocity that characterizes storm events, and are unlikely to contain complete peds of entrained deep subsoil (Brill et al. 2016). A well-developed A horizon and two mature subsoil horizons, B1 and B2, formed at the surface of this sand layer, consist predominantly of medium and coarse sand. Silt concentration is relatively high in horizon A but

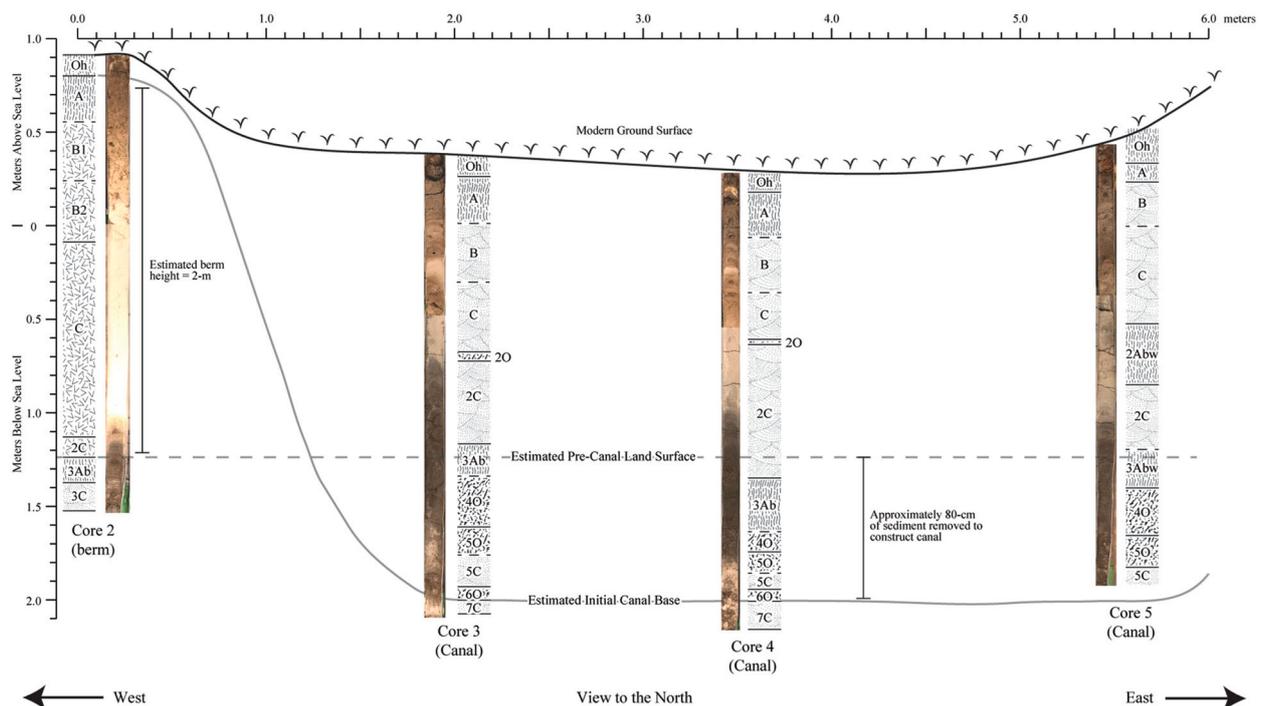
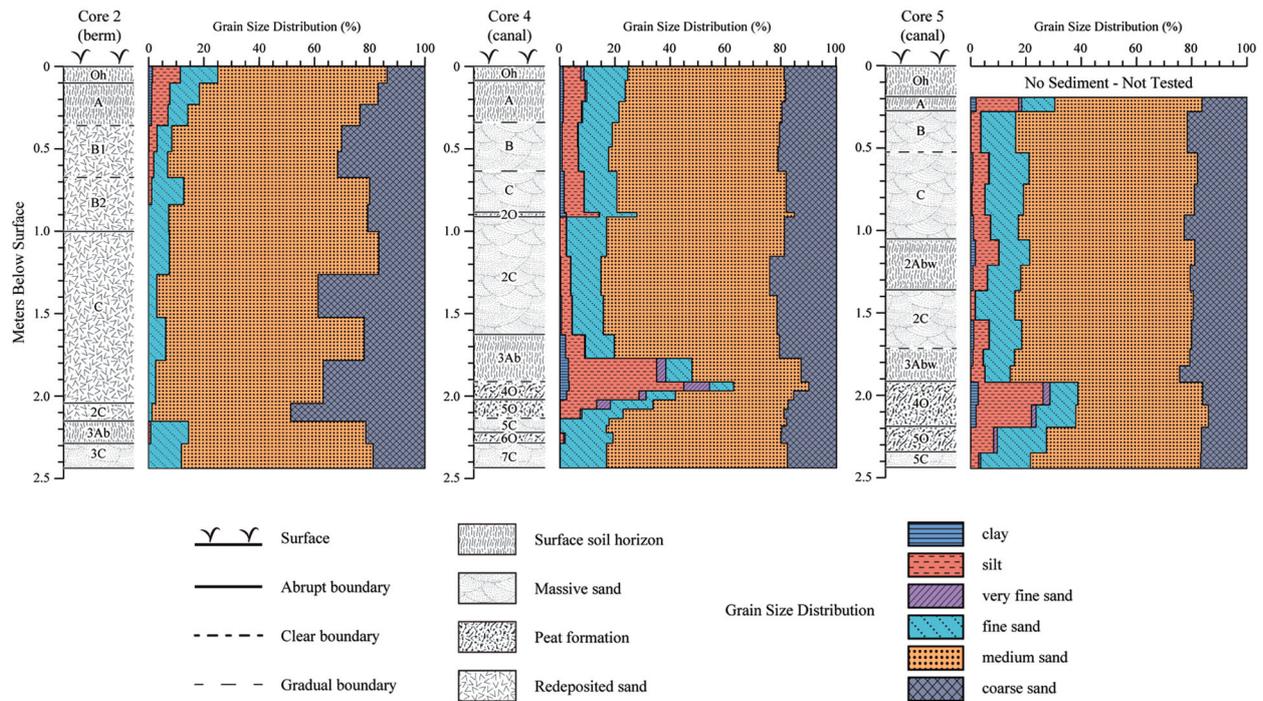


Figure 5. Southern canal segment stratigraphic cross-section from sediment cores (H. Cyr, GeoArch Solutions).



**Figure 6.** Grain size distributions for Cores 2, 4, and 5. Vertical scale in meters below surface (H. Cyr, GeoArch Solutions).

decreases down the profile, representing natural soil formation processes and long-term in situ weathering of the redeposited subsoil making up horizon C.

Stratigraphies within Cores 3–5, collected within the canal, are very similar. The basal stratum, horizon 7C, consists of light gray sand with faint manganese and iron oxide staining. Grain size distributions consist of fine to coarse sand comparable to the basal sand of berm Core 2. This suggests the basal sand in the canal cores represents subsoil truncated by canal construction. Abruptly overlying 7C is a series of organic-rich peat deposits (horizons 4O, 5O, and 6O), separated by thin light gray sand layers, that represent vegetation growth within the seasonally inundated canal bottom, likely post-dating canal abandonment. Manganese and iron oxide surface coatings indicate seasonal fluctuations of the water table consistent with mesic soil conditions. Grain size distributions within the peat layers illustrate a sharp increase in silt and clay (both absent in 7C) consistent with mesic soil development. Fine to coarse sand within the organic matrix and the interspersed sand layers may represent sheetwash transport of coarse material from the berm but may also reflect introduction of wind-blown or overwash sand during strong storm events.

The organic-rich peat horizons in the inundated canal base are overlain by wet meadow soil, horizons 3Ab and 3Abw, consisting of black sand with weak subangular blocky soil structure and a high concentration of silt consistent with active soil development and surface vegetation. Up profile, however, silt concentrations decrease as medium sand increases. The change from active peat formation to weak soil development may indicate reduction in soil moisture over time. However, the diffuse nature and increased grain size suggest that horizons 3Ab and 3Abw represent cumulic soil formation during a time of increased storm activity and windblown or overwash deposition. Increased storm-driven deposition would likely have disrupted vegetation communities growing in the inundated canal bottom. Accumulated

sediment would have raised the ground surface in the canal above fluctuating water levels, effectively reducing soil moisture.

Horizons 3Ab–4O–5O–5C together reflect natural infilling and vegetation growth within the excavated canal bed. Since the surface of horizon 3Ab in Cores 3, 4, and 5 approaches the pre-canal land surface, the accumulated material likely reflects disuse or abandonment of the canal.

Horizons 3Ab and 3Abw are overlain by a thick layer of massive brown sand, horizon 2C. Grain size distribution dominated by medium and coarse sand varies little across the stratum, which strongly suggests storm-driven deposition, not a water-borne deposit created by flooding of the tidal flat or water movement down the canal from the interior to the lagoon. A clear boundary with the underlying soil horizon, as well as internal similarity in texture, suggests that horizon 2C marks a dramatic increase in the high-energy storm activity initially responsible for cumulic horizons 3Ab and 3Abw. Horizon 2C could represent a single storm event or a series of high-energy storms, but absence of internal stratification or buried soil horizons suggests rapid deposition.

A weakly developed cumulic soil, horizon 2Abw, and a thin organic-rich peat layer of dark gray loamy sand, horizon 2O, are preserved at the surface of the 2C sand-rich matrix. Horizon 2Abw resembles horizon 3Abw and represents a reduction in storm deposition. Grain size distribution, with an increase in silt and very fine sand and a decrease in medium and coarse sand (the parent material), is consistent with long-term surface stability and soil formation within a vegetated surface.

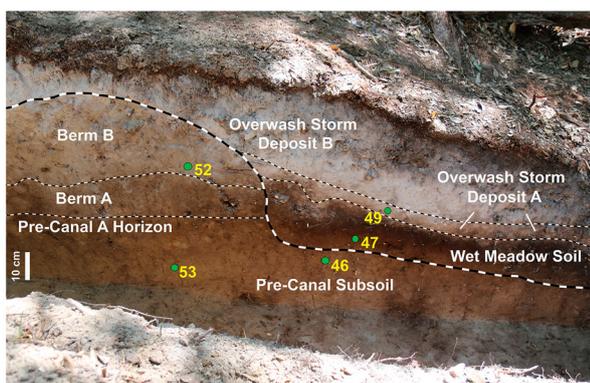
Horizon 2Abw, in Core 5 from the eastern edge of the canal bed, has a slightly higher elevation than horizon 2O in Cores 3 and 4 from deeper portions of the canal. With a reduction in storm-driven deposition, low-lying portions of the canal were likely seasonally inundated, while canal margins were relatively dry. Formation of these horizons may

mark an increase in groundwater levels associated with a rise in the nearby lagoon or simply a period of increased precipitation.

Overlying horizons 2O and 2Abw is a thick layer of massive gray sand, horizon C, consisting primarily of medium sand with moderate amounts of silt, very fine sand, and coarse sand. Horizon C shares characteristics with horizon 2C and likely represents an increase in sand deposition associated with high-energy storm events. Although lacking internal structure or buried soil horizons, the presence of silt within the sand-rich matrix may represent brief periods of surface stability associated with incipient soil development and vegetation growth undetectable in the stratigraphy. This suggests that horizon C represents episodic storm-driven deposition and not a single high-energy storm event. Formed at the surface of horizon C are moderately developed soil and subsoil, horizons A–B, both consisting of very dark grayish brown to dark grayish brown sand with massive soil structure. Horizons A and B represent soil formation within the modern land surface, with grain size distributions resembling the underlying parent material, horizon C, and minor increases in silt and clay consistent with *in situ* soil weathering.

The modern surface soils above the canal bed, with immature soil structure and weakly developed subsoil horizons A–B, are less developed than berm surface soils (horizons A–B1–B2 in Core 2), which have mature soil structure and stratified illuvial horizons. Soil forming at the berm surface is considerably older (and, hence, the berm is older) than the soil forming at the modern-day surface of the canal. The difference in relative ages of the two soils supports an ancient origin for the canal. If canal and berms were attributable to historically recent construction, one would expect canal and berm to exhibit similarly aged surface soil horizons, since both would have developed within the past couple of centuries.

Cores 2–5 provide a canal cross-section that enables an estimate of the canal's original vertical dimensions in that location near its southern mouth (see Figure 5). Using horizon 3Ab within Core 2 as the pre-canal land surface, approximately 80 cm of sandy soil was excavated to create the canal. The berm stood approximately 2 m above the original ground surface in that spot. Note the surface of horizon 3Ab/3Abw is approximately 1.2 m below present-day mean sea level, indicating the effective extent of sea level rise since canal construction. Since cessation of use, the canal in this location has infilled with approximately 2.4 m of sediment.



**Figure 7.** Eastern end of Trench 1, south profile, inland canal segment stratigraphy and locations of OSL samples (abbreviated with the last two digits; see Table 2); heavy dashed line indicates canal surface (S. Mattics, University of South Alabama).

Soil stratigraphy observed in Trench 1, excavated across the inland canal segment (Figure 7), exhibited the same characteristics seen in the sediment cores taken from the southern canal segment. Builders of the canal dug into the sand-rich tan surface soil (Pre-Canal A Horizon) and piled that topsoil along the canal's margins to create a low berm (Berm A), redeposited A horizon. As they dug deeper, they created a second berm layer (Berm B) consisting entirely of subsoil sand. Although one might suppose Berm B resulted from seasonal cleaning of the canal bed, the massive nature of the layer and its similarity to the deeper subsoil argue for its origin (at least at this location) during initial canal construction, not from canal maintenance. While the nature of the berm in this canal transect and the unconformity of the infilling sediments above the canal base seen in Cores 3 and 4 argue against canal maintenance after construction, these few observations are insufficient to discount continued maintenance on a feature more than a kilometer in length.

Wet meadow soil eventually formed from plant growth in the seasonally inundated canal bed, probably after canal abandonment. Above the wet meadow soil is a thin layer of sand that could have originated from the berm, transported downslope as sheetwash (overland flow) during periods of extreme rainfall or as overwash deposit (Overwash Storm Deposit A) from a major hurricane. Overlying both the berm sand and the sand atop the wet meadow soil within the canal is a thicker layer of white sand resulting from overwash (Overwash Storm Deposit B). In the memory of lifelong residents, this location 0.35 km inland from Little Lagoon has never been overtopped by storm surge; these storm deposits atop the inland canal segment represent exceptional storm events, such as Liu and Fearn (1993) documented in cores from nearby Lake Shelby that fall into the canal's timeframe: one ca. 1400 B.P. and another ca. 800 B.P.

## Dating Canal Construction and Abandonment

A small suite of AMS radiocarbon dates (Table 1) is available from the Gulf Shores canal and site 1BA61, a shell midden occupying relict sand dunes on each side of the canal near its southern end. Ceramics from 1BA61 are classified as Santa Rosa series (including Franklin Plain, Alligator Bayou Stamped, Basin Bayou Stamped, and Swift Creek Complicated Stamped), contemporary with the Marksville series to the west and the Swift Creek series to the east, and assigned to the late Porter phase of the late Middle Woodland period. Plash Island (1BA134), the largest Middle Woodland village site in the area, at the entrance to Oyster Bay 2.5 km north of the canal, has late Porter phase features with a pooled radiocarbon range of CAL A.D. 574–642 (Price 2008, 14, 127–128, 155–156). Residents of Plash Island were likely responsible for both the canal and site 1BA61, which functioned as a fish and shellfish processing camp (Reitz et al. 2021, 150). Recovery of two small sherds of Franklin Plain pottery from the base of the canal bed in Trench 2, next to the western portion of site 1BA61, provided additional confirmation of a Porter phase date of canal construction and use.

Three nearly identical radiocarbon dates—two from 1BA61 and one from the canal—place both site and canal late in the Porter phase of the late Middle Woodland period, CAL A.D. 576–650 (see Figures 7, 8). The samples from Zone 7 and the base of the midden at 1BA61 date inception of

**Table 1.** Radiocarbon-dated samples from the Gulf Shores canal (1BA709) and site 1BA61.

Site	Lab Number	Site Context	Material	$^{14}\text{C} \pm \sigma$ Yrs B.P.	$\delta^{13}\text{C}$ ‰	CAL B.C./ A.D. Yrs $\pm$ 2 $\sigma^*$
1BA709	Beta-464662	Trench 1, base of berm, redeposited A horizon	Wood charcoal	1440 $\pm$ 30	-27.3	CAL A.D. 576–654
	UGAMS-38549	Trench 1, post-canal wet meadow soil	Wood charcoal	4290 $\pm$ 25	-24.63	3003–2926 CAL B.C.
1BA61	UGAMS-37838	FS62, Zone 3 (40–53 cm below surface)	Carbonized hickory ( <i>Carya</i> sp.) nutshell	5520 $\pm$ 25	-25.38	4445–4406 CAL B.C.
	UGAMS-37839	FS66, Zone 7 (96–136 cm below surface)	Carbonized hickory ( <i>Carya</i> sp.) nutshell	1440 $\pm$ 20	-25.88	CAL A.D. 594–650
	UGAMS-37840	FS68, base of midden (136–150 cm below surface)	Carbonized hickory ( <i>Carya</i> sp.) nutshell	1440 $\pm$ 20	-27.12	CAL A.D. 594–650

\*Calibrated with IntCal20 (Reimer et al. 2020) using OxCal v. 4.4 (Bronk Ramsey 2009)

midden accumulation. An Archaic-period carbonized nutshell from the upper stratum at 1BA61 is out of stratigraphic sequence and cannot be in primary depositional context. Zooarchaeological analysis of the shells from this small midden, atop two relict dunes, give every indication that the site served as a shellfish and fishing processing camp; there is no evidence for redeposition of older midden for construction purposes. We suspect the carbonized nutshell derives from elsewhere, perhaps carried onto the shell midden in mud clinging to harvested oyster valves.

The late Middle Woodland sample from the canal consisted of wood charcoal taken from the base of the canal berm. Since the sample derived from the surface of the pre-canal A horizon, it provides a terminus post quem, a date after which the canal was constructed. Since forest clearance must have preceded canal construction, we suspect this charcoal resulted from fire-assisted clearing. Paleoecological literature on Indigenous uses of fire for landscape modification in southeastern North America documents analogous pre-contact forest clearance, such as for gardens and fields, as well as preparatory burning of pre-mound construction surfaces as early as the Late Archaic (Mehta 2019; Sherwood and Kidder 2011, 74, fig. 4).

A carbonized wood sample from the Gulf Shores canal's wet meadow soil yielded another Late Archaic date, far older than the canal. Both incongruous radiocarbon samples are out of stratigraphic sequence and reflect a dynamic depositional environment subject to anthropogenic sediment transport and high-energy storm events. A source for both Archaic plant samples could be a submerged Archaic occupation site in Little Lagoon, immediately south of the canal. There are no terrestrial archaeological sites predating 4100 B.P. on the Alabama coast (Holmes and Trickey 1974, 122; Morgan 2016, 135), due to coastal subsidence and sea level rise, but sites are likely present along drowned tributaries, such as Little Lagoon.

The challenge of dating the canal's abandonment led us to collect five sand samples from the Trench 1 canal profile (see Figure 7) for optically stimulated luminescence (OSL) analysis at the Netherlands Centre for Luminescence Dating, Wageningen University. Luminescence analyses were conducted following standard procedures to isolate and measure quartz sand (see Chamberlain et al. 2020 and Supplemental Material 2 for analytical details).

Summary OSL ages are presented in Table 2. Errors indicate 1-sigma (68%) uncertainty, including all systematic and random uncertainties in both paleodose and dose rate estimation. Results indicate two sets of deposits: older material underlying the canal returned ages in the 1-sigma range of 4.13–6.39 kya (4370–2110 B.C.); younger material associated with canal construction and infilling returned ages in the 1-sigma range of 1.92–3.04 kya (1020 B.C.– A.D. 100).

Samples NCL-7420053 and NCL-7420046, from soil identified as “Pre-Canal A Horizon,” are among the oldest, with OSL ages that agree within 2-sigma uncertainty. Sample NCL-7420047, from the wet meadow soil deposit in the canal bed, also dates within this range, which is implausible for the date of canal abandonment. We suspect slumping on the sides of the canal delivered A horizon sediments to the canal bed without opportunity for light exposure. In other words, sample NCL-7420047 also dates pre-canal natural deposits. A weighted mean of those three oldest samples gives an age of  $5.26 \pm 0.28$  kya (3520–2960 B.C.), a credible date for local Holocene relict dune ridge formation (Bellais et al. 2020) and consistent with our soils interpretation. The canal thus represents human modification of a relatively stable and mature coastal landform, which suggests that canal-building was not just a minor component of ongoing natural change in the coastal landscape. Rather, Indigenous people made a primary contribution to shaping their surroundings during the interval of canal construction, underscoring



**Figure 8.** 1BA61, composite north profile of Units 1–2 (4 m wide) with stratigraphic locations of radiocarbon samples (abbreviated with the last two digits; see Table 1) from shell midden deposits (G. Waselkov, University of South Alabama).

**Table 2.** Summary of OSL Dating Results.

NCL Sample Code	Sample Depth (m)	Paleodose (Gy)	Dose Rate (Gy/ka)	Age Relative to 2020 (ka)	Age (B.C./A.D.)
NCL-7420052	0.40	1.64 ± 0.18	0.60 ± 0.02	2.72 ± 0.32	1020–380 B.C.
NCL-7420049	0.55	1.37 ± 0.14	0.63 ± 0.03	2.16 ± 0.24	380 B.C.–A.D. 100
NCL-7420047	0.65	3.42 ± 0.18	0.66 ± 0.03	5.20 ± 0.39	3570–2790 B.C.
NCL-7420046	0.70	4.03 ± 0.32	0.69 ± 0.04	5.83 ± 0.56	4370–3250 B.C.
NCL-7420053	0.75	3.08 ± 0.33	0.66 ± 0.03	4.67 ± 0.54	3190–2110 B.C.

the significance of canal-building as an early form of landscape reformation in Native North America.

The berm sand sample (NCL-7420052) returned a luminescence age of  $2.72 \pm 0.32$  kya (1020–380 B.C.), which ought to correspond to canal construction. The initial storm deposit (NCL-7420049) provides a canal abandonment age of  $2.16 \pm 0.24$  kya (380 B.C.–A.D. 100), which is younger than the berm sand, as anticipated. However, both dates are far ( $> 500$  yr) older than the radiocarbon assay from beneath the berm and the AMS dates from site 1BA61 that straddles the canal near its southern end. As with the wet meadow OSL result, we again suspect incomplete resetting (heterogeneous bleaching) of these OSL signals prior to deposition. Perhaps canal construction happened rapidly enough to limit sunlight exposure. Certainly, the rapid and chaotic depositional conditions present during stochastic overwash events, such as hurricanes, are known to be less than ideal for resetting OSL dates (Brill and Tamura 2020, 715–717).

In sum, three radiocarbon dates on the canal berm and base levels of an associated shellfish and fish processing campsite provide a terminus post quem for canal construction of CAL A.D. 576–650, sometime within that date range late in the Porter phase of the late Middle Woodland period. Additional radiocarbon and OSL dates pose various interpretive challenges, similar to those encountered at the Florida long-distance canals (as discussed below). Length of canal use and date of abandonment remain uncertain.

### Hydrologic Function of the Gulf Shores Canal

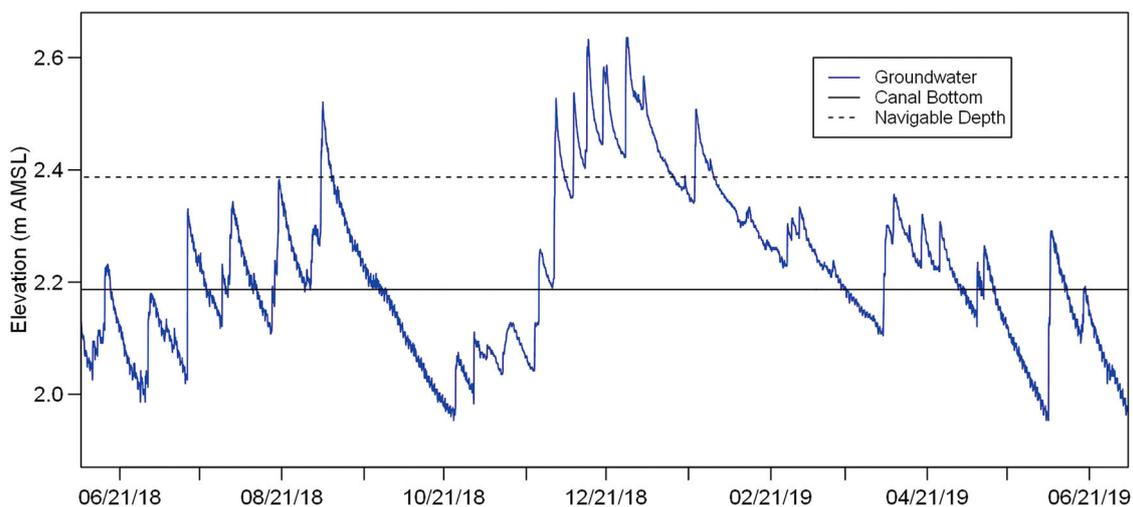
Researchers studying long-distance canals in Florida, none of which are sea level canals, have argued that their use for canoe traffic depended on seasonally high water tables (Luer 1989, 107; Luer and Wheeler 1997, 119). Determining the feasibility of canoe traffic via a canal that crosses a topographic divide depends on assessments of several key

environmental factors: the location's hydrogeology, hydrology, and precipitation patterns.

Shallow hydrogeology in this coastal region is characterized by a surficial (6–20 m thick) Beach Sand aquifer consisting of coarse-grained quartzose sands and silts with locally interbedded clays (Chandler, Moore, and Gillett 1985). Rapid infiltration through these sandy soils precludes surface runoff, and no defined surface drainage network exists in the Little Lagoon area. The Beach Sand aquifer is responsive to temporal changes in precipitation, recharge, submarine groundwater discharge, and evapotranspiration. The water table fluctuates from 1.2 m below ground surface during periods of high precipitation and recharge to as low as 5 m below ground surface during dry periods (Murgulet and Tick 2016). Along the Gulf coast, groundwater is lost through evapotranspiration, which peaks in late summer, and submarine groundwater discharge, which peaks in late winter (Beebe and Lowery 2018; Montiel et al. 2019).

To investigate the hydrologic function of the Gulf Shores canal, we took advantage of the serendipitous presence of a shallow groundwater monitoring well located adjacent to the Gulf Shores canal and between the two visible canal segments (see Figure 4; Liefer et al. 2009). Groundwater depth at the monitoring well was recorded by automated electronic pressure transducers (see Supplemental Material 3). Water table elevation data from one calendar year (June 21, 2018 to June 20, 2019) permitted derivation of empirical cumulative distribution functions (ECDFs) at annual, seasonal, and monthly time scales to investigate water depths in the two canal segments and infer canal navigability.

Over the calendar year, water table elevations in the well ranged between 1.88 and 2.64 m AMSL, with minimum elevation on October 24, 2018 and maximum on December 28, 2018 (Figure 9). At a place with average annual precipitation exceeding 165 cm (Robinson, Moreland, and Clark 1996), groundwater monitoring well data confirm that the



**Figure 9.** Water table elevations in the Gulf Shores groundwater monitoring well (D. Beebe, University of South Alabama).

water table is especially responsive to precipitation events. Several slow-moving, rain-bearing cold fronts contributed to generally higher water table elevations in cooler months, while dry periods of no precipitation contributed to lower water table elevations from late spring through early fall.

To be clear, this canal and the others known from southeastern North America are unlike irrigation canals from the pre-contact American Southwest, which had clay (or clay-lined) beds to hold and convey water. Because the berm and bottom soils of the Gulf Shores canal largely consist of fine to coarse sand (see Figures 5, 6) with efficient drainage and limited potential for water pooling, depression storage of precipitation is unlikely to have provided sufficient canal flooding for navigation, which, instead, would have depended on a seasonally high water table in the canal bed.

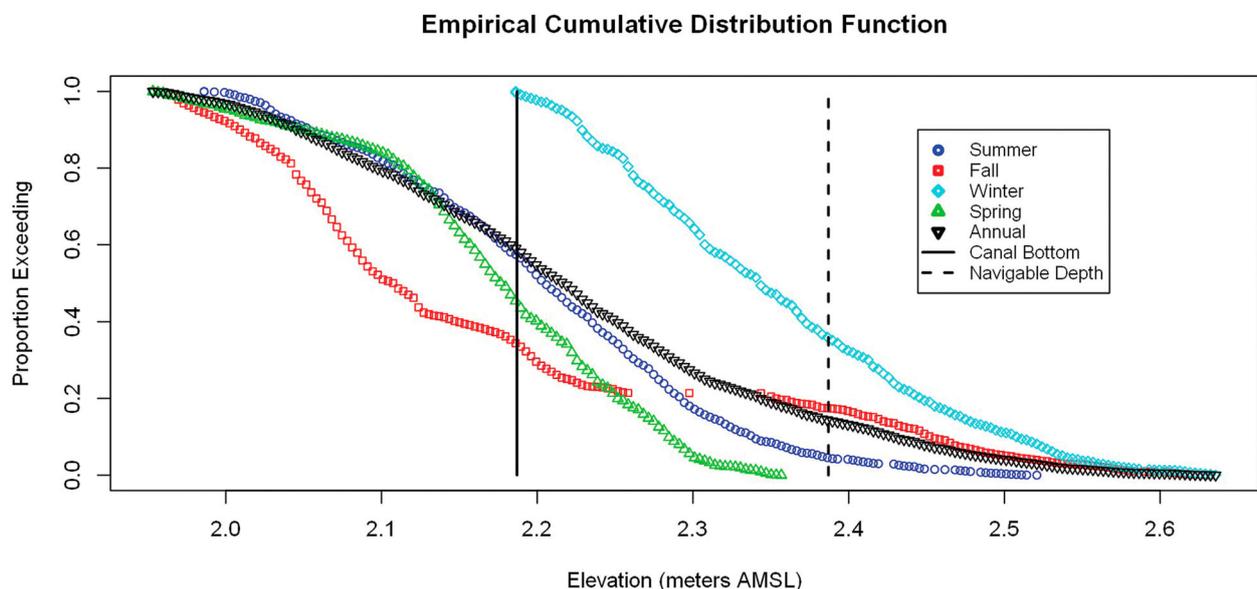
Comparisons between water table elevations at the monitoring well and surveyed canal bottom elevations reveal periods when the canal segments were submerged and demonstrate the feasibility of dugout canoe navigation. The surveyed canal bottom elevation in Trench 2, adjacent to site 1BA61, was 0.88 m AMSL, approximately 1 m below the minimum water table elevation measured at the nearby monitoring well during the calendar year. Groundwater in the vicinity of the well and surveyed canal segments flows southward towards Little Lagoon where submarine groundwater discharge is known to occur (Su et al. 2014). Therefore, the water table decreases in elevation towards Little Lagoon and is presumably lower at 1BA61 than in the well (Liu, Rich, and Zheng 2008). A simple linear interpolation between minimum water table elevation in the well and the surface water elevation of Little Lagoon (0 m AMSL) suggests that the canal bottom at 1BA61 remained more than 0.5 m below the water table all year.

To assess canal navigability, we also need to estimate canoe draft. Although no Middle Woodland dugout canoes survive in the region, five Mississippian dugouts have been found in southwestern Alabama and southeastern Mississippi with gunwale heights ranging from 0.30–0.45 m (Fuller 1992). These heights are comparable to heights of 33 Archaic, Late Woodland, and Mississippian dugout canoes from Florida (Hartmann 1996, 127, 137, 155, 172).

According to one study of modern West African dugout canoes, fully loaded dugouts minimally have a 1:2 ratio between freeboard and draft (Ambrose et al. 2001). This suggests 0.20–0.30 m drafts for the five local Mississippian examples at full loads. Of course, modern notions of a full load for a dugout may differ from ancient ones, and the Mississippian canoes recovered locally may not have been designed for canal navigation. If we conservatively posit a minimum navigable water depth of 0.20 m to match the presumed draft requirements of Woodland period dugouts, the southern canal segment held sufficient water for navigation, regardless of the time of year. The same can be presumed for the northernmost segment of the canal, which Jones (1934, 1939) observed in the wetland marsh bordering Oyster Bay.

The surveyed bottom elevation of the inland canal segment was 2.18 m AMSL. Although much higher than the surveyed canal bottom elevation adjacent to site 1BA61 (0.88 m AMSL), this still falls within the range of water table elevations measured in the monitoring well (1.88 and 2.64 m AMSL). Comparisons between the annual water table elevation ECDFs, inland canal bottom elevation, and safe navigation elevation (0.20 m above the canal bottom) reveal that water table elevation for the inland portion of the canal exceeded canal bottom elevation 61% of the year and safe navigation elevation 15% of the year (Figure 10). Seasonal ECDFs indicate that winter was most likely to support navigation, with water table elevation exceeding canal bottom elevation 100% of the time and safe navigation elevation 38% of the time. All four seasons had periods when water table elevation exceeded canal bottom elevation, although navigation feasibility was much lower in summer, fall, and spring, when water table elevation exceeded safe navigation elevation 5%, 18%, and 0% of the time, respectively. These results therefore suggest the central canal segment was rarely useable except during cooler months when water table elevations were high.

Our comparisons of the inland segment do not consider the water table's slope toward Little Lagoon. Since the inland canal segment is located near the topographic divide between Little Lagoon and Oyster Bay, we expect water table elevations in that canal segment to be higher than the



**Figure 10.** Water table elevation ECDFs, indicating feasibility of canal navigability by season (D. Beebe, University of South Alabama).

water table elevations observed in our monitoring well to the south. However, a simple linear extrapolation of the water table elevation is not feasible here, because the water table elevation slope should decrease toward the divide. In any event, our estimations for canal submergence and navigation are conservative, yet still demonstrate the feasibility of seasonal canoe navigation.

These comparisons assume that water table elevations today are reflective of water table elevations in the late Middle Woodland period. However, there have been subsequent regional hydrologic and oceanographic changes, some natural and some anthropogenic in origin, including an increase in relative sea level rise, hydrologic modification of surface water bodies, and ongoing groundwater extraction from the aquifer system.

The estimated rate of relative sea level rise attributed to eustasy (and minimally to regional subsidence) in the northern Gulf of Mexico from 2000 CAL B.C.–CAL A.D. 1850 ranges from 0.4–0.6 mm a<sup>-1</sup> (Milliken, Anderson, and Rodriguez 2008; Minzoni et al. 2020). Recently, the rate of relative sea level rise has increased to approximately 4.1 mm a<sup>-1</sup> according to tidal gauge records since 1966. Long-term and recent sea level increase since the late Middle Woodland period accounts at least partially for submergence of the canal's northernmost segment in the Oyster Bay marsh and for the presence of the pre-canal ground surface 1.2 m below mean sea level near the canal's southern terminus at Little Lagoon, as observed in Core 2. This increase in relative sea level also contributes to an increase in coastal water table elevation, an effect known as groundwater shoaling (Befus et al. 2020). Conservatively estimating water table elevation during the late Middle Woodland period at (maximally) 120 cm below the present-day level, the inland segment of the canal would not allow navigation, or even reach below water table elevation. However, this estimate assumes that rising relative sea level was not accompanied by any hydrologic responses to heightened water table elevation (May 2020). With increased relative sea level and groundwater shoaling comes a decrease in aquifer recharge, leading to some negative feedback to water table elevation increase. For example, as the sea invades inland during relative sea level rise, the area of exposed land to support groundwater recharge decreases. Furthermore, groundwater shoaling causes the water table to approach the land surface in low-lying coastal areas, decreasing capacity for infiltration and groundwater recharge and instead increasing saturation excess runoff (Nuttle and Portnoy 1992). These hydrologic responses to groundwater shoaling limit the water table elevation increase to less than the relative sea level rise.

In addition, recent anthropogenic modifications to the hydrology surrounding the canal have altered groundwater hydrology and likely affected water table elevation. Modern commercial, agricultural, and residential development in the region has brought increased demand for water resources, especially fresh groundwater. Irrigation and domestic water supply wells extract groundwater east and west of the canal; increasing reliance on groundwater has resulted in saltwater intrusion and water table elevation declines in the subsurface aquifer system (Liu, Rich, and Zheng 2008). Construction in 1934 of the Intracoastal Waterway, which bisects the northern end of Oyster Bay, created a major groundwater sink in the region, increased saltwater intrusion, and

separated the surficial aquifer surrounding the canal from upland groundwater recharge (Murgulet and Tick 2016).

Furthermore, stabilization in 1981 of an inlet connecting Little Lagoon to the Gulf of Mexico permanently fixed the lagoon's surface water elevation to sea level. Prior to that engineered intervention, Little Lagoon functioned as a coastal dune lake and cycled through periods of intermittent connection to the Gulf of Mexico as natural inlets opened temporarily following storm events, then closed due to infilling from coastal processes (Bellais et al. 2020; Gibson, Campbell, and Kennedy 2009). As a coastal dune lake, surface water elevations rose during periods of closure and caused groundwater shoaling. In the summer of 2010, the stabilized inlet was temporarily filled with sand for two months to prevent oil spilling from the Deepwater Horizon offshore well from entering Little Lagoon (Su et al. 2014). During those two months, surface water elevation in the Lagoon rose by approximately 20 cm and groundwater discharge decreased, indicating increased storage in the surficial aquifer and a rise in water table elevation. The net effect of these changes, natural and anthropogenic, is difficult to resolve. However, seasonal trends should remain consistent, as the hydrology of the area and water table elevations in the region are largely governed by the balance of rate of evapotranspiration, which peaks in summer and is lowest in winter.

Luer and Wheeler (1997) reached a similar conclusion about Florida long-distance canals: a narrow seasonal window of navigability would have seriously limited their utility. As they pointed out, this conclusion rests on the assumption that these canals were simply open channels that allowed groundwater to flow unimpeded to their ends, leaving water levels in the middle portions of canals too low to support canoe traffic for most of each year. They argued, instead, that inland sections of canals, especially sections with steep gradients, must have been impounded by dams to maintain water sufficient for navigability (Luer and Wheeler 1997, 117–119; Luer 1998, 33; Wheeler 1998b, 177–178; 2005, 16–17). Luer and Wheeler have pointed to “inflection points or anomalies” in the Pine Island, Naples, and Walker's canals—discontinuities in otherwise straight canal courses—as evidence for the existence of dams. Those inflection points coincide with changes in canal slope, locations where a dam would effectively impound water in a steeply-sloped canal section that otherwise would hold little or no water in the dry season (Luer and Wheeler 1997, 122–124, 127; Wheeler 1998b).

To date, no canal dams have been confirmed by archaeology, but several 19th century A.D. observers noted upright posts visible in the Naples and Pine Island canals (Kolianos and Weisman 2005, 102; Luer 1998, 35, n. 8; Wheeler 2005, 16–17). In 1895, Frank Hamilton Cushing remarked on “remains of posts or small logs” at a channel junction of the Pine Island Canal, “which seemed to be fragments of piles ... they were certainly artificial” (Kolianos and Weisman 2005, 66 [quote], 249, n. 34).

Dams would have been essential to maximize water elevation year-round in the Gulf Shores canal. Without them, groundwater would run to the lowest elevation waterbodies, Little Lagoon and Oyster Bay, and the canal would have lowered the proximal water table. An open-ended canal would function like a horizontal well, a conduit draining groundwater to the sea. Without impoundments, there would

at first be some tidal exchange and scouring in parts of the canal and shoaling in others. The modern local analogue is Little Lagoon Pass, which is constantly filling with sand. Dams would have limited shoaling at the canal mouths, which otherwise would have necessitated routine clearing.

In the currently traceable portion of the Gulf Shores canal, there is one discontinuity in the canal's path that may correspond to a dam location. From its southern mouth at Little Lagoon, the canal followed a north-south course as far north as Fort Morgan Road, where our Trench 2 intercepted a remnant of the canal between the two midden-covered sand dunes comprising site 1BA61. The canal's inland segment, by contrast, follows a northwest-southeast course. Extending the course of the inland segment on a southeast bearing intersects with the north-south segment approximately at Trench 2. If a dam interrupted the canal at that abrupt turn in its course, evidence of a water control structure may still exist in this vicinity.

### Implications of the Gulf Shores Canal Study

Confirmation of the Gulf Shores feature as a long-distance canoe canal expands the small corpus of known examples in southeastern North America to seven and raises a question: are ancient canoe canals more numerous and more widely distributed than previously thought? Perhaps others will be found (e.g., Bigelow 1853, 191) if we look beyond their apparent epicenter in southwestern Florida. And what more can be learned about the few known examples?

Prior radiocarbon dating of samples from Florida canals, all from canal beds and therefore presumably post-dating canal use, yielded a wide timespan, from  $1880 \pm 50$  years B.P. (CAL A.D. 23–250, 295–310) at Ortona (Carr, Zamanillo, and Pepe 2002, 16–21) to  $590 \pm 40$  years B.P. (CAL A.D. 1300–1420) at Snake Bight (Ferik 2003, 58–60). We opted not to radiocarbon date uncarbonized organics in the Gulf Shores canal's "wet meadow soil," because such near-surface contexts routinely yield misleadingly young radiocarbon dates due to intrusion of visually indistinguishable recent rootlets (e.g., Shore, Bartley, and Harkness 1995). And, as we have seen, a canal bed can contain overwash deposited materials unrelated to, and potentially much older than, the canal. Some of the radiocarbon dates from Florida canals probably reflect such errors.

We can confidently place construction of the Gulf Shores canal at ca. A.D. 600, based on calibrated AMS dating of the canal and an adjacent contemporaneous midden site and supported by a well-established ceramic sequence for the northern Gulf coast region. Given the uncertain construction dates of the Florida canals, resolving the origin of the Gulf Shores canal to late in the Middle Woodland period suggests it may be the oldest canoe canal in North America. However, we suspect several of the Florida canals are roughly contemporary with the Gulf Shores example (and there are much older conceptual precursors, such as the ca. 800 B.C. Great Circle ditch at Fort Center; Thompson and Pluckhahn 2012). Our study offers some methodological improvements for future canal studies, including reanalyses of the Florida canals. For instance, radiocarbon dating of charcoal sealed beneath canal berms is a more effective way to date canal construction than attempting to date canal bed sediments of uncertain origin and age. The colossal task of clearing vegetation from a long canal's proposed course through a forested environment

surely involved use of fire, followed soon afterwards by burial of freshly burned organics beneath berms.

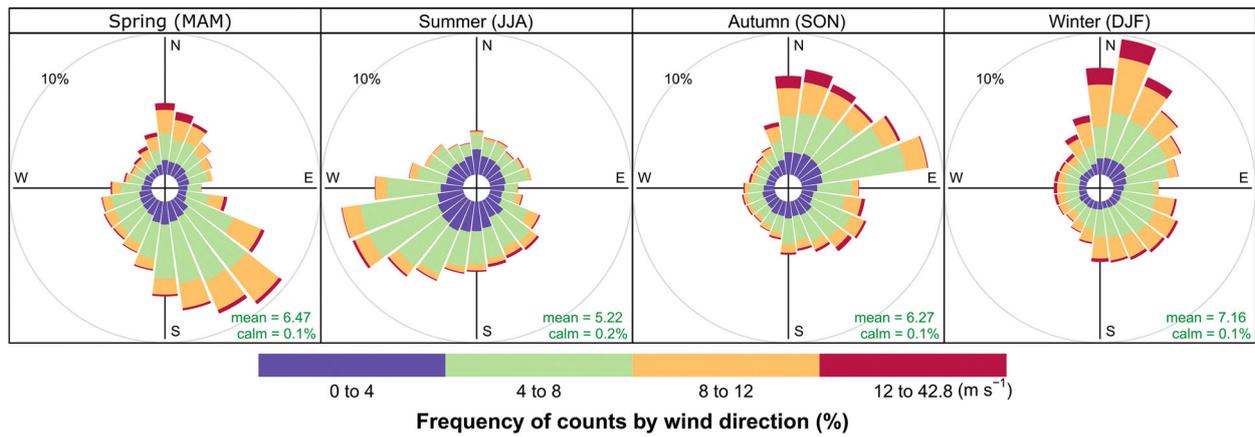
Detailed analyses of canal sediments and hydrologic function are useful complementary approaches for understanding canal structure and navigability. The Gulf Shores canal's utility (like that of the Florida canals) appears to have been strictly seasonal, reliably navigable only during wet winter months. That is, unless dams were deployed to slow outflow and extend a canal's utility into other seasons. The presence of dams on long-distance canals remains hypothetical.

We wonder if the two measured bottom elevations of the Gulf Shores canal reflect seasonal lows for the water table during the late Middle Woodland period. Digging through saturated sands would have been exceedingly difficult, as we learned when our trench excavations extended beneath the present water table. To maximize canal bed depth, initial digging to the water table presumably occurred during a dry season, summer or fall (when conditions for burning would also have been ideal). In other words, maybe seasonality limited canal construction options, as well as navigation. The canal's soil profiles (see Figures 5, 7) provide some support for dry season construction in the absence of soft sediment deformation at the base of the berm and possibly at the base of the canal itself. Relatively dry sediment was excavated and piled along the margin of the canal during initial construction.

Determining a canal's length of use and date of abandonment remains challenging, with no obvious means to resolve the problem. The Gulf Shores canal, in any case, may not have seen extended use. After sand was dug and piled rapidly en masse to form canal berms, there is no evidence of further berm accretion (albeit from our limited views of a long canal), such as one might expect if sediments accumulating in the canal bed were periodically cleaned out and added to berm tops. We tentatively propose two alternatives: either this canal was so well designed that it needed little to no maintenance or its use-life was brief. In the absence of supporting evidence, we question arguments positing centuries-long use of the structurally similar Florida canals (Luer 1989; Luer and Wheeler 2001; Marquardt and Walker 2013, 884–886).

To what purposes did the late Middle Woodland population put the Gulf Shores canal? Residents of the largest contemporary village in the area, Plash Island (1BA134), could have used it to access small camps on Little Lagoon (including 1BA61) to harvest and process high-salinity fish and shellfish, smoking and drying meat for transport to the village. Analysis of invertebrate biomass from 1BA61—28.2% from hard clam (*Mercenaria mercenaria*), 18.7% variable coquina (*Donax variabilis*), 11.9% marsh periwinkle (*Littorina irrorata*), 11.2% ribbed mussel (*Geukensia demissa*), and 7.3% Eastern oyster (*Crassostrea virginica*)—suggests how Little Lagoon's diverse habitat could have complemented dietary contributions from Plash Island's immediate locale, where oysters supplied 79.3% of the invertebrate biomass. Seasonality data from Plash Island reveal 70% of oysters were intensely harvested in the winter, when the canal was certainly navigable (Reitz et al. 2021, 140, 149, supp. table 5).

There were also long-distance coastal mobility implications to a 1.39 km canal. Access to Little Lagoon via the canal opened an extensive sheltered water path through marshes, coastal dune lakes, and back bay estuaries to Pensacola Bay and points east, enabling canoers to parallel the



**Figure 11.** Wind roses prepared using data from the NOAA Fort Morgan, AL Station (8734673, 2008–2021). Winter cold fronts produce strong (> 8 m/s) cross-shore winds and hazardous conditions for open water navigation. Winds and sea conditions are more favorable for open water navigation during the warmer months, except during infrequent tropical cyclonic activity (D. Beebe, University of South Alabama).

coast and avoid Gulf waters at least as far as Choctawhatchee Bay (location of Walker’s Canal). Closer to home, the canal made circumnavigation of the 30 km long Fort Morgan Peninsula unnecessary, thereby avoiding long and potentially dangerous canoe voyages in the open waters of Mobile Bay and the Gulf of Mexico. Indeed, the same weather fronts that raise the peninsula’s water table elevation in the winter also bring high surf conditions in the Gulf of Mexico and Mobile Bay.

In the northern Gulf of Mexico, sea conditions are largely controlled by regional winds from passing storm fronts. During winter months, when the canal was most likely to be navigable, strong cross-shore (north or south) winds associated with passing cold fronts produce dangerous conditions in open waters (Figure 11). Cold fronts, which pass through the region about every six days, generate strong southerly winds (> 8 m/s) and offshore swell in the days preceding frontal passage and strong northerly winds and inshore chop in the days afterward. Mean wave height in the Gulf of Mexico is highest in the winter because of these frequent storms (Appendini et al. 2014). The waters off Fort Morgan are especially perilous during the winter when offshore swells interact with inshore chop and tidal currents.

Northerly winds following frontal passage also result in lowered surface water levels in Mobile Bay and connected tidal waterbodies, including Oyster Bay. North winds flush water through the mouth of Mobile Bay towards the Gulf of Mexico, resulting in a lowered tide base (Huang and Li 2017). This winter effect is most noticeable during the day because the astronomical tide here is phase-locked, with low tide occurring predominately during the day. In the days following frontal passages, when strong north winds limit open water voyage and fishing, lowered water levels provide easy daytime access to the benthos, including oysters and other shellfish (Hadden et al. 2022). Because Little Lagoon lacked a stabilized inlet to the Gulf of Mexico, it was less susceptible to flushing events and provided more stable fishing opportunities. Furthermore, the small size and shallow depths of Little Lagoon limit wind fetch and wave height.

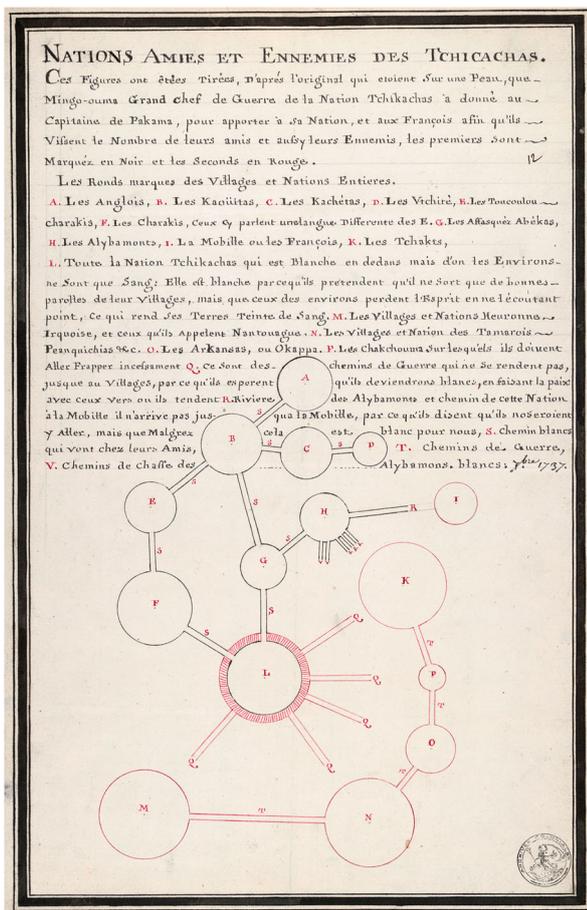
## Discussion and Conclusions

Since most of the archaeological literature on canals focuses on their applications to water management for agricultural intensification or long-distance transport by hierarchical

societies, the potential of the Gulf Shores canal to diversify and intensify the subsistence and political economies of the local (non-agricultural and non-hierarchical) Middle Woodland community is an important observation. However, would such practical or utilitarian purposes have been sufficient to justify the major effort required to modify the landscape at this scale? Labor required to accomplish canal construction may well have exceeded the capacity of immediately adjacent communities, and the long-term canal maintenance costs posited by others would have entailed enduring social obligations and interdependencies (Marquardt et al. 2022; Thompson 2016). However, we should consider whether the impressive size and complexity of canals may have led us to assume long use lives and continuing maintenance costs, implications for which we have little or no supporting evidence. Finding a method to determine their lengths of use remains an important goal.

Building long-distance canoe canals, whatever their function, constituted monumental construction. Recent studies define monumentality primarily as the outcome of large-scale community work projects that entailed architectural and engineering challenges with “attention to symbolic and ritual meaning” (Rosenswig and Burger 2012, 7; Scarre 2011, 17; Sherwood and Kidder 2011, 69 [quote], 71). Measured simply by volume of displaced soil, long-distance canals easily rivaled the largest mound structures of pre-contact southeastern North America (Blitz and Livingood 2004; Marquardt and Walker 2013, 880–881). With an estimated 10,000 m<sup>3</sup> of soils displaced during construction (based on a length of 1.39 km and average bed dimensions of 6 m wide and 1.2 m deep) through a blackjack oak forest, the Gulf Shores canal qualifies as a monumental structure by that standard. Canal-building permanently altered landscapes by creating new channels, bounded by tall earthen berms, with beds broad enough and deep enough to accommodate dugout canoe traffic. These were some of the most dramatic landscape modifications of their age. All of them presumably expedited movements of goods and people, but by their design, layout, construction, maintenance, and use, these canals also altered the relationship between land and water.

Although goods and people no doubt transited the Gulf Shores canal, this extraordinary landscape feature challenged normalcy. Through immense community effort, Indigenous people of the northern Gulf coast created their own river (cf. Brophy 2000, 66). Certainly, the engineering acumen



**Figure 12.** “Nations Friendly and Hostile to the Chickasaws,” a French re-drawing of a map by Chickasaw headman Mingo Ouma, with overland paths and the Alabama River (R) both represented by double lines (F3/290/12, 1737, Collection Moreau de Saint Méry, Archives nationales d’outre-mer, France).

essential to create a functioning canal rivaled that which informed mound construction. Although space does not permit development of this idea here, there are also many reasons to believe that earthmoving by Indigenous southeastern North Americans to create a “river” and earthmoving to build a mound involved comparable deliberations about Native cosmologies (Pauketat 2014; Scarre 2011). Given Native southeasterners’ complex beliefs in the purifying power of streams, constructing a new stream must have been undertaken with great care and respect (e.g., Hudson 1976, 324–325; Jackson 2013, 229, n. 15).

If we view a long-distance canal as a path (albeit, on water) bounded by a pair of linear earthworks, the Middle Woodland societies of eastern North America created many similar monumental pathways. The famous parallel embankments of the Ohio Hopewell “roads” from several centuries earlier echo in the double linear embankments of the Belle Glade II sites of south-central Florida, dating to A.D. 200–800, and similar features at Mount Royal and other St. Johns II sites in northeastern Florida, dating to A.D. 900–1250 (Ashley 2005, 281; Lawres 2017, 655–656; Thompson and Pluckhahn 2012, 61). A fundamental complementarity of earth paths and water paths suggested by these varied Middle Woodland and later structures remained implicit in maps drawn by Native southeastern cartographers as recently as the 18th century A.D., in which portrayals of rivers and trails are indistinguishable, identically represented by an interconnected maze of double lines (Waselkov 2006,

439–444, 481–484) (Figure 12). The impressive long-distance canoe canals of the southeast are but one manifestation of the web of paths that interconnected Indigenous peoples of the Gulf coast with places near and far.

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## Data Availability Statement

Data available on request from the Center for Archaeological Studies, 6052 USA Drive South, University of South Alabama, Mobile, 36688.

## Disclosure Statement

The authors report there are no competing interests to declare.

## Notes on Contributors

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