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Lewis, Joshua Alan

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Article

Pathologies of Porosity: Looming Transitions Along the Mississippi River Ship Channel

Joshua Alan Lewis

ByWater Institute, Tulane University, USA; jlewis9@tulane.edu

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Abstract

This article explores recent developments along the Mississippi River Ship Channel, the Mississippi River Delta, and the port city territory of New Orleans, US. The lower reaches of the Mississippi River through which the ship channel is maintained have become increasingly porous over the past decade, as flooding events have triggered or expanded multiple breaches or crevasses along the river's eastern bank. This increasing porosity has generated debates between political and economic assemblages favoring different approaches to navigation management, flood control, and ecosystem restoration. The tensions and contradictions facing delta residents, planners, managers, and engineers come down to a question of hydrological porosity in the Mississippi River Delta, both in the river's navigation channel itself, but also in the estuarine basins that extend from its banks towards the Gulf of Mexico. This article describes how over the past several decades different modes of porosity have emerged in scientific and public discourse around water management. The science and politics of these competing modes of porosity animate a great deal of environmental decision-making in the region today. The article's analytical framework bridges research focused on the theme of porosity in port city territories, the political ecology of infrastructure standards, and management pathologies in ecosystem management.

Keywords

dredging; infrastructure; management pathologies; Mississippi River; ship channels; urbanized deltas

Issue

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1. Introduction

Ship channels are critical pathways for waterborne trade, supporting economic activities across vast areas, and driving land use/land change dynamics in port city territories (Hein, 2021; Rodrigue, 2020). Sea level rise, increasing storm intensities, and other phenomena related to climate change present significant threats to the operation of coastal/riverine ship channels and port city territories in the coming decades (Carse & Lewis, 2020; Lewis & Ernstson, 2019). These threats are especially acute in low-lying river deltas, home to between 328 (Edmonds et al., 2020) and 500 (Giosan et al., 2014) million people, nearly 90% of whom live in latitudes where tropical cyclones are an annual threat (Edmonds et al., 2020). A recent study by Edmonds et al. (2020) esti-

ated that 41% of the global population exposed to tropical cyclone threats reside in river deltas. Recent analyses examining current and future risks associated with global inland waterways and climate change showed that infrastructure investments in regions with relatively high GDPs like the Rhine and Mississippi systems have achieved a high degree of stability and sustainability (Tessler et al., 2015; Wang et al., 2020). However, Tessler et al. (2015) also point out that future changes in energy costs and economic growth could trigger a crisis in which the maintenance demands of these systems lead to increased risk for both the Rhine and Mississippi navigation systems. These findings shed light on the massive financial and technological demands involved with maintaining delta sustainability in systems subject to complex infrastructural interventions and climate risks.

The Mississippi River Ship Channel (MRSC) is a deep-water ship channel maintained through the Lower Mississippi River, extending 410 km between the city of Baton Rouge and the Gulf of Mexico. The ports of South Louisiana, New Orleans, St. Bernard, and Plaquemines comprise along with Baton Rouge the largest port cluster in the United States by volume (Hartman et al., 2022). The MRSC port cluster connects oceangoing trade routes with the Mississippi River Navigation System and the Gulf Intracoastal Waterway, making it a central node in the largest and most utilized network of inland waterways on Earth. This strategic location has driven the growth of the region's ports and riverbank communities, including the City of New Orleans, which anchors the broader port city territory. The MRSC was recently deepened to a standardized depth of 15.2 m (50 ft) to match the dimensions of the newly expanded Panama Canal. Several major new investments in port terminals are currently being considered and undertaken, including a \$21 billion liquified natural gas terminal in Plaquemines Parish and a planned \$1.8 billion container terminal for the Port of New Orleans. These recent investments underscore the continued growth in port and maritime industrial facilities in the region. The MRSC's banks are home to one of the largest petrochemical and chemical processing/manufacturing clusters in the United States, a sector still experiencing growth despite public concern over air and water pollution (Younes et al., 2021). Another growth area is the export of bulk agricultural commodities. Soybeans, corn, and other grains are shipped by barge through the Mississippi inland navigation system to the MRSC for export. The recent deepening of the MRSC creates additional incentives for agricultural export terminals. Containerized shipping represents a significant but relatively small portion of trade through the MRSC, though a newly planned container terminal near New Orleans aims to make the region more competitive in the container trade.

As trade volume grows in the region, the landscape itself has been shrinking for over a century. Between 1932 and 2016, the Mississippi River Delta (MRD) experienced the loss of 5,000 km² of land (Blum et al., 2023). The vulnerability of the MRD to accelerating rates of land loss due to sediment starvation, sea-level rise, subsidence, and several other factors is also well documented. In the nearly two decades since Hurricane Katrina struck the region in 2005, the City of New Orleans and coastal Louisiana have become global avatars for the risks that climate change poses to urbanized coasts and deltas. The measures being undertaken to address this crisis have also garnered attention from scientists, planners, and environmental advocates in recent years. The State of Louisiana's Coastal Master Plan, a well-financed and scientifically robust suite of restoration projects, has been promoted as a global model for climate adaptation (Kline & Maloz, 2023), and has been subject to scrutiny and critique from social scientists (Barra, 2021; Domingue, 2022; Nost, 2019). A central focus of the

coastal master plan is the reintroduction of riverine freshwater and sediment into the deltaic plain to mitigate land loss. The planned diversions of the Mississippi are promoted as critical for the long-term sustainability of MRD and its communities and industries, while critics have pointed to potential negative impacts on navigation and fisheries as a reason to reconsider the approach, instead prioritizing the use of dredged material to rebuild land (Lewis & Ernstson, 2019).

The proliferation of naturally occurring passes (or *crevasses*) along the lowermost sections of the MRSC has brought these competing visions for the MRD and MRSC into sharper focus (Figures 1 and 2). A recent analysis by geomorphologists and hydrological modelers at Tulane University found that the final reach of the MRSC through the "birdfoot" of the lower delta is increasingly unstable due to sediment deprivation and marine encroachment. As a result of recent flooding events, hurricane impacts, and containment breaches, only 20% of the river's freshwater and 5% of its sediment load is reaching the terminus of the MRSC at the Gulf of Mexico (Allison et al., 2023). The decreasing supply of sediment and reduction in stream power is occurring at precisely the moment that new value is being placed on these flows for their potential to reduce land loss further upstream. Balancing the needs for efficient navigation, coastal restoration, and flood protection is becoming challenging for responsible agencies in the region. This article provides an overview of recent developments in the management and operation of the MRSC and articulates a conceptual framework for grappling with the management pathologies that animate the politics of hydrological porosity along the MRSC.

2. Conceptual Framework

2.1. Infrastructural Zones, Hydrocracies, and Disturbance Regimes

Infrastructural zones are complex systems which apply technological interventions to link environmental, hydrological, and economic systems through standards (Barry, 2006; Carse & Lewis, 2017). In the case of navigable waterways, locks, levees, pumps, floodwalls, dredging technologies, and bank protection structures are all utilized to ensure the smooth circulation of goods and prevent flooding in communities. Infrastructural zones are designed and managed by large, sometimes transnational water bureaucracies or "hydrocracies" (Molle et al., 2009) that work to ensure waterway connectivity and predictability. The need for consistent waterway dimensions, efficient transit times, and safe docking conditions has led to decades and even centuries of layered hydrological modifications in such regions (Carse & Lewis, 2017). Establishing port city territories in river deltas involves the modulation of historical patterns of environmental disturbances like river floods and coastal storm surges to enable urbanization and



Figure 1. Porosities along the MRSC during the 2019 flood. Notes: The black dashed line shows MRSC; the white dashed line shows the route of Mississippi Gulf Outlet (MRGO); the red lines show flood protection levees; the yellow arrow shows flood control spillway; the white arrows are naturally occurring channels or outlets; the blue arrows are existing and planned coastal restoration projects; the arrow size represents approximate relative flow rates; the red dot indicates Head of Passes; all flows in cubic meters/second; the water losses were measured on March 10, 2019, during a maximum flow scenario below Bonnet Carre Spillway (40918 cm/s at Tarbert Landing). Source: Author’s work based on ESRI images and the analysis in Allison et al. (2023).

waterborne transportation. The disturbance regime concept is intended to capture the varying ways that the frequency and magnitude of disturbances like floods, fires, and droughts undergird broad-scale ecological patterns (Turner, 2010). For example, levees designed to prevent overbank flooding along the MRSC deprived deltaic wetlands of freshwater and sediment input, contributing to staggering rates of land loss and compromising ecosystem function and resilience in the region (Edmonds et al., 2023). This demonstrates how infrastructural zones can modulate disturbance regimes, altering the historical range of variability that previously determined landscape-scale environmental dynamics. In response to the unintended consequences of these changes, hydrocracies are being called upon to implement so-called

“nature-based” or “green/blue infrastructure” strategies. However, no simple solutions exist for reestablishing the historical disturbance regimes in systems that have been so profoundly altered. These efforts are confronting centuries of path dependencies and infrastructural/institutional lock-ins that circumscribe the potential nature-based initiatives precisely when they are most urgently needed (Markolf et al., 2018).

2.2. Management Pathologies

Management pathologies have been the focus of considerable research in ecosystem management and the study of social-ecological systems (Allen & Gunderson, 2011; Cox, 2016; Holling & Meffe, 1996). Scholars in this area

have identified common tendencies within water governance bureaucracies that prevent broad stakeholder engagement and the adoption of adaptive management strategies. In delta systems like the Lower Mississippi, environmental and water governance systems were largely developed with a “command and control” philosophy deeply embedded in the design and management of water systems and infrastructural zones (Carse & Lewis, 2017; Holling & Meffe, 1996). Environmental change and extreme events are increasingly reaching magnitudes and frequencies that existing systems can no longer efficiently absorb. Each earlier wave of adaptation, the deepening of a ship channel for example, or the construction of flood diversion structures constrain contemporary attempts to maintain deltaic sustainability in the face of accelerating change. According to Holling and Meffe (1996, p. 329), the command-and-control approach:

Implicitly assumes that the problem is well-bounded, clearly defined, and generally linear with respect to cause and effect. But when these same methods of control are applied to a complex, nonlinear, and poorly understood natural world, and when the same predictable outcomes are expected but rarely obtained, severe ecological, social and economic repercussions result.

As centuries of layered infrastructural interventions in natural systems reflecting these pathologies accumulate and face changing patterns of environmental disturbance, cascading sequences of unpredictable events can begin to unfold (Carse & Lewis, 2017; Cox, 2016; Lewis & Ernstson, 2019).

A multi-scalar matrix of economic and political power clustered around ship channels influences the dynamics of political contention surrounding their adaptation. This arises through the combination of economic and environmental dynamism that characterizes deltaic port city territories. Different economic or public policy goals generate varied engineering strategies for hydrological control, with constellations of interests seeking to optimize the territory for economic development goals. Port city territories have economic constituencies that extend far beyond the territory itself, adding political complexity to seemingly localized hydrological management decisions. For instance, New Orleans and Rotterdam serve as transshipment points between oceanic trade networks and inland waterway systems. Oceanic and inland navigation systems are utilized by different shipping technologies: large ocean-going vessels entering from the sea and inland vessels like barges arriving from within the continent. These port city territories are thus organized to stitch together infrastructural zones with different standards, in this case, deep and shallow waterway dimensions (in addition to road, rail, and pipeline connections). This interstitial character also alters the economics and politics of environmental governance in the port city

territory and its major shipping channels. Agricultural commodity, global shipping, energy firms, and even individual farmers operating thousands of kilometers away have a direct stake in how hydrological flows are configured in port city territories. Conversely, this may mean that natural systems with a high value to small-scale, local interests (take fisheries for example) may be devalued relative to the demands of the major industries that seek to optimize port-city territories and ship channel systems for navigation alone.

The command-and-control system that frequently governs large navigable waterways has historically negotiated this complexity with crude bureaucratic instruments like cost-benefit analysis or other mitigation mechanisms (Carse, 2021). With the operation of large global shipping and commodity firms in the balance, local interests may find that their political power to guide key decisions regarding infrastructural zones may be constrained. Indeed, in many countries, political and patronage relationships between hydrocracies, political leaders, and businesses form so-called “iron triangles” (McCool, 1994). Molle et al. (2009, p. 337) describe iron triangles as “systems of vested interests that encourage...overestimation of benefits and neglect of costs in order to secure a steady flow of projects.” This assessment is echoed by Holling and Meffe (1996, p. 331), who suggest that management pathologies often lead to “less resilient and more vulnerable ecosystems, more myopic and rigid institutions, and more dependent and selfish economic interests all attempting to maintain short-term success.” The authors continue with a warning that command-and-control approaches to challenges like flood control and navigational access in the MRSC are typically successful initially, but ultimately “the result is increasing dependency on continued success in controlling nature while, unknown to most, nature itself is losing resilience and increasing the likelihood of unexpected events and eventual system failure” (Holling & Meffe, 1996, p. 331). While recent policy development has emphasized “nature-based solutions” that better attend to ecological impacts of infrastructural zones, the same hydrocracies that dominate water resources development retain some control over such programs, exposing them to the influence of management pathologies despite programmatic or discursive shifts.

In the case of the MRSC and MRD region, the pre-eminent hydrocracy is the United States Army Corps of Engineers (USACE), a branch of the military with a broad mandate to manage water resources, build and maintain flood protection systems, and maintain waterborne transportation systems. Increasingly, the USACE has also developed programs that emphasize *engineering with nature*, an attempt to mitigate the pathologies inherent to command-and-control approaches and better balance economic development and natural resources management. It bears mentioning however that this also represents more authority and scope for the USACE in water management, not less, and will likely mean that

more public finances will flow to the USACE to build and maintain projects framed discursively as green infrastructure, nature-based solutions, or as mentioned above, engineering with nature. Following Hurricane Katrina in 2005, the State of Louisiana established the Coastal Protection and Restoration Authority (CPRA). This state-level agency, established in 2007, drew inspiration in part from the Dutch state's Rijkswaterstaat. The CPRA, infused with legal settlement funding following the BP oil disaster in 2010, has been gradually challenging the historical role of the USACE in the areas of ecosystem management. While the USACE now focuses primarily on its navigation and flood protection role along the MRSC, the CPRA and its supporters have moved forward on an ambitious plan to increase the MRSC's porosity for coastal restoration purposes. This emerging tension speaks to our next section exploring competing modes of porosity along the MRSC.

2.3. Modes of Porosity

The concept of "porosity" has recently received attention in this journal as a way of viewing planning dilemmas in port city territories (Hein, 2021). This thematic issue included several fascinating case studies viewed through the lens of porosity and its attendant concepts of boundaries, flows, and territories was explored. Interestingly, given porosity's frequent usage in relation to the movement of water, the issue broadened this to explore the movements of people, characteristics of the built environment, and the movement of capital. In this article, I will draw on this work but in a perhaps more orthodox way—Here I am interested in the hydrological porosity of the MRSC itself, as well as the porosity of the estuarine landscapes through which the channel passes. In doing so I identify three *modes of porosity* that have historically competed for influence along the MRSC and port city territory of New Orleans (Table 1). Within the three modes of porosity, I identify intensities (high/low) and configurations of porosity emphasized in each. By *river-*

ine porosity, I am referring to the spatial patterns and flow intensities of freshwater and sediment from the Mississippi's main channel/distributaries into surrounding deltaic wetlands, though during low water this flow can be reversed with marine waters entering the MRSC channel. *Estuarine porosity* refers to the spatial patterns and flow intensities through which marine waters and sediments penetrate and circulate within the deltaic wetland landscapes in the MRSC's vicinity. *Mixed riverine porosity*, here explored in the context of flood control, refers to the varied spatial patterns and flow intensities that engineers seek to optimize to reduce riverine flood risk to infrastructure and human settlements. It should be noted that this is not an exhaustive hydrological typology, but is intended to capture the dominant modes of porosity inscribed into infrastructural zones in the study region.

Each mode of porosity explored here can be viewed as distinct imaginaries of an ideal disturbance regime for the region. The higher riverine porosity currently occurring in the MRSC's lower reach is a window into the natural disturbance regime that created the landscape itself via overbank flooding and crevasse formation. Lower estuarine porosity translates into reduced maritime encroachment, and in some instances, a broader range of estuarine salinities (and therefore landscape diversity). Engineers and planners in the region are engaged in a process of discerning the benefits and limitations of each of these modes, understanding where they may overlap in some circumstances, and balancing the tradeoffs between constituencies clustered around them.

2.3.1. The Navigation Mode

The first mode of porosity we can identify is the *navigation mode*. In this view of the deltaic system, efficient and predictable navigational access to port terminals is paramount. Historically this has been pursued by maritime industrial interests and state authorities through command-and-control interventions (Barry, 2007; Lewis,

Table 1. Modes of porosity in the MRSC context.

Mode of porosity	Emphasis	Hydrocracies and constituencies	Engineering tools
Navigation	Low riverine porosity, high estuarine porosity	USACE, maritime industry, port authorities	Navigation dredging, levees, port terminals, navigation locks, and shipping canals meant to maximize economic flows
Flood control	Mixed riverine porosity, low estuarine porosity	USACE, nearly all residents, businesses, most local interests	Levees, floodwalls, pumping systems, and spillways meant to strategically manage river flows
Delta mimicry	High riverine porosity, low estuarine porosity	CPRA, environmental NGOs, conservation organizations, freshwater fishing interests	Freshwater and sediment diversion structures meant to build land and mitigate land loss over a multi-decade time scale, restoration of compromised distributary ridges

2019). The infrastructural zone organized around this mode includes river levees, jetties, navigation locks, shipping canals, and bank protection systems. Dredging plays a central role both in terms of maintaining standardized depths within the MRSC and also creating linear shipping canals through estuaries to enhance navigational access. This mode emphasizes the low porosity of the MRSC channel and Mississippi River, while historically prioritizing high porosity within the estuarine ecosystems comprising much of the delta's landforms. Pathologies associated with this mode arise from the economic imperatives of waterborne transportation for the local, national, and global economies. The demands of navigation interests have historically far overpowered local concerns over flood risk and ecosystem impacts from near complete MRSC containment, in line with the pathologies of command-and-control approaches described above (Lewis & Ernstson, 2019).

Prior attempts at achieving maritime connectivity via estuarine porosity led to disastrous outcomes for communities and ecosystems. These failures effectively rendered the MRSC the obligatory point of passage for ocean-going deep-water trade in the Mississippi system and limited possible solutions to emerging contemporary navigation issues. The MRGO Channel was a 120 km long ship channel dredged through the Lake Borgne and Breton Sound estuaries southeast of New Orleans in the late 1950s (Figure 1). The channel was intended to become the main ship channel for the Port of New Orleans, reducing transit times and avoiding the water level variations, mouth shoaling, and fog on the MRSC that caused problems for navigation access. The project was supported by economic interests and political leaders throughout the Mississippi Basin like bulk agricultural export companies (Freudenburg et al., 2012). Because the MRGO directly accessed the urban center of New Orleans by connecting with an inner harbor canal, the MRGO was an attempt by port officials in New Orleans to preempt port regionalization along the MRSC, attracting the bulk of oceanic trade into the city itself, and opening up large areas of marshlands in the eastern part of the city for maritime industrial development. The Port of New Orleans, local political leaders, and USACE were closely linked institutions in the 1950s, with a revolving door of leadership between the two, an arrangement described by scholars as an "iron triangle" or "growth machine" (Freudenburg et al., 2012; Youngman, 2015).

The dredging of the MRGO altered the disturbance regime in the estuaries east of New Orleans, perforating coastal ridges that controlled tidal circulation and salinity over a 2,500 km² area, and led to the direct destruction or habitat conversion of 265 km² of deltaic wetlands (Day et al., 2006). The loss of storm surge-buffering wetlands brought on by this increase in estuarine porosity elevated flooding risk in New Orleans dramatically, and the MRGO was a key conduit for floodwaters during Hurricane Betsy in 1965 and Hurricane Katrina in 2005 (Shaffer et al., 2009). Due to these destructive impacts,

the MRGO was decommissioned by the US Congress in 2008, and new flood protection measures were undertaken in the area, including a massive storm surge barrier that enclosed part of the Lake Borgne estuary, reducing the porosity of the degraded wetlands along the city's eastern margin.

The MRGO's economic promise also never fully materialized, and, by 1998, 95% of ships were simply using the MRSC instead (Campanella, 2022). The dramatic environmental changes triggered by the MRGO (e.g., land loss, subsidence) prevented maritime industrial expansion along its banks, and the broader process of port regionalization along the MRSC had already begun by the time the channel was completed. The MRGO's failure solidified a "river only" navigation scenario, where the MRSC became the only option for most ocean-going trade. These events influence contemporary decision-making around the MRSC, where discussions of "alternative outlets" for navigation in the face of looming environmental changes confront political opposition forged through the experience of flooding and economic losses from the MRGO (Lewis & Ernstson, 2019). Projects like river and sediment diversions, which ostensibly would help address some of the ecological damages wrought by the MRGO face resistance from coastal communities and fishing groups. The MRGO catastrophe undermined public trust in hydrocracies, and the echoes of this failure are frequently heard in public hearings about MRSC management and new port investments (Lewis & Ernstson, 2019).

2.3.2. The Flood Control Mode

The second mode of porosity in our case is the *flood control mode*. Like the navigation mode, this mode has historically emphasized the containment of the Mississippi River and urban settlements behind levees and other flood control structures. Management pathologies in this mode usually relate to forced tradeoffs between navigational access, urban spatial planning, and fisheries health. The pursuit of river containment has on the one hand prevented overbank flooding in populated areas and enabled greater urbanization in the delta by attenuating risks associated with annual riverine flooding. This effort to limit the river's porosity had the major side effect of depriving nearly the entire deltaic plain of new freshwater and sediment inputs, which along with other drivers, has triggered a land loss crisis that threatens the entire region with coastal inundation (Blum & Roberts, 2009). As infrastructural zones reduced riverine porosity and the frequency and/or magnitude of flood disturbances, urbanization expanded into areas previously deemed too hazardous. As disturbance regimes began to change in response to infrastructural zones, novel vulnerabilities emerged, making infrastructure failures more costly and potentially deadly for people (Kates et al., 2006). This phenomenon is referred to by scholars as the "levee effect" (Collenteur et al., 2015) or "safe develop-

ment paradox” (Breen et al., 2022; Burby, 2006). In the case of communities along the MRSC, river and perimeter storm surge levees reduce both riverine and estuarine porosity, preventing flooding for annual and fairly typical disturbances, while dramatically increasing potential losses when flood control standards are overwhelmed by extreme events (Kates et al., 2006).

In the case of the MRSC, the pathologies associated with the “levees only” approach were recognized following a major river flood in 1927. The USACE constructed two large flooding diversion structures upriver from New Orleans, signifying a willingness on the part of the nation’s dominant hydrocracy to allow greater porosity along the MRSC, but in highly controlled and strategic locations which enabled impacts to be managed. Spillways like the Bonnet Carre near New Orleans were not intended for ecosystem restoration purposes, and indeed significant fisheries losses and natural resource damages can be incurred during their use (Posadas & Posadas, 2017). Flood control, as previously mentioned, has also contributed to the overall degradation of the lower MRD via sediment, freshwater, and nutrient starvation of deltaic wetlands. As this degradation process has taken hold in the past century, marine encroachment into previously freshwater wetlands has created more favorable fishery habitats for certain commercially important species like shrimp, oysters, and finfish. As fishing communities adapted to this mode of porosity and its attendant disturbance regime and ecological systems, over decades, an additional pathology emerged: Increasing riverine porosity for flood control or ecosystem restoration is now likely to negatively impact marine fisheries, despite the practice reflecting the historical disturbance regime and range of hydrological variability. This can be observed in contemporary disputes over the reintroduction of river flows into deltaic wetlands that place fishing interests at odds with both flood control agencies and ecosystem restoration advocates (Lewis & Ernstson, 2019).

2.3.3. The Delta Mimicry Mode

The final mode of porosity is *delta mimicry*. Actors within this mode generally advocate for high riverine porosity, restoring aspects of the delta’s historical disturbance regime. Reduced estuarine porosity is also frequently advocated, through both restoration of coastal ridges and perimeter marshes and in-filling of fragmented interior wetlands via sediment diversions. Within this mode, we find a political assemblage comprised of primarily urban residents, state lawmakers, large national environmental NGOs like the National Wildlife Federation and Environmental Defense Fund, the state hydrocracy CPRA, and, increasingly, the USACE with its “Engineering With Nature” program. This mode emphasizes high MRSC porosity both through naturally occurring overbank flooding and new distributary formation in the river’s lower uninhabited reaches and through large-scale sed-

iment diversions slated to begin construction in 2023. These sediment diversions are designed to capture bed-load sand and suspended river sediments and convey them into estuarine basins lining the MRSC banks. Proponents point to overbank flooding and crevasses that were the main physical process through which the delta itself was built over millennia. Discourses around “allowing nature to take its course” and other organicist ontologies are prevalent in this mode (Snell, 2022). In reference to strategically placed and heavily engineered river diversions soon to begin construction, the executive director of the CPRA recently stated that “the fundamental problem in coastal Louisiana is [a] lack of sediment, and so we’re trying to mimic the way Mother Nature would have delivered that sediment to our coast in the past” (Santana, 2019). As the MRSC begins to lose containment in its lower reaches, proponents of the delta mimicry mode have advocated for leaving these new outlets open to allow the Mississippi to flow into nearby estuaries, leading to tensions with navigation and fisheries interests (Snell, 2022).

The broader impacts of sediment diversions and the emerging loss of containment on the MRSC can be veiled through discourse claiming that these developments might restore a “natural” or “balanced” deltaic system. Due to the temporal sequence of infrastructural zone development and altered disturbance regimes, projects promoted for their “natural” attributes also carry significant risks to commercial fisheries and marine mammals that have taken advantage of the more saline estuarine conditions brought on by the flood control measures (Smith, 2023). A further contradiction with delta mimicry occurs during acute low water stages resulting from droughts. Higher salinity water is denser than freshwater, creating a wedge of saltwater along the river bottom, especially during low water. The passes/crevasses (pores, for our purposes) along the lower MRSC provide additional pathways for marine encroachment into the main river channel. The propagation of this saltwater wedge upstream places drinking water intakes for communities at risk of contamination. During low water years, like 2022, the USACE has been forced to build a massive underwater sill structure along the river bottom to intercept the saltwater wedge. In this sense, the MRSC bank failures hailed by delta mimicry proponents as environmentally beneficial may also negatively impact drinking water quality in New Orleans and other nearby communities.

3. Looming Transitions Along the Mississippi River Ship Channel

Climate change threatens to further alter the frequency and magnitude of floods and storms, presenting novel conditions that may exceed flood protection levels in unexpected ways and trigger abrupt environmental changes. In the spring and summer of 2019, a sequence of hydrological and meteorological events

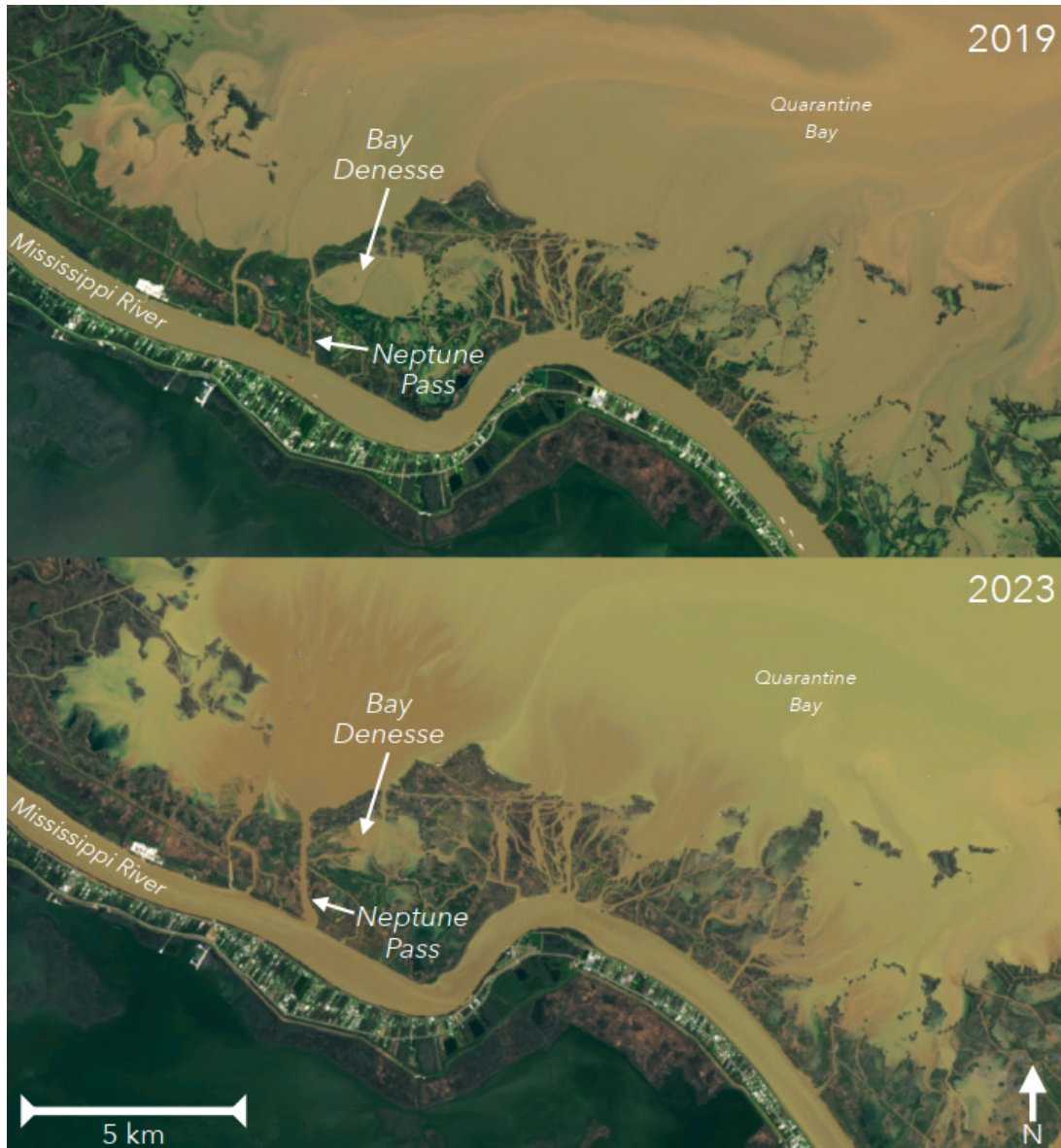


Figure 2. Expansion of Neptune Pass and nearby outlets between 2019 and 2023: Widening of outlets and land formation in Bay Dessen, as well as suspended sediment on the north side of the river versus the lack of sediment on the southern side where levees preserve channel containment. Source: Author’s work overlaying USGS Landsat 8 Imagery (see Nussbaum, 2023).

revealed serious problems with the infrastructural zones governing the MRSC. The Lower Mississippi River experienced its longest flood stage duration ever recorded, exceeding the previous record set during the 1927 flood. The Bonnet Carre Spillway, a flood control structure designed to mitigate riverine flood risk and maintain consistent navigation conditions was opened twice in a single year for the first time, and remained open for several months, injecting unprecedented volumes of freshwater and nutrient loads into coastal estuaries near New Orleans, producing harmful algal blooms and impacting marine fisheries up to 100 km away (Parra et al., 2020; Schleifstein, 2022). Navigation was disrupted along the MRSC and further upstream in the inland navigation system by the high water, interrupt-

ing bulk agricultural commodity exports through New Orleans (Sullivan et al., 2019). With the Mississippi still in flood stage into the summer, an early season hurricane approached the Louisiana coast, generating an alarm in the region that a storm surge near the MRSC mouth could cause storm surge to propagate upriver, potentially causing riverine flooding in New Orleans for the first time in over a century. Initial forecasts of a 20 ft (6.1 m) river crest in New Orleans, fortunately, did not materialize. Such a crest could have overtopped river levees in the city and wider region (Schleifstein, 2019). The summer of 2019 signaled that climate change’s expected impacts in the region, which are likely to include higher flood stages for longer durations and increasingly frequent and intense tropical storms, were perhaps already evident.

The 2019 flood also exposed worrying trends at the mouth of the MRSC, at the tip of the river delta known as the “birdfoot,” so named for its exposed sinuous shape extending into the Gulf of Mexico (Figure 1). This shape reveals an important reality—This landscape is a historical anomaly. Previous delta lobe formations have likely not extended as far towards the continental shelf (Blum et al., 2023). The birdfoot is an artifact of the infrastructural zones in place to prevent riverine flooding and maintain navigational access. Flood control and navigation interventions like levees, jetties, and dredging have historically increased stream power in the river’s lower reach and helped maintain ship channel containment. Without these modifications, the river’s main distributary would have likely shifted further upstream in the past century, as it would naturally seek the shortest route to the Gulf by gravity during high-water events. Even so, multiple flooding events in the past two decades have led to an increasing share of the river’s flow escaping the main channel along a portion of its east bank where levees are lower or nonexistent and no human settlements exist to incentivize further interventions (Figures 1 and 2).

The aforementioned study by Tulane researchers (Allison et al., 2023) shows that the Mississippi is losing a significant portion of its stream power, flow volume, and sediment load before it reaches its terminus in the Gulf of Mexico. The analysis showed that only 20% of the river’s freshwater and only 5% of its suspended sediment reaches the Gulf. The MRSC’s main channel through Southwest Pass was losing an additional 50% of its freshwater just in its final reach below the head of passes (Figure 1). This trend has gathered pace significantly over the past two decades, as bank failures have proliferated during recent floods and new artificial diversions have been opened to stave off land loss further upstream. This trend has several implications, including, according to Allison et al. (2023), “river containment and the sustainability of the navigation channel is threatened.” Some of the effects of this process are already becoming apparent. The decrease in stream power is likely to blame for the increasing dredging demands in the southwest pass of the MRSC. Historically, the river has only required dredging in its lower reach below a consistent point at and below the head of passes, where the river branches out into its final major distributaries. As the edges of the lower MRSC become more porous, stream power and velocity decrease, leading to greater volumes of sediment being deposited in the streambed. This is increasing dredging demand, and the point at which dredging operations are necessary is gradually shifting further upriver and triggering draft restrictions (Hartman et al., 2022). The analysis shows further that this deprivation of sediment in the delta’s terminal reach may lead to increased maritime encroachment, and ultimately, rising instability of the birdfoot landform itself. In short, the infrastructural zones designed to confine the river are reaching the limits of delta progradation in their current

arrangement, suggesting that the risk of rapid delta backstepping (landward retreat) may be looming.

A debate has developed over what to do about these new distributaries forming in the MRSC’s lower reach. For navigation interests and the USACE hydrocracy, the channel of the MRSC needs to remain as integral as possible, which will increase stream power and reduce sedimentation and dredging demands. For interests more aligned with a delta mimicry mode of MRD porosity, the loss of MRSC containment demonstrates precisely the power of the river to create new land and mitigate land loss. Indeed, new delta splays have emerged in the past two years at Neptune Pass and other new openings (Figure 2). For environmental groups and residents concerned with land loss and the increased coastal flooding hazard it represents, these developments serve as a proof of concept for the highly engineered sediment diversion structures soon to be constructed further upstream. Creating additional outlets for river and sediment flow, artificial or naturally occurring, could further compound the dredging issues and navigation concerns at the Southwest Pass of the MRSC. Whether or not greater porosity in the MRSC lower reach would mitigate potential storm surge propagation upriver has not been firmly established at present.

These dynamics in the birdfoot of the delta are relevant for port and maritime planning closer to the urban core of New Orleans. For the past two decades, competing proposals for container terminals have coalesced. One proposal has advocated for building a massive intermodal container terminal in the birdfoot itself, only a few kilometers from the MRSC’s terminus (Figure 1). This proposal failed to attract sufficient financing and regulatory approval, was widely criticized for its hazard-prone location, and was superseded by the proposal for a similar terminal some 80 km further upstream. Investors and partners in this second project have also recently pulled out when the Port of New Orleans acquired land only 20 km downstream from the current container terminal, which, unlike most major container terminals, remains located near the city center (McCormack, 2022). Like the hydrological and geomorphological dynamics of the lower MRSC, the container terminal proposals have been migrating upstream, as has the human population in riverside communities. Between 2000 and 2020, there was a 60% decline in population in communities downstream from Mardi Gras Pass (Figure 1; US Census Bureau, 2023). The Port of New Orleans’ proposed container terminal closer to the urban core (Figure 1) is facing staunch political opposition from the communities around the proposed site, with opponents frequently referencing the port’s failed MRGO project as a reason to doubt the port’s claims that the terminal would benefit local communities (Chapman, 2022). MRSC channel instability and ongoing land loss in the river’s lower reach are pushing infrastructure investment upstream, while community opposition to port regionalization is placing pressure back downstream. This social-hydrological

“squeeze” effect (combined with the failure of the MRGO project) threatens to limit the spatial range of port regionalization in the future.

4. Conclusions

With the limits of delta progradation potentially at hand and the possibility of delta backstepping emerging, the centuries-long arc of disturbance regime alteration through infrastructural zones is confronting new patterns of extreme events. As a USACE official stated at a recent panel, “We don’t have normal river years anymore, it always changes” (panel discussion, Kornick, 2023). This uncertainty vexes a system of global economic exchange that thrives on standardization and predictability. As political constituencies and economic interests cluster around different modes of porosity, emerging contradictions and pathologies have created a landscape of high-stakes political contestation around MRSC and coastal estuary management that eludes straightforward solutions. Barring the emergence of stronger coordination among these interests, critical decisions around the future alignment of the MRSC in its lower reach, the fate of the birdfoot landmass, and the sustainability of human communities in the area may only occur when abrupt environmental changes or disturbance events force a public policy response. This sentiment was expressed by a representative of navigation interests at a recent panel discussion, who warned that “if we don’t secure the eastern side [of the MRSC], somebody else might be making decisions for us” (panel discussion, Duffy, 2023), implying poorly coordinated policy responses will ultimately cede major decisions around the MRSC to dynamics of the river itself.

Different modes of porosity point towards narrow policy prescriptions to confront future uncertainty. Dredging, engineered river diversions, and “naturally” occurring passes and crevasses are all posited by proponents as singular best practices in public events and communication materials. The USACE operates a “beneficial use” program for the dredged material it excavates from the MRSC, pumping sediment over MRSC banks and into adjoining estuaries, creating new platforms for marsh colonization. The bulk of this program, however, is focused on the birdfoot. While these landforms may modestly contribute to MRSC bank stability, the storm surge mitigating effects for cities and other settlements is not established. Similarly, proponents of the delta mimicry mode may be technically correct that the newly opened outlets in the lower MRSC represent “free diversions” that will build new land (Snell, 2022). However, the land built by these outlets is not in a highly strategic area for land loss mitigation or storm surge buffering and will take decades to build significant acreages—during which sea level rise may nullify the benefits. For delta mimicry skeptics, the beneficial use of dredged material further upstream, closer to New Orleans, represents an alternative solution to coastal land loss—

quickly creating new land (panel discussion, Duffy, 2023). Whatever the eventualities, the dredging industry will see its business opportunities grow. Greater porosity in the MRSC, engineered or “natural,” will increase the need for navigation dredging to maintain MRSC standard depths. Decreased MRSC porosity or poor performance of sediment diversions may lead to increased demand for beneficial use and dredge and fill operations to address land loss. Proponents of the delta mimicry mode point to the fuel costs and carbon footprint of dredging operations, arguing for natural and engineered river diversions as a low-carbon option that can be operated for decades at low cost once the initial diversion structure is built (Renfro, 2022).

The CPRA hydrocracy is occupying a novel space vis-à-vis these competing modes of porosity. To implement its ambitious coastal master plan, it must work against the pathologies of the flood control, navigation, and delta mimicry modes, synthesizing their critical insights and avoiding any totalizing ontological positions they may carry about the proper infrastructural matrix for the MRSC in the coming century. Regardless of the sustainability of the region and its population centers, access to the Mississippi River’s inland navigation system is an economic imperative for the United States and the global economy. The potential shifts at the MRSC’s terminus are a harbinger of the hydrological, geomorphological, and ecological future of the region. The political assemblages and public debates animating infrastructural responses to this process will, as I have argued here, cluster around competing modes of hydrological porosity in the MRD.

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Conflict of Interests

The author declares no conflict of interests.

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About the Author



Joshua Alan Lewis is a Schwartz Professor of River and Coastal Studies and a research associate professor at the ByWater Institute at Tulane University in New Orleans. He has previously held appointments at the Stockholm Resilience Centre and KTH Royal Institute of Technology in Sweden. With a background in systems ecology and human geography, his research explores the relationship between water infrastructure, coastal ecosystems, and human communities.