2023 COASTAL MASTER PLAN

VISUALIZING THE FUTURE OF LOUISIANA'S COASTLINE

ATTACHMENT F8

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COASTAL PROTECTION AND RESTORATION AUTHORITY

This document was developed in support of the 2023 Coastal Master Plan being prepared by the Coastal Protection and Restoration Authority (CPRA). CPRA was established by the Louisiana Legislature in response to Hurricanes Katrina and Rita through Act 8 of the First Extraordinary Session of 2005. Act 8 of the First Extraordinary Session of 2005 expanded the membership, duties, and responsibilities of CPRA and charged the new authority to develop and implement a comprehensive coastal protection plan, consisting of a master plan (revised every six years) and annual plans. CPRA's mandate is to develop, implement, and enforce a comprehensive coastal protection and restoration master plan.

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Visualizing the Future of Louisiana's Coastline

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ABSTRACT

In this paper, we summarize the research efforts undertaken by the Louisiana Coastal Protection and Restoration Authority (CPRA) during their 2023 Coastal Master Plan planning period, and the tools created by the Pittsburgh Supercomputing Center (PSC) to support them in their efforts. Specifically, we introduce the Master Plan Data Viewer and explore how creating interactive accompaniments for print material is a key element in the community's goal of data democratization. This proof of concept focused on creating an easy-to-use geospatial data portal that would reduce barriers to entry, tell the story of the master plan, and inform Louisiana residents of the potential changes to their state's coast.

CCS CONCEPTS

• **Information systems → Geographic information systems**; • **Human-centered computing → Geographic visualization**; *Scientific visualization.*

KEYWORDS

data visualization, GIS, geospatial, vector, raster, portal, HPC

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1 INTRODUCTION

Coastal Louisiana is facing potentially devastating changes to the coastline over the next 50 years. The Coastal Protection and Restoration Authority (CPRA), a state agency in Louisiana, develops and maintains a master plan to address these changes [1]. The plan forecasts changes to the coastal environment over a 50-year time horizon and proposes projects to mitigate impacts such as storm surge-based flooding and loss of coastal habitats. The project concepts are sourced from public solicitations, refined with stakeholder input, and evaluated and selected using a series of computationally intense models. CPRA received an allocation through the XSEDE program (now ACCESS) to run the models on the Pittsburgh Supercomputing Center's Bridges-2 system [5]. The outputs from these models are both complex and critically important for the region's future.

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CPRA partnered with software engineers from the Pittsburgh Supercomputing Center and designers from the landscape architecture firm SCAPE to develop interactive online software for visualizing and presenting the model outputs and proposed projects. In this paper we introduce the result of that collaboration: Louisiana's 2023 Coastal Master Plan Data Viewer [2]. We outline the goals of the project, the user experience, the technology that supports it, and the ongoing and future efforts surrounding it. We believe this project can serve as a template for future collaborative efforts to visualize and present complex data from modeling on high performance computing systems.

2 GOALS

Our work on the data viewer was guided by three key principles:

- **Serve multiple audiences.** The Master Plan Data Viewer is used by state and federal leaders, members of the public, academic researchers, and CPRA staff. It is used in public meetings and presentations, as well as by individual users. To serve these varied audiences and contexts, we tried to balance configurability with ease of use. We also developed multiple pathways for accessing the plan's content tailored to specific audiences.
- **Take advantage of the medium.** The digital format of the data viewer offers opportunities to move beyond the static content of the plan document. We used interactivity to highlight relationships that would be difficult to discover using print maps, and to encourage user to explore these connections.
- **Leverage open tools and formats.** To reduce costs and avoid vendor lock-in, we prioritized the use of open source tools and geospatial data formats. Using these open source tools, we were able to run data preparation pipelines on Bridges-2 and serve map data in formats compatible with a wide variety of GIS software.

3 USER EXPERIENCE

Based on these goals, we developed a user interface that offers multiple content pathways and prioritizes interactivity.

3.1 Content Pathways

The Master Plan Data Viewer features two content pathways targeting different audiences. Users select a pathway from an introductory screen and can change pathways at any time using controls at the top of the viewer. While similar in substance, the pathways differ in their presentation based on the needs of the audience.

The guided tour pathway provides a narrative overview for first-time visitors unfamiliar with the plan and the data viewer, or for use in presentations by CPRA staff. Through a series of slides, it

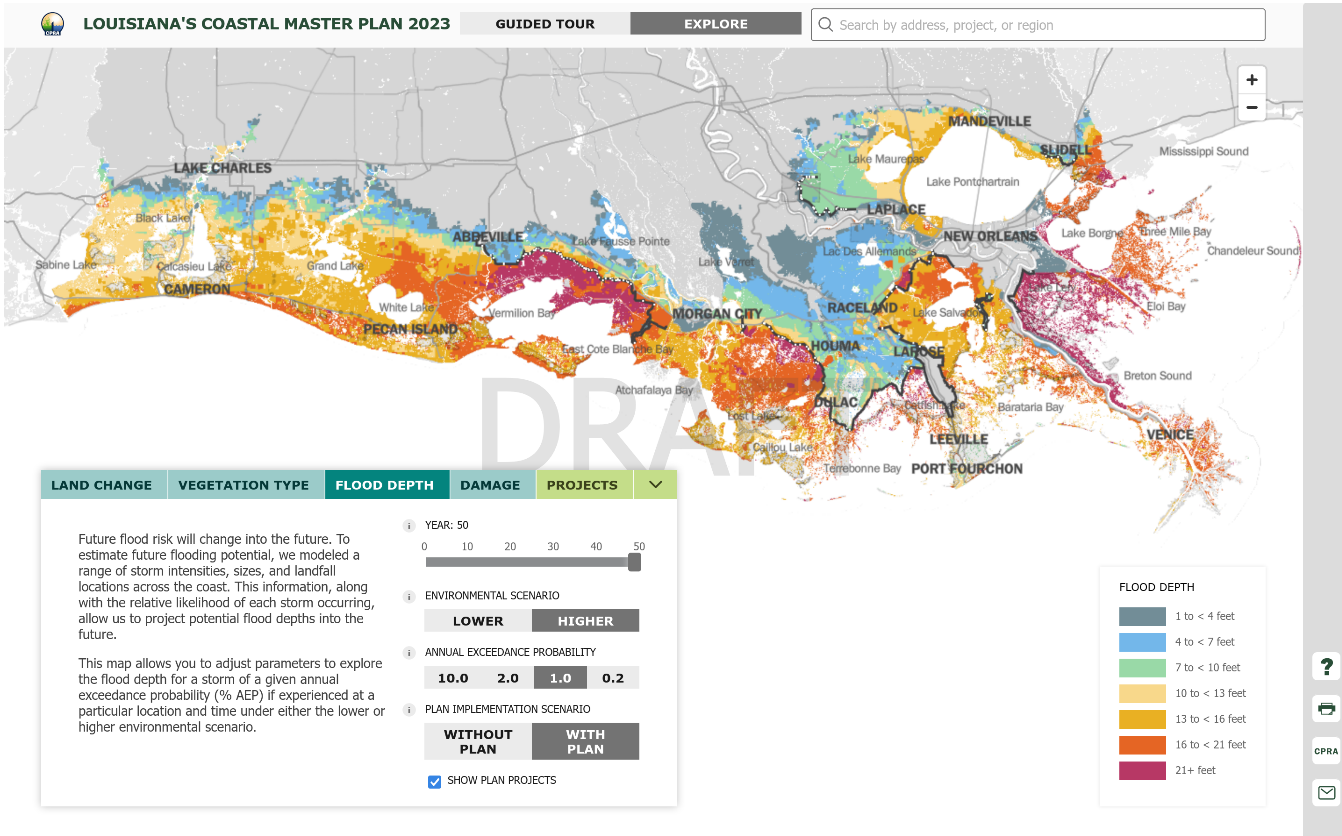

Figure 1: The Master Plan Data Viewer user interface showing flood depth in the explore pathway.

gradually introduces user interface controls and provides explicit instructions about how to use them. The tour presents model data and proposed projects while framing them within the larger story of coastal change in Louisiana. At the conclusion of the tour, users are invited to enter the explore pathway.

The explore pathway allows more experienced users to access all data and controls in a more streamlined interface with minimal narrative content. Unlike the guided tour, this pathway is nonlinear, with tabs that allow users to access the content areas in any order. It is designed to allow users to explore the relationship between projects and model outputs and to compare forecasts with and without the plan.

3.2 Interactivity

The data viewer uses interactivity to engage users and provide detail beyond what is available in the print plan. In some cases, additional information appears as users zoom in on the map. For example, when users are viewing estimated damages on the map, zooming in reveals labels containing the dollar amount and number of structures impacted. Similarly, zooming in on a project displays the project name and project type icon. These zoom interactions provide a seamless way for users to discover more detail about a map feature without changing contexts.

The data viewer also uses click interactions to allow users to learn more about a project. Clicking a project name or symbol reveals an information panel with details about the project, including its proposed implementation year and description. From the information panel, users can choose to download a project fact sheet with further details. Being able to click a project to learn more about it encourages users to explore projects in regions of interest. It also simplifies the process of getting project information compared to the print map, where the project number is used to look up details in a table.

In developing the user interface, we prioritized internal consistency and familiarity. User interface controls, such as buttons and sliders, have a consistent appearance and behave the same regardless of where they appear in the application. Wherever possible, we used controls and paradigms common to map applications instead of developing novel approaches that users would have to learn. For example, the presentation of search results and the way selected results are highlighted on the map mirrors the approach used by popular navigation applications, making it familiar to many users.

4 ARCHITECTURE

The architecture of the Master Plan Data Viewer was designed with simplicity and performance in mind. Since comparing scenarios and showing change over time were key functions of the viewer,

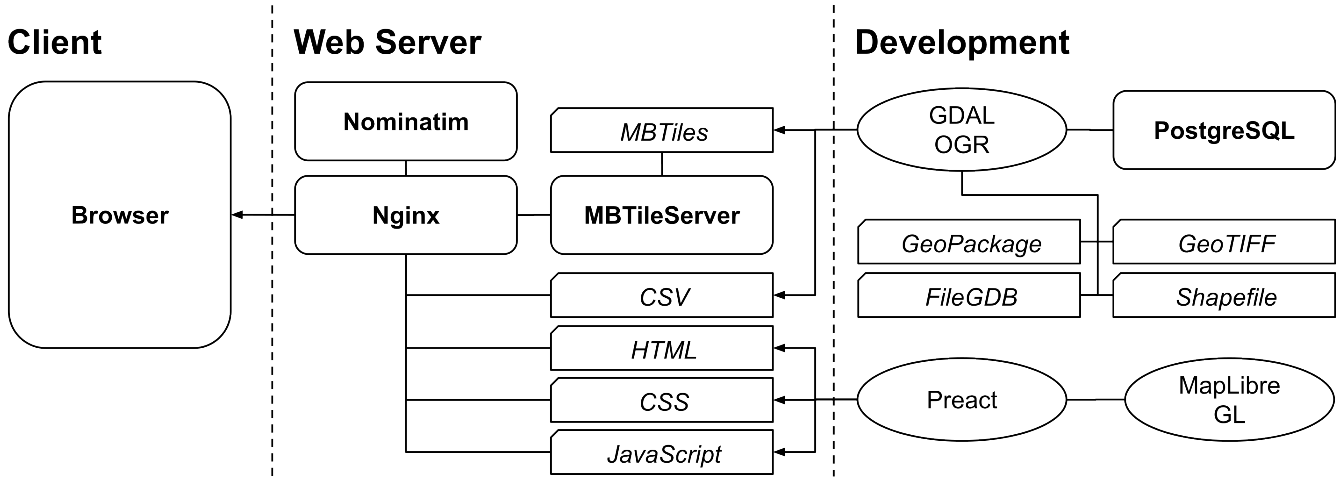

Figure 2: Diagram of the Master Plan Data Viewer architecture.

we prerendered and tiled all of the map data to allow for fast load times and smooth animation between decadal datasets. We used GDAL/OGR [3] to generate tilesets from the raster images produced by the models, as well as a PostgreSQL database and several file-based vector data formats. We also used these data sources to generate CSV files with information about the projects and an index of available search geometries. These files are used to populate the user interface.

We decided to implement as much of the functionality on the front end as possible to keep the architecture simple and reduce ongoing maintenance costs. Other than the tile server, the only dynamic service used by the data viewer is a Nominatim [4] instance used for geocoding search results. All of the other resources are static files that are served directly to the browser.

4.1 Open Source Libraries and Tools

The Master Plan Data Viewer employs open source libraries and tools in all aspects of its life cycle, from data preparation and development to production:

- **GDAL/OGR** is a toolkit for converting and transforming spatial data. It was used to render and tile the model results and to prepare vector tilesets containing projects, communities, and base map features. The tiles are stored as MBTiles, a SQLite-based tile archive format.
- **MBTileServer** is an application for serving raster and vector map tiles from MBTiles archives. Storing all map data in MBTiles files greatly simplifies the backend architecture by eliminating the need for separate database and data access layers. MBTileServer reads the MBTiles archives and provides a catalog that can be used by the application to get information about available tilesets.
- **MapLibre GL JS** is a community-led fork of Mapbox GL JS, a popular JavaScript mapping library. It consumes vector and raster tiles from MBTileServer and renders them client-side according to a style sheet. The library uses WebGL for rendering, allowing the map to take advantage of hardware acceleration.
- **Nominatim** is a geocoding server that looks up geographic coordinates based on an address or place name. It uses data from the OpenStreetMap project and powers the map search feature of the data viewer.
- **Preact** is a lightweight, open source component framework with an API similar to React. It provides tools for managing application state and keeping the user interface in sync with the state. Adopting a component-based approach allowed the application and user interface to evolve as model results became available.

5 USAGE PATTERNS

The Master Plan Data Viewer had its public launch on January 6, 2023. During the first four months after its launch, it was used by 1,762 unique users, who used the viewer for 4 minutes and 30 seconds on average. Of these users, 270 started the guided tour pathway, and 140 completed it. Average dwell times on the guided tour slides ranged from 14 seconds to 39 seconds. The tabs in the explore pathway were each viewed by between 484 and 1,193 users. After land change, the projects tab was the most viewed despite being the last in order. It also generated the most engagement, with users spending 3 minutes and 27 seconds on average.

During the first four months in production, 806 users changed at least one of the interactive map controls, such as selecting an implementation year or changing the environmental scenario. In total, these interactive controls were changed 19,259 times during this period. In addition, 655 users selected a total of 7,148 projects or geographic areas by clicking them on the map or selecting them from the project list or search results.

These initial usage statistics highlight the importance of providing multiple content pathways to serve distinct audiences. While the guided tour slides were viewed by a relatively small share of the overall users, they were also used by CPRA staff in public meetings and presentations and had a greater reach than the usage numbers suggest. The dwell times and interactivity numbers in both pathways suggest a high level of engagement with the interactive features of the map.

6 FUTURE WORK

While work on the Master Plan Data Viewer ended in December 2022, PSC continues to partner with CPRA on visualizing and sharing data from the master plan process. A data access portal, currently under development, will provide researchers with more detailed data and forecasts. The enhancements and features planned for the data access portal include:

- **Use compute resources for the tile generation pipelines.** The Master Plan Data Viewer includes approximately 150 map tilesets, which were generated on a virtual machine running on Bridges-2. The data access portal is expected to include more than 900 tilesets. We plan to run the tile generation pipelines in parallel by directly leveraging Bridges-2 compute resources.
- **Provide access to time series data.** The data access portal will allow users to view and download time series datasets. We plan to develop a REST API to serve the time series data from a database.
- **Allow selection of multiple geographies.** Users of the data access portal will be able to select multiple geographies of interest, including hydro compartments and ecoregions. We plan to develop JavaScript code to combine data for the selected geographies in the user's browser.

Beyond the development of the data access portal, possible future improvements include integrating the map tile generation into the model output post-processing pipeline, and adding mapping capabilities to the existing quality assurance portal, which is used by CPRA staff to review model outputs.

7 CONCLUSION

The CPRA Master Plan Data Viewer project demonstrates a collaborative approach to visualizing and presenting complex results from models run on high performance computing resources. It highlights some of the key questions and considerations inherent in designing interactive visualizations:

- **Audience:** Who are the audiences for the visualization?
- **User experience:** What entry points and pathways are appropriate for the audiences based on their current knowledge? What types of interactivity are most helpful?
- **Architecture:** Can elements of the visualization be prerendered to increase performance? Can open source tools and libraries be leveraged?
- **Evaluation:** What types of usage data are available? Are the planned entry points and pathways being used as intended?

Our experience with the CPRA Master Plan Data Viewer shows that attention to user experience considerations is key to sharing scientific data with diverse audiences. It also shows how open source tools and frameworks can be combined to create a simple software architecture with good performance and low ongoing maintenance costs. We believe this effort can serve as a model for future efforts to broaden the reach of high performance computing beyond the scientific community to engage directly with policymakers and the public.

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