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2017 Coastal Master Plan

Attachment C4-1: Modeling Quality Assurance and Quality Control (QA/QC)

Report: Version I

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Coastal Protection and Restoration Authority

This document was prepared in support of the 2017 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 five 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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Executive Summary

A concerted effort was undertaken to ensure thorough quality assurance / quality control (QA/QC) of the 2017 Coastal Master Plan modeling effort. All components of the modeling effort were subject to QA/QC, including input and output data associated with the Integrated Compartment Model (ICM), Ecopath with Ecosim (EwE), Advanced Circulation (ADCIRC) and Simulating Waves Nearshore (SWAN) models, and the Coastal Louisiana Risk Assessment (CLARA) model. These reviews were conducted by topical experts involved in the modeling with technical assistance from the Coastal Protection and Restoration Authority (CPRA) and/or The Water Institute of the Gulf, where needed. Project-level model runs and associated QA/QC was followed by alternative-level model runs and QA/QC. Several new resources, including additional spatial maps, were used during alternative-level QA/QC to help team members interpret broad patterns of change across the coast in model runs containing many projects.

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List of Abbreviations

ADCIRC	Advanced Circulation
CLARA	Coastal Louisiana Risk Assessment
CPRA	Coastal Protection and Restoration Authority
DEM	Digital Elevation Model
EAD	Estimated Annual Damage
EwE	Ecopath with Ecosim
FEMA	Federal Emergency Management Agency
FWA	Future With Action
FWOA	Future Without Action
HSI	Habitat Suitability Index
ICM	Integrated Compartment Model
LMI	Low-to-Moderate Income
QA/QC	Quality Assurance and Quality Control
RL/SRL	Repetitive Loss or Severe Repetitive Loss
RMS	Root Mean Square
SWAN	Simulating Waves Nearshore
TKN	Total Kjehldhal Nitrogen
TSS	Total Suspended Sediment
USACE	U.S. Army Corps of Engineers

1.0 Introduction

The goals of the 2017 Coastal Master Plan modeling Quality Assurance and Quality Control (QA/QC) process were to ensure that the model runs were set up correctly and that the model(s) performed appropriately. This appendix details the QA/QC process for both project-level and alternative-level output from the Integrated Compartment Model (ICM), the Ecopath with Ecosim (EwE) model, the Advanced Circulation (ADCIRC) and Simulating Waves Nearshore (SWAN) models, and the Coastal Louisiana Risk Assessment (CLARA) model. Project-level QA/QC was not intended to be an evaluation of project effects. During QA/QC, unusual changes in parameters or distribution patterns were identified as potential errors in the model or in input files. If an error was suspected, further investigation was performed to diagnose the source and remedy the problems for future model runs to the extent possible. Alternative-level QA/QC focused both on model performance and on interpreting and documenting regional changes over the 50-year simulations.

2.0 Integrated Compartment Model (ICM)

The ICM simulations were conducted by one of three modeling teams, each with several modelers. For each subroutine (e.g., hydrology, morphology, vegetation, etc.), either the subroutine developers or other topical experts were identified to participate in the QA/QC process. Tracking and documentation occurred via a QA/QC checklist. This section outlines how the information that underwent QA/QC was selected and how the overall process was undertaken. Throughout the ICM section, both hydrology compartments and ecoregions are referenced. Figure 1 shows the hydrology compartments, and Figure 2 shows the ecoregions. There are 946 hydrology compartments across the coast and 12 ecoregions. Ecoregions are defined in Attachment C3-22 ICM Development.

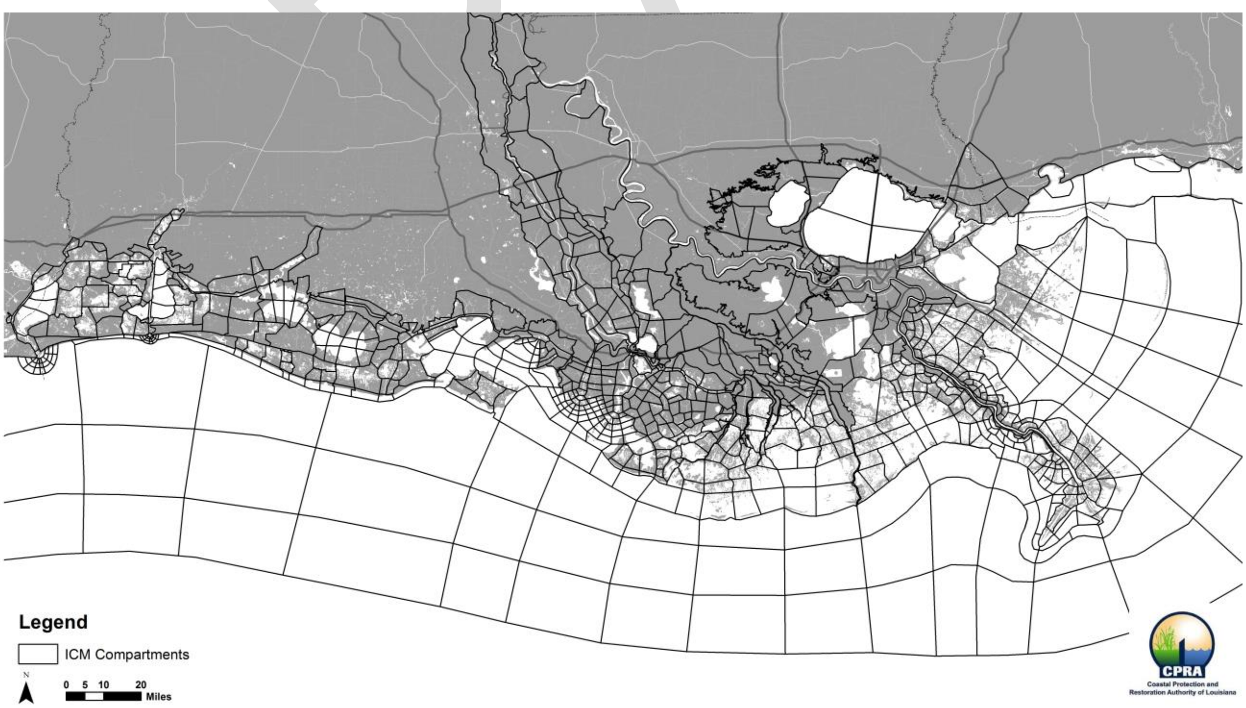

Figure 1: Hydrology Compartments within the Integrated Compartment Model.

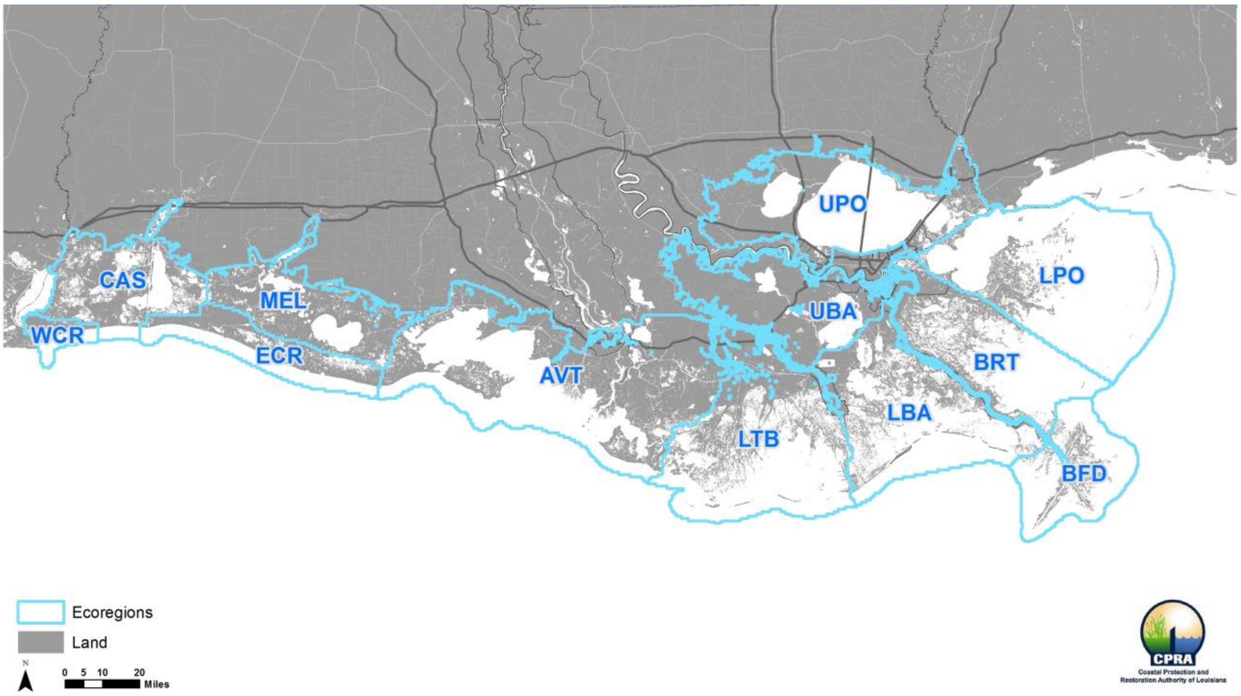

Figure 2: 2017 Coastal Master Plan Ecoregions.

2.1 Project-level Set-up

The purpose of reviewing the project level set-up in the ICM was to ensure that model features (e.g., design elevations of levees and marsh creation projects, size of hydraulic control features, etc.) were appropriately configured and that correct input files (e.g., correct sea level rise and subsidence rates) were used. When a project was put into the ICM model grid, changes were made to the hydrology (grid links), Digital Elevation Model (DEM), etc. as needed (see Chapter 4 Model Outcomes and Interpretations) for more details on project set up in the ICM). These changes were documented by the modeler setting up that project in a QA/QC checklist. Teams clearly documented changes made to model attributes and input files and an additional team member confirmed that the changes were correctly made and were accurately documented before the run began.

The modeler responsible for setting up a particular simulation identified a minimum of five hydrology compartments within the anticipated project influence zone. A subset of compartments was selected as it would have been time prohibitive to analyze output in all 946 compartments within the model grid. Additional compartments were identified outside the expected project influence zone (these were referred to as 'mid-point' compartments) to ensure there was no overlap of project effects in cases where multiple projects were included in a single model run. The Coastal Protection and Restoration Authority (CPRA) and The Water Institute of the Gulf reviewed the compartment selections prior to the beginning of each model run. The compartments were identified in the QA/QC checklist for each model run, and these compartments were considered the primary "compartments of interest" during QA/QC.

The implementation year was defined for individual projects as part of the project attributes. In the QA/QC procedure this was termed the "project year." It was assumed that a project was implemented (i.e., put into the ICM grid) on the first day of the project year. The pre-project year was defined as the year before the project year. Output from both pre-project year and project year was inspected, as described below, to ensure the project features were appropriately included and/or causing change within the model grid or relevant model dynamics.

The next step was to conduct the model runs. Simulation outputs were reviewed by each model subroutine team, as described below. Output reviews included comparisons of project run outputs over time, comparisons of project run outputs to future without action (FWOA), and comparisons of output across low, medium, and high environmental scenarios. Refer to Chapter 3, Section 2 for more information on the environmental scenarios.

2.2 Project-Level Outputs

The following sections provide example ICM outputs used by subroutine team members and the comparisons that were made during QA/QC of the project-level simulations. Outputs and intermediate data were reviewed by subroutine developers or informed modelers using several formats generated specifically for the QA/QC process. Specific scripts were written to automate the generation of these files. If issues of concern were raised by a subroutine reviewer, the larger modeling team was notified and further investigations were conducted to either interpret the output or identify if an error had indeed occurred. In the event an error was discovered, the error was resolved and the model was re-run.

2.2.1 Hydrology

The hydrology subroutine members reviewed stage, salinity, sediment, and Total Kjeldahl Nitrogen (TKN) output as part of the project-level QA/QC process. These variables were selected, as they are considered key inputs for subsequent ICM subroutines such as morphology, vegetation, HSIs, and EwE.

For stage, the team reviewed bar charts of mean stage for future with action (FWA) minus future without action (FWOA) in all compartments (Figure 3), root mean square (RMS) of daily max/min stage (tidal range) for future FWA minus FWOA (Figure 4), and time series line plots of daily stage for FWA compared to FWOA in compartments of interest (Figure 5).

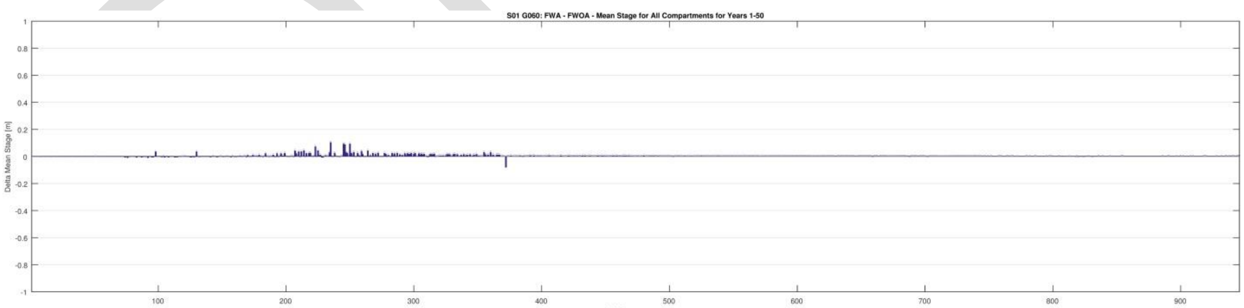

Figure 3: Example of 50 Years Mean Stage Difference (FWA-FWOA) in All Compartments.

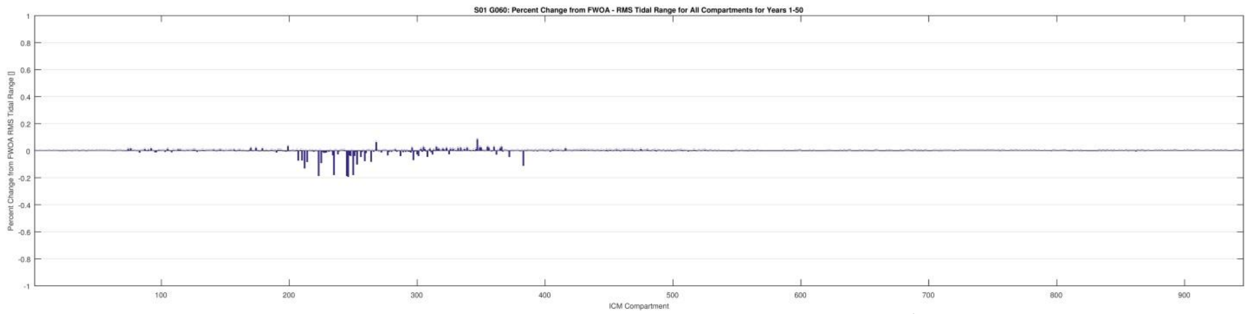

Figure 4: Example of 50 Years RMS Tidal Range Percent Change (FWA-FWOA) in All Compartments.

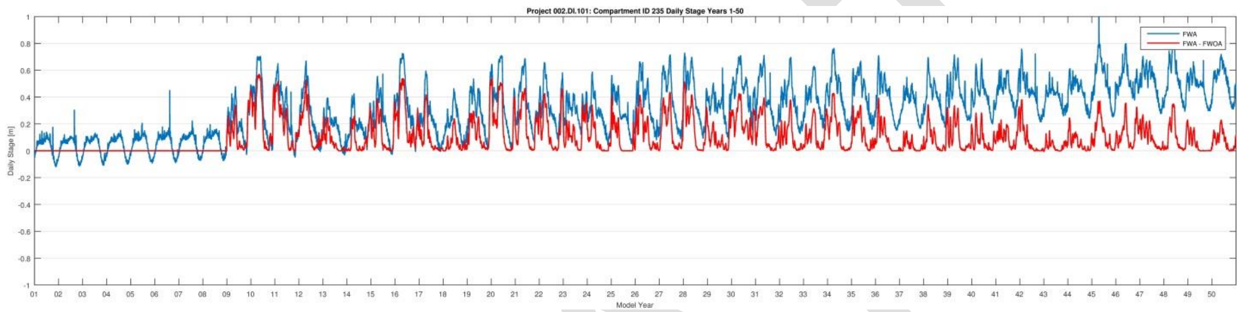

Figure 5: Example Time Series of Daily Stage (FWA and FWOA) in Compartments of Interest.

For salinity, the team reviewed bar charts of mean FWA salinity compared to FWOA in all compartments (Figure 6) and time series plots of monthly mean salinities for FWA compared to FWOA (Figure 7) in compartments of interest.

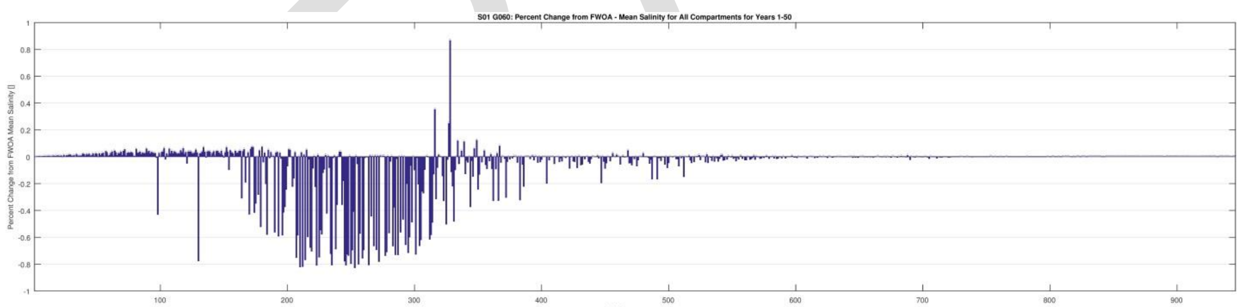

Figure 6: Example of 50 Years Mean Salinity Percent Change (FWA-FWOA) in All Compartments.

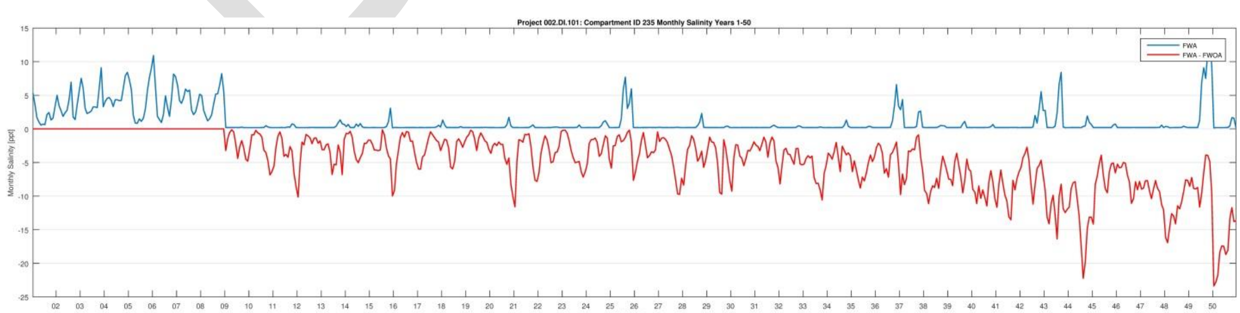

Figure 7: Example Monthly Mean Salinities for FWA and FWOA in Compartments of Interest.

For sediment, the team reviewed bar charts of mean sediment accumulation in open-water (Figure 8), marsh interiors (Figure 9), and marsh edges (Figure 10) for FWA compared to FWOA in all compartments. Open-water mean total suspended sediment (TSS) and standard deviations were also reviewed for FWA compared to FWOA (Figure 11).

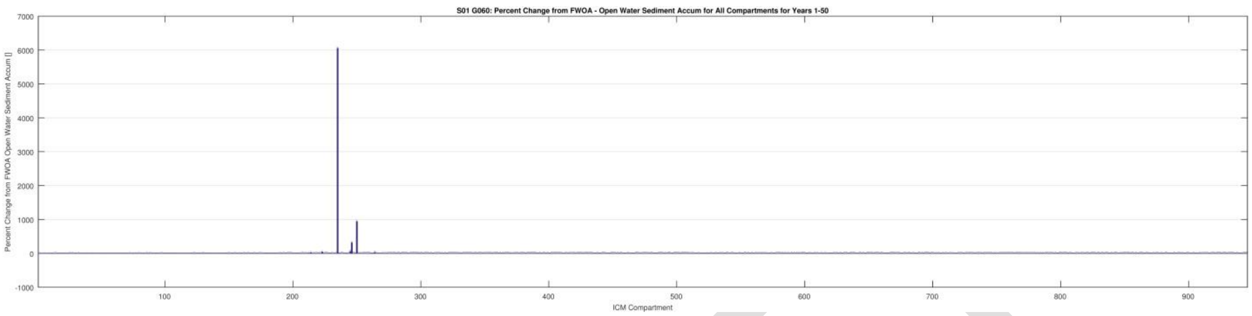

Figure 8: Example Open-Water Sediment Accumulation Percent Change (FWA-FWOA) in All Compartments.

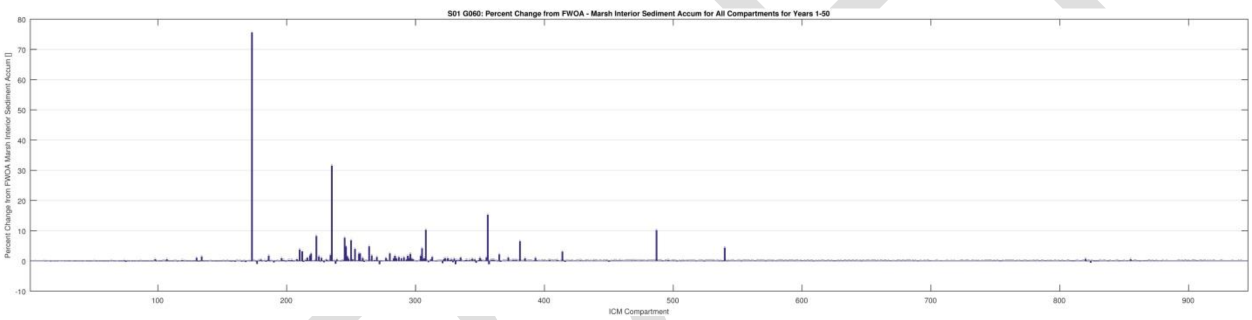

Figure 9: Example Marsh Interior Sediment Accumulation Percent Change (FWA-FWOA) in All Compartments.

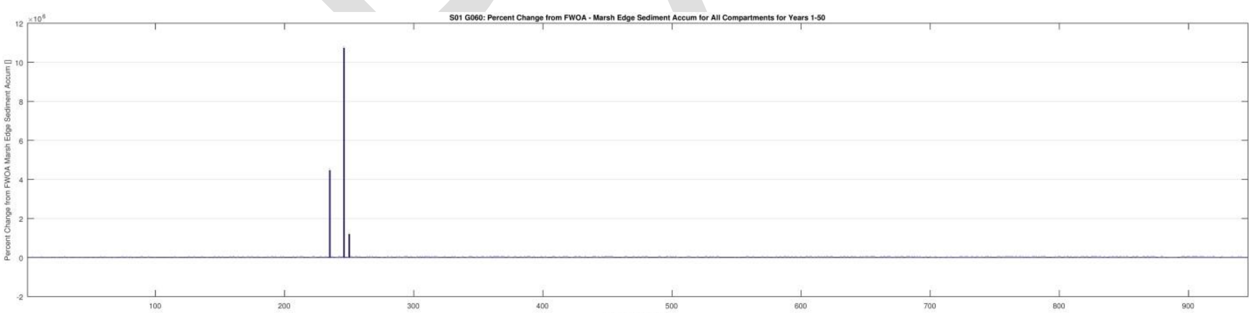

Figure 10: Example Marsh Edge Sediment Accumulation Percent Change (FWA-FWOA) in All Compartments.

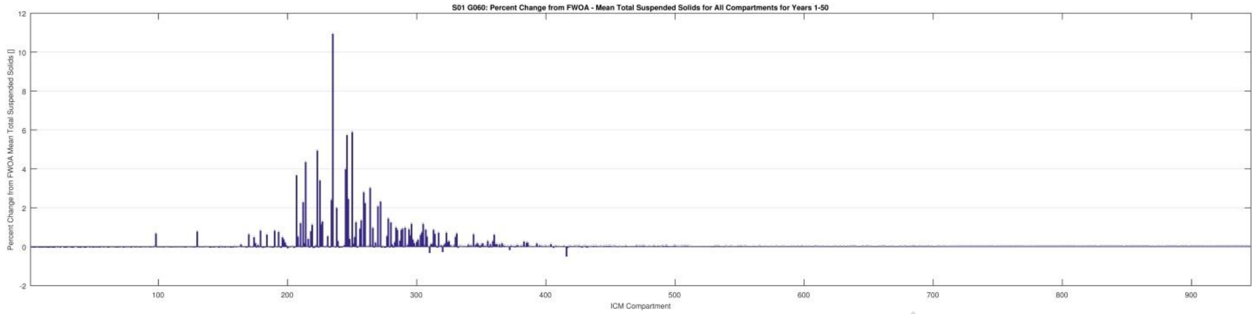

Figure 11: Example Open-Water Mean TSS and Standard Deviations for FWA Compared to FWOA in All Compartments.

For TKN, the team reviewed bar charts of mean FWA TKN concentrations compared to FWOA in all compartments (Figure 12). The team also reviewed time series plots of monthly mean TKN for FWA compared to FWOA in compartments of interest (Figure 13).

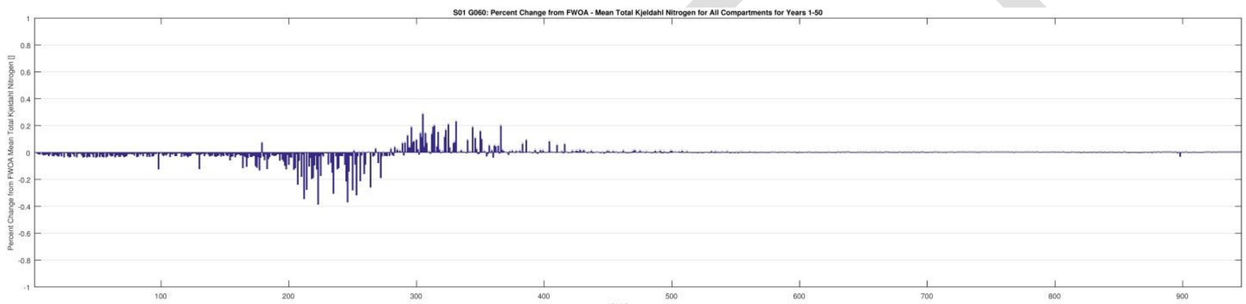

Figure 12: Example of 50 Years Mean TKN Percent Change (FWA-FWOA in All Compartments).

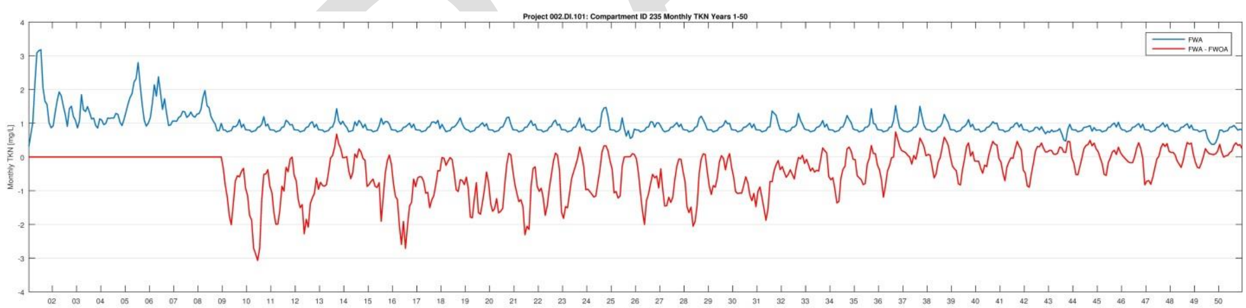

Figure 13: Example of Monthly Mean TKN for FWA Compared to FWOA in Compartments of Interest.

In addition to the compartments of interest, model output from FWA was compared to FWOA for mid-point compartments (Figure 14). These mid-point compartments were examined to ensure that two projects included in the same model run were sufficiently far apart and that there was a region within the model that was not impacted by either project. If no such compartment could be found, it would indicate that the projects were interacting within the model run. This would prevent the assessment of each project's individual effects. To prevent projects from interacting with one another within the model, large-scale projects with an anticipated far field effect (e.g., river diversions) were run independently from any other projects.

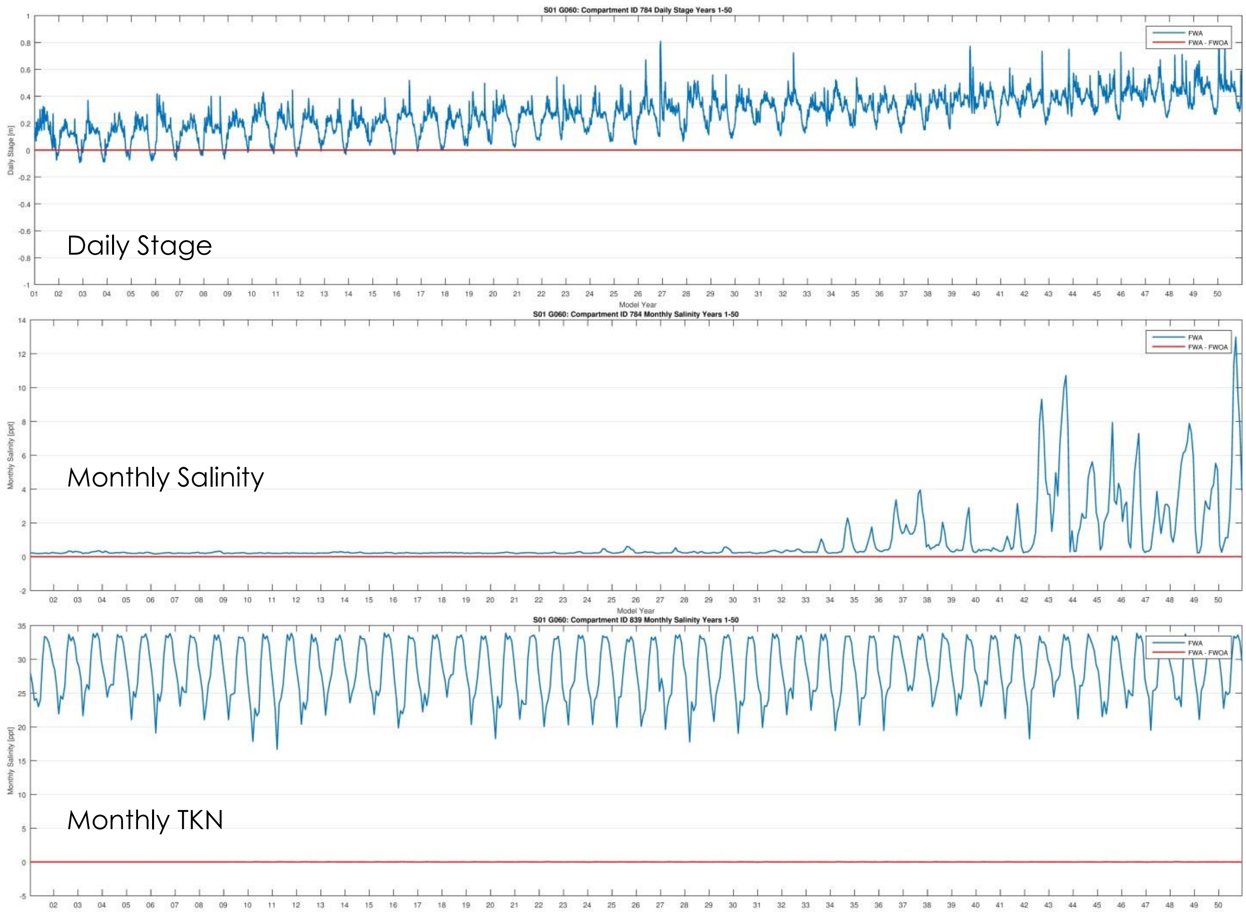

Figure 14: Examples of Stage, Salinity, and TKN FWA Compared to FWOA in Mid-Point Compartments.

2.2.2 Morphology

The morphology subroutine team evaluated several types of output to determine if patterns of land change over time from project-level model runs were reasonable. Both coast wide and zoomed-in land/water maps at years 1, 10, 20, 30, 40, and 50 for FWA compared to FWOA were evaluated. Decadal change was assessed by visual inspection of difference maps, which were generated by comparing land/water (Figure 15), elevation (Figure 16), and datasets from both FWA and FWOA. Figure 16 also demonstrates the change in elevation due to diversions off of the Mississippi River, causing an elevation gain in upstream regions and a loss in elevation at the Bird's Foot Delta. Tabular summaries of land area (km^2) for FWA compared to FWOA in each ecoregion were also reviewed. Lastly, the team assessed line graphs of land area for FWA compared to FWOA in compartments of interest. In some cases, the morphology subroutine team referred to aforementioned hydrology outputs to help interpret patterns of change over time.

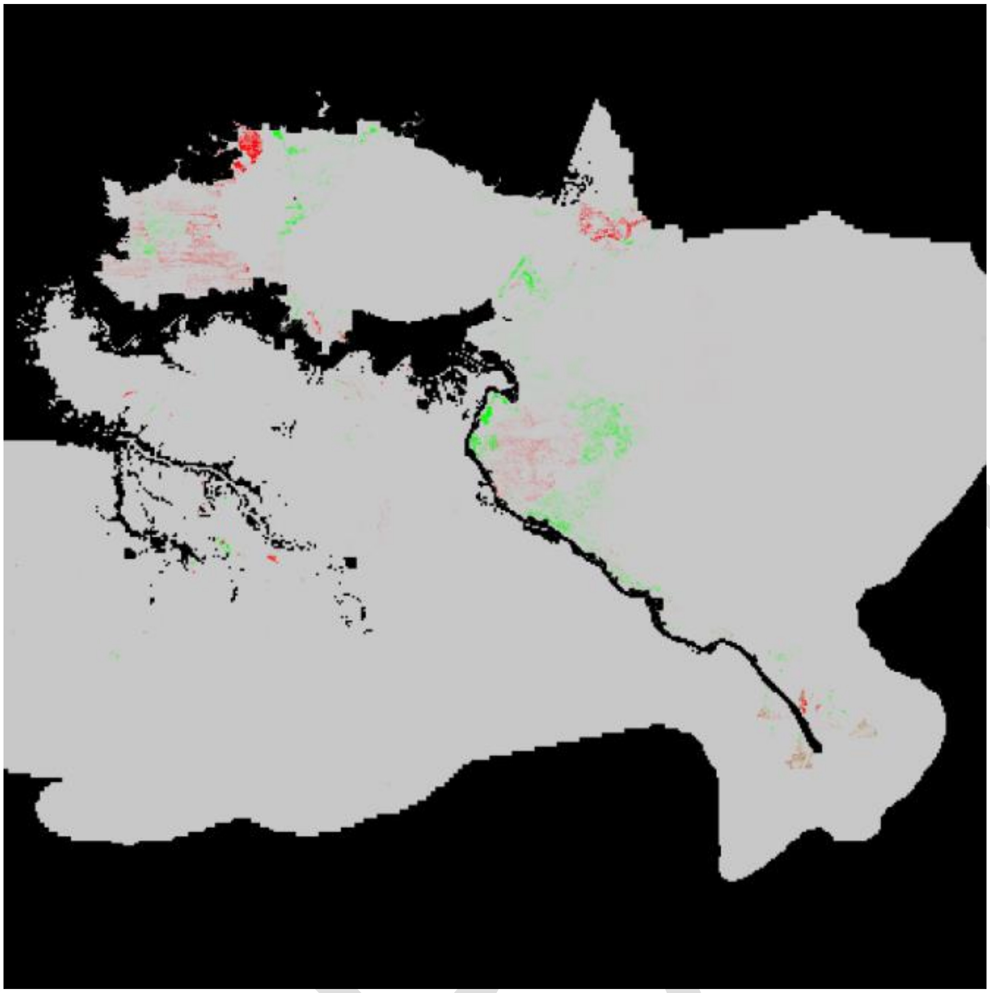

Figure 15: Example Land/Water Change at Year 50 (FWA-FWOA). Green/Red (Land Gain/Loss in FWA Compared to FWOA; Gray (No Change Between FWA and FWOA); Black (No Model Data).

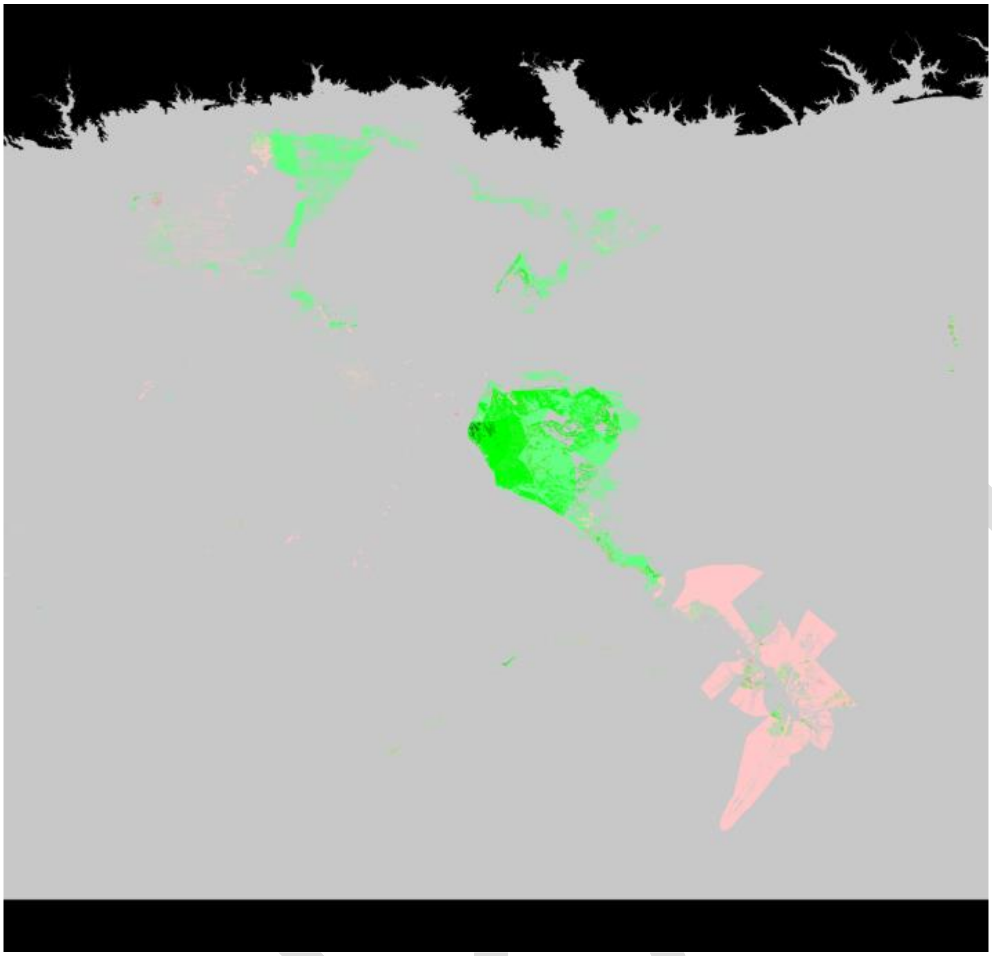

Figure 16: Example Elevation Change at Year 50 (FWA-FWOA). Green/Red (Higher/Lower Elevation in FWA Compared to FWOA); Gray (No Change Between FWA and FWOA); Black (No Model Data).

2.2.3 Barrier Islands

The barrier islands are divided into six island "regions" across coastal Louisiana. Regions include: Isle Dernieres, Timbalier, Caminada, Barataria, Breton, and Chandeleur (see Chapter 4 – Section 3 FWOA for maps of the regions). QA/QC of the island regions for FWA model runs were only conducted for those runs that contained barrier island projects. The barrier island subroutine team reviewed plan views of gulf side and bay side shoreline positions at years 1, 10, 30, and 50 (Figure 17) and representative cross sections at years 1, 25, and 50 (Figure 18) to evaluate model output and change in islands over time. The team also reviewed cross sections of select islands that had restoration projects at pre- and post-project years (Figure 19) to confirm the proper implementation of the projects in the model. Finally, the team examined cross sections of select islands where storm related impacts occurred (e.g., overwash or breaching) at pre and post-storm years (Figure 20) to confirm the proper implementation of the episodic storms in the model.

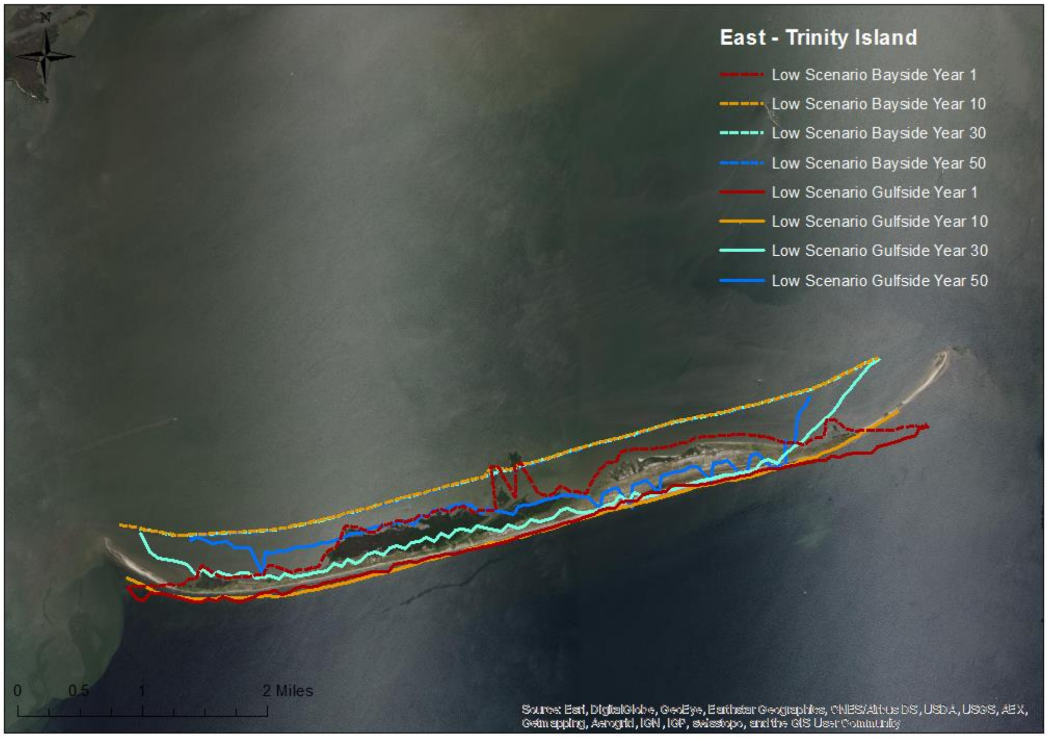

Figure 17: Example Plan View of Gulf Side and Bay Side Shorelines for Trinity Island Over 50 Years Under the Low Scenario.

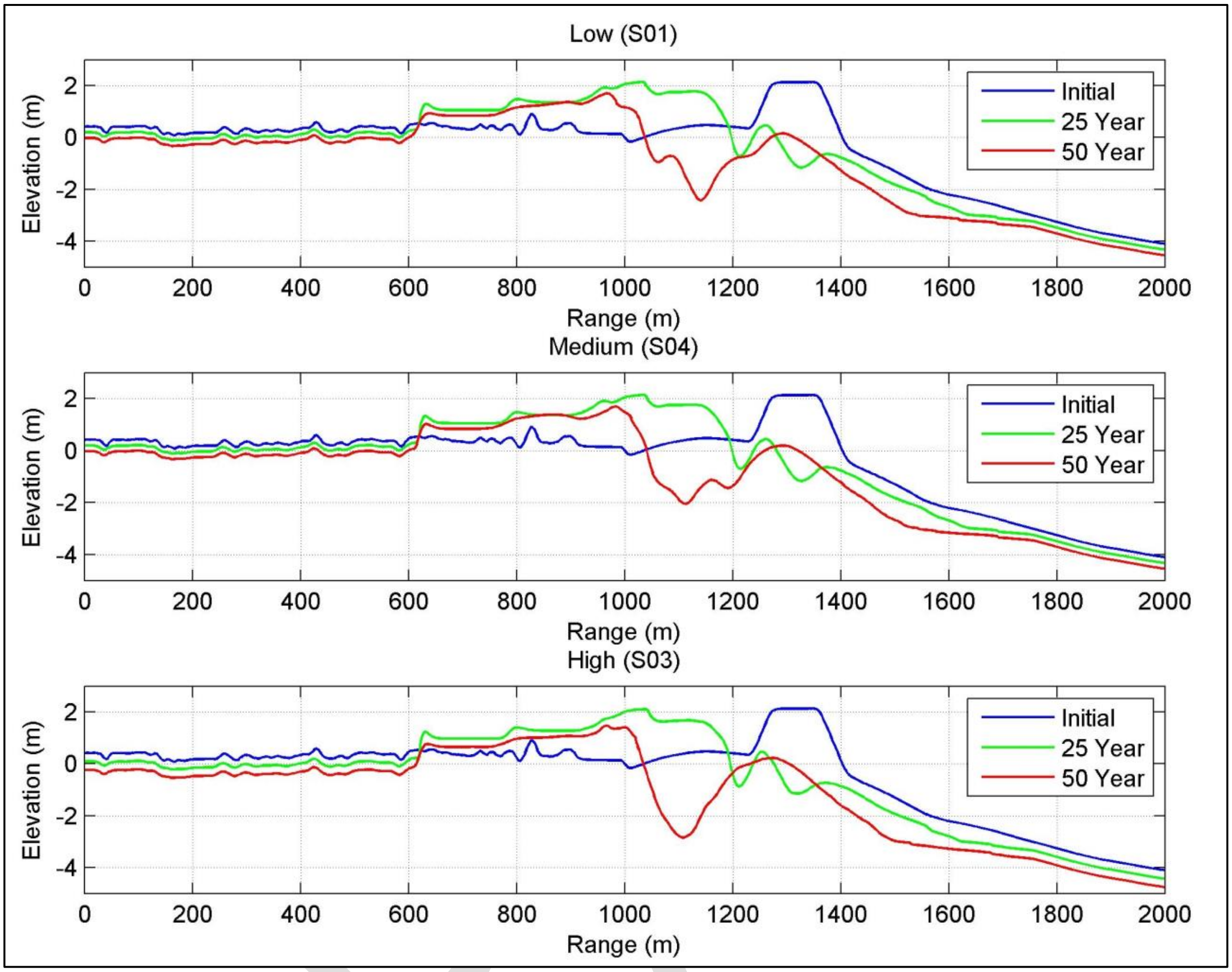

Figure 18: Example Cross Section Change Over Time for Low (S01), Medium (S04), and High (S03) Scenarios. Elevation is in Meters Relative to NAVD 88.

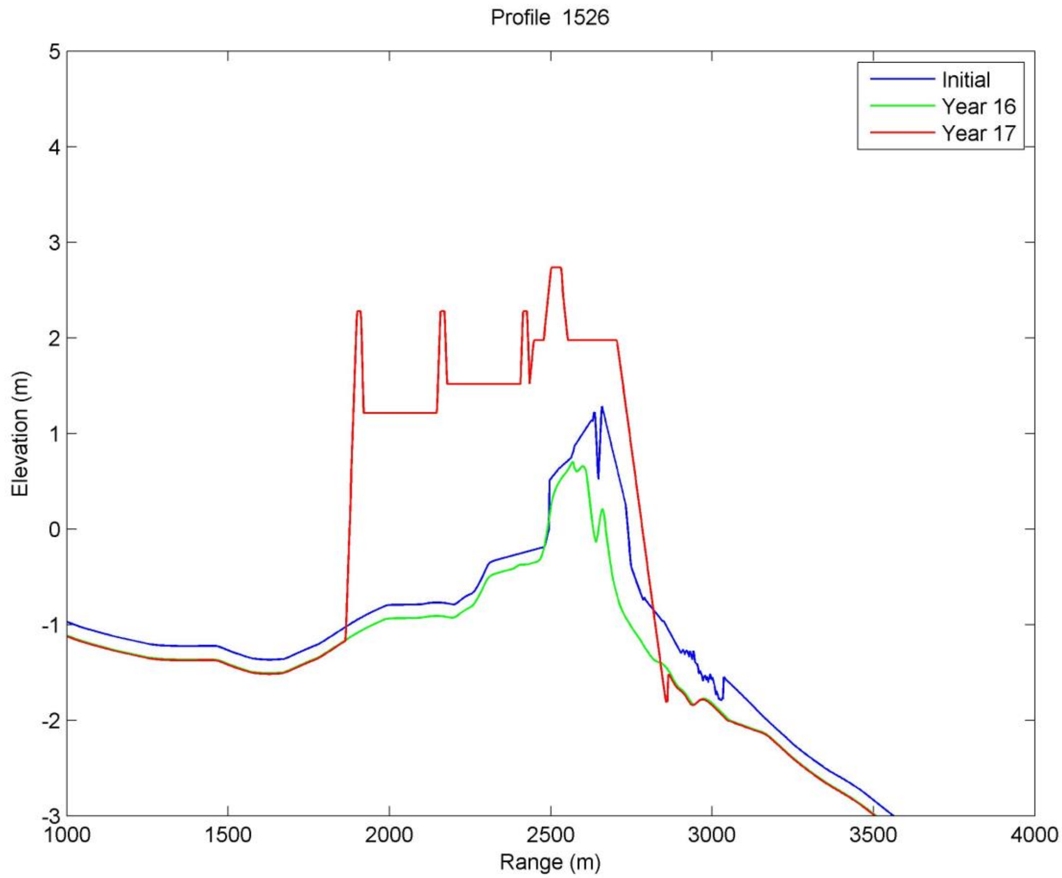

Figure 19: Example Cross Section Change at Pre and Post-Project Years. Elevation is in Meters Relative to NAVD 88.

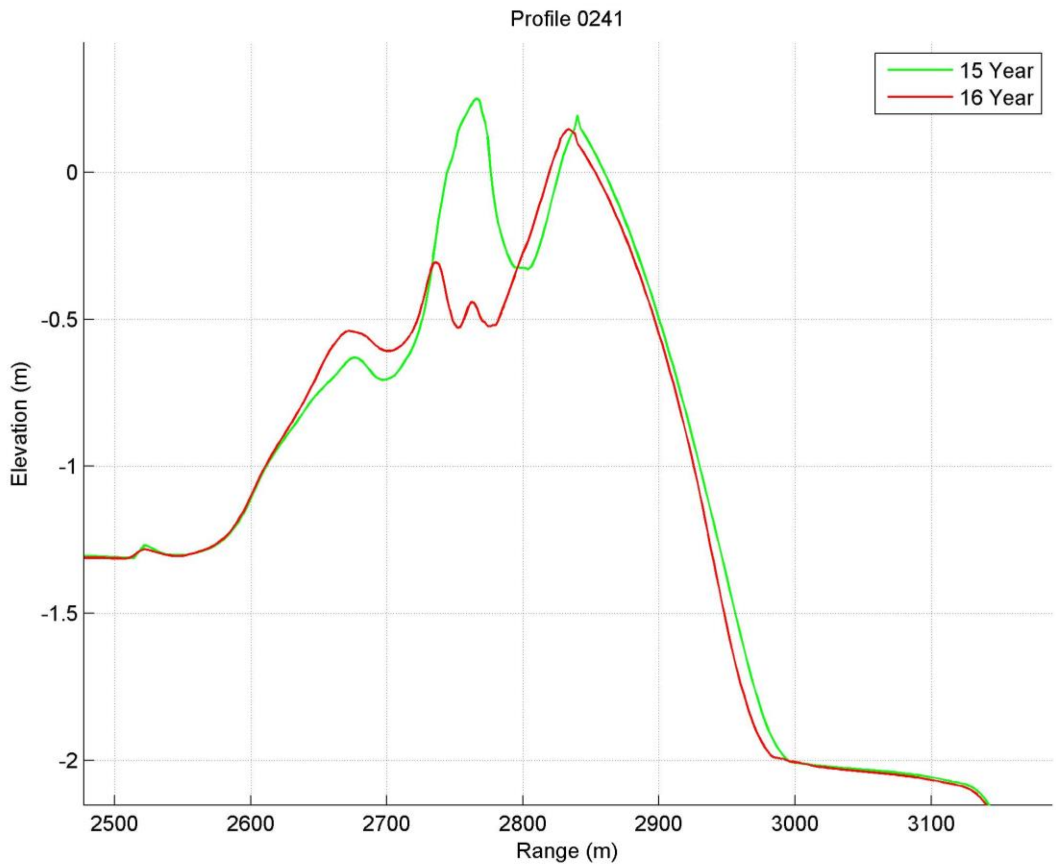

Figure 20: Example Cross Section Change at Pre and Post-Storm Years. Elevation is in Meters Relative to NAVD 88.

2.2.4 Vegetation

The vegetation subroutine team used bar charts showing differences in vegetative cover between FWA and FWOA for each wetland type and ecoregion (Figure 21). Comparisons were also made for FWA output (over time) to evaluate changes in vegetative cover (Figure 22). For FWA model runs containing barrier island projects, additional bar charts were checked for each barrier island region. In some cases, the vegetation subroutine team referred to aforementioned hydrology and morphology outputs to help understand patterns of vegetation change over time.

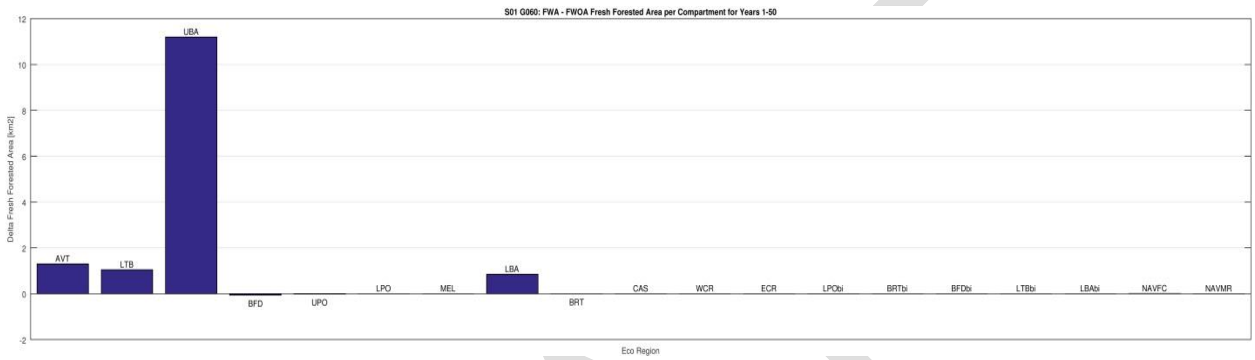

Figure 21: Example of Vegetation Area Change per Ecoregion (FWA-FWOA).

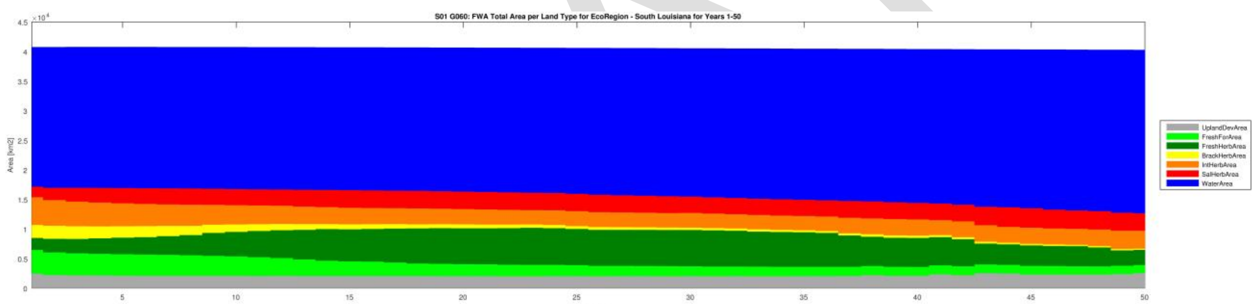

Figure 22: Example of Vegetation Type Coverage per Ecoregion (Colors Represent Different Vegetation Categories).

2.2.5 Habitat Suitability Indices (HSIs)

Developers of the following HSIs reviewed their HSI output, respectively: 1) all fish and shellfish, 2) alligator, 3) three waterfowl species and pelican, and 4) crawfish. The team used tabular HSI output in compartments of interest to compare FWA and FWOA outputs for both pre-project and post-project years, and line graph comparisons of FWA and FWA minus FWOA for relevant ecoregions (Figure 23). They also reviewed FWA minus FWOA for pre-project and post-project years for key HSI input variables (refer to Attachments C3-6 – C3-19 for HSIs inputs). In some cases, the HSI team referred to additional hydrology, morphology, and vegetation outputs to help understand patterns of change over time.

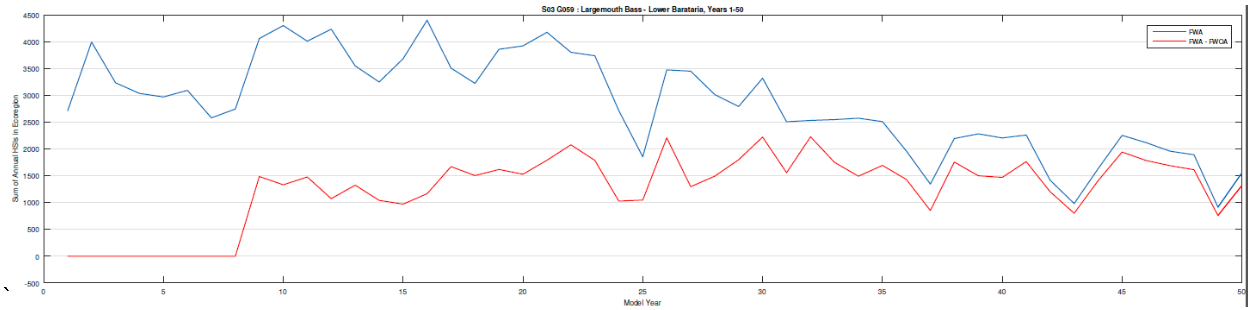

Figure 23: Example 50 Year Habitat Suitability Index Line Graph for One Ecoregion. This Example Output is for Largemouth Bass (Freshwater Species) in an Ecoregion Receiving a Sediment Diversion Starting in Year 9.

2.2.6 Ecopath with Ecosim (EwE)

To efficiently QA/QC the project-level output for all the species and groups included in the EwE model, a critical Ecospace end/start index of biomass was identified per species as an indicator of potential error in the simulation. The EwE model automatically calculated the ratio of biomass at the end of the model run versus the start of the model run, and flagged those which indicated impossible biomass increases or population crashes. The EwE team reviewed this index for each model run, and further scrutiny was performed for any model runs that were flagged.

2.3 Project-Level QA/QC Checklist

Because some project-level model runs contained more than one project, a single checklist file was created for each project, not for each model run. The checklists clearly identified the following:

- Name of person who performed the model run;
- Date of model run;
- Model run identifier (i.e., group number and scenario) using the 2017 Coastal Master Plan file naming convention;
- Project identifier and brief description of the project (e.g., 001_DI_17);
- Changes that were made to the ICM grid and link cross sections to implement a project;
- A series of 'logic' questions specific to each model subroutine team (designed to help focus the QA/QC effort);
- Name of model subroutine team members who reviewed and approved the output of the model run; and
- Confirmation that the model performed appropriately; if it did not perform appropriately, the entire ICM modeling team was notified and examinations were performed. In some cases, an actual error was uncovered, and the model set-up was corrected with the run being performed again. If this occurred, QA/QC was conducted a second time.

Each ICM subroutine had a point of contact that sent an email update to the overall ICM QA/QC point of contact at end of each workday. The ICM QA/QC point of contact then updated the entire ICM team (i.e., all subroutine team members) the following morning. Doing this allowed all team members to keep track of the status and identify if certain runs were delayed.

Each QA/QC checklist is archived along with the input and output files associated with each project-level run.

2.4 Project-Level QA/QC Lessons Learned

Upon completion of the project-level analyses, the ICM team was asked what, if anything, they would change about the process for future model runs, including alternative-level runs:

- The ICM team agreed that the coordination process used was quite efficient and that this practice should continue for future runs;
- The vegetation, morphology, and HSIs team agreed that it was helpful to have access to the hydrology output to help understand patterns of their subroutine outputs; and
- The HSI QA/QC team lead suggested that although future QA/QC efforts could continue to rely on multiple specialists (one person for fish and shellfish; one person for pelicans and the three waterfowl; one person for alligator; and one person for crawfish), as long as one person has a basic understanding of the HSI equations and the QA/QC process, he/she could adequately conduct the QA/QC and could consult specialists as needed.

2.5 Alternative-Level QA/QC Process

Alternative-level model runs contain many projects (e.g., approximately 100 in some cases). Projects span both restoration and protection project types, are located across the entire coastal area, and are implemented at different years throughout the 50-year model runs. Several changes were put into place for alternative-level QA/QC to account for these differences.

2.5.1 ICM Set-Up

Projects for alternative-level runs were set up using a lookup table. To ensure the lookup table had the accurate information, hydrology subroutine team members reviewed it and confirmed the attributes for the projects they set up during the project-level phase. In order to remove a level of potential human error, the implementation was automated. This is also helpful considering the number of projects included in each alternative run.

Before a model run began, cross-team checks were performed to ensure projects were set up correctly. This was done using shape files for each alternative with project IDs and implementation years and a lookup table to ensure attributes were correct. A modified QA/QC checklist was developed for use during the alternative-level model runs. Information regarding project set up was documented in these checklists.

2.5.2 Alternative-Level Output QA/QC

Because the nature of alternative-level runs (multiple projects) is different than single project-level runs, a number of changes were made to the QA/QC process. Unlike the project-level QA/QC, alternative-level QA/QC focused not only on ensuring proper model performance, but also on interpreting the output and documenting this as brief narratives by the subroutine teams. The narratives expound upon the key parameters examined and interpretations of changes seen over time in the western, central, and eastern regions of the coast over the 50-year simulations. For alternative-level QA/QC, team members relied on additional spatial maps in place of bar plots and line graphs. Overall, the QA/QC process for alternatives followed the same process in terms of review by individual subroutine teams as described above.

3.0 ADCIRC

Storm surge and waves QA/QC procedures were conducted to ensure that results were reasonable and model instabilities or set up errors were captured and corrected.

The first step of QA/QC began before the simulations took place. These steps ensured that the model inputs were reasonable. The inputs were reviewed in three ways:

1. Model topographic and bathymetric contours were visualized in two dimensions and compared to previously QA/QC'd model inputs for differences that were expected. Unexpected differences often meant that there was an error during model set up. An example of expected output is shown in Figure 24;
2. Model nodal attributes, including frictional parameters, were visualized in two dimensions and compared to previously QA/QC'd frictional inputs for reasonable changes. Examples are shown in Figures 25 and 26; and
3. Model-raised features were visualized in three dimensions. This ensured that a feature such as a levee was not mistakenly left with a low-elevation section that would allow flow to pass over/through it. An example is shown in Figure 27.

The second step in the QA/QC process was conducted following the model run and includes visualizing the maximum water surface elevation, maximum wave height, and peak period. These are the model outputs passed to the CLARA model and are also critical ADCIRC+SWAN model outputs that are best used to identify significant model errors. During QA/QC, each of these parameters were reviewed for each storm by two individuals who were looking for, but not limited to, ADCIRC model mass imbalance issues and unreasonable SWAN wave heights and peak periods. Example QA/QC images used for these checks are shown in Figures 28 through 30. Though only one frame is shown, nine frames were used in order to adequately QA/QC the entire coast.

Next, the water surface elevation was compared to previously reviewed results to ensure that there was a reasonable change in the values between simulation conditions. In the case of initial conditions, comparisons were made to the 2008 Federal Emergency Management Agency (FEMA) storm surge results (USACE, 2008a; USACE, 2008b). For simulations of various scenarios, comparisons were made to the initial conditions simulations because those serve as a baseline (Figure 31).

Finally, because water surface elevation is not only passed to the CLARA model in the form of maximum elevations but also in the form of time series of elevations, water surface elevation time series plots were generated for selected locations across the coast. These were reviewed to ensure that the water surface elevation results were smooth and free of significant errors such as oscillations, which can be difficult to identify by simply looking at maximum values. An example water surface elevation time series is shown in Figure 32.

At the conclusion of each of these checks, each reviewer noted observations on a shared spreadsheet. Once all checks passed, data were packaged for distribution to the CLARA model in netCDF format.

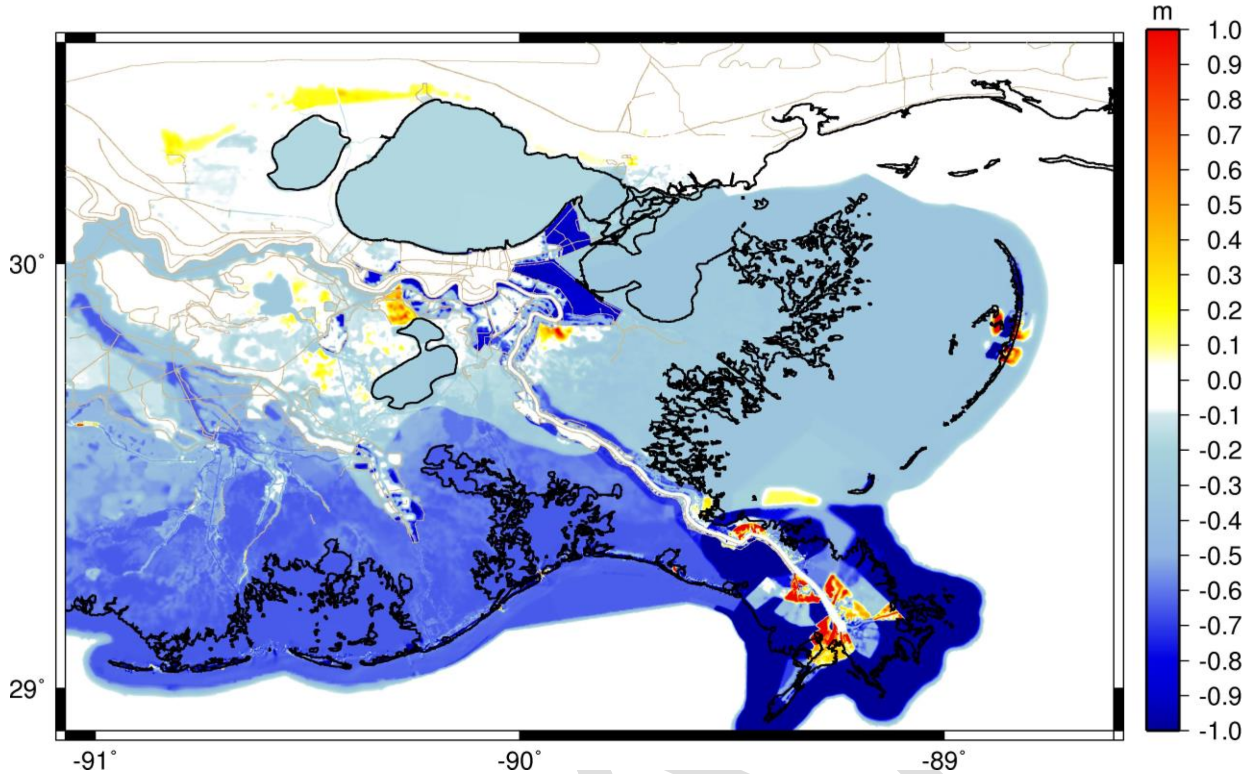

Figure 24: Example QA/QC Image to Observe Model Input Changes to Topography and Bathymetry (Elevation in Meters).

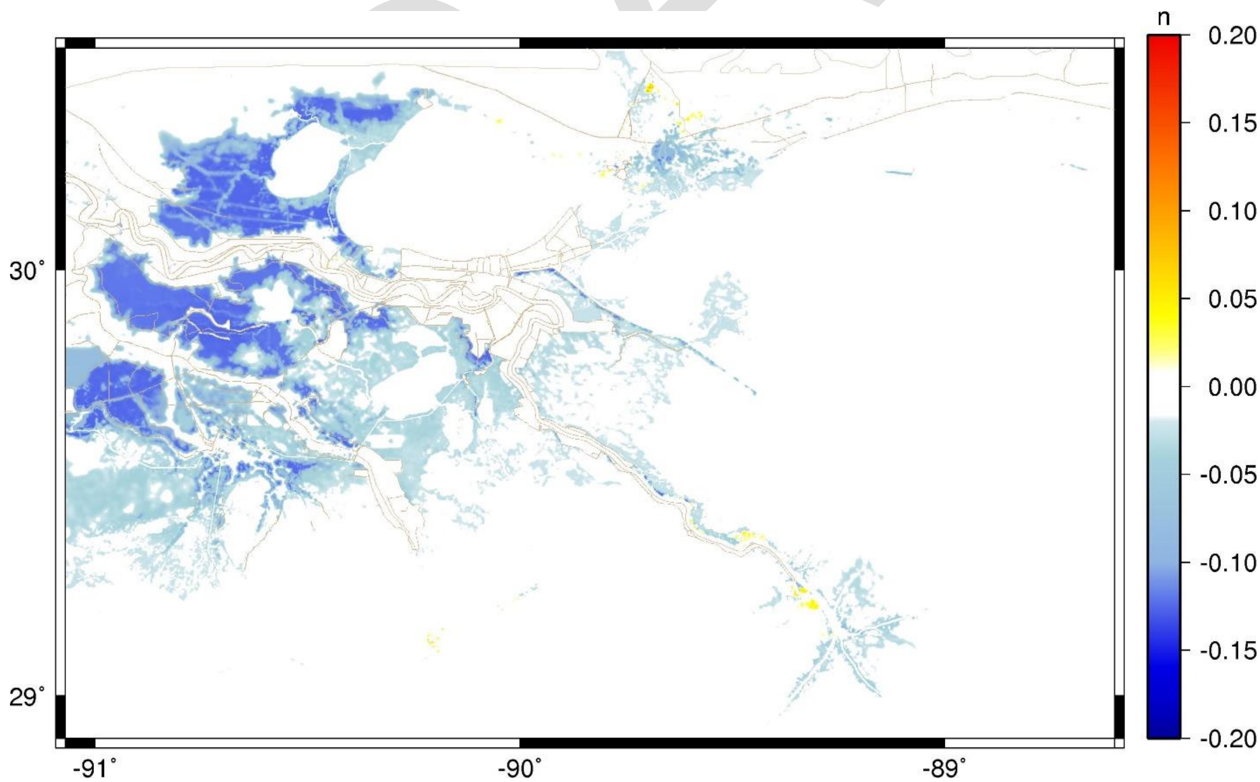

Figure 25: Example QA/QC Image to Observe Model Input Changes to Manning's *n* Roughness Coefficients.

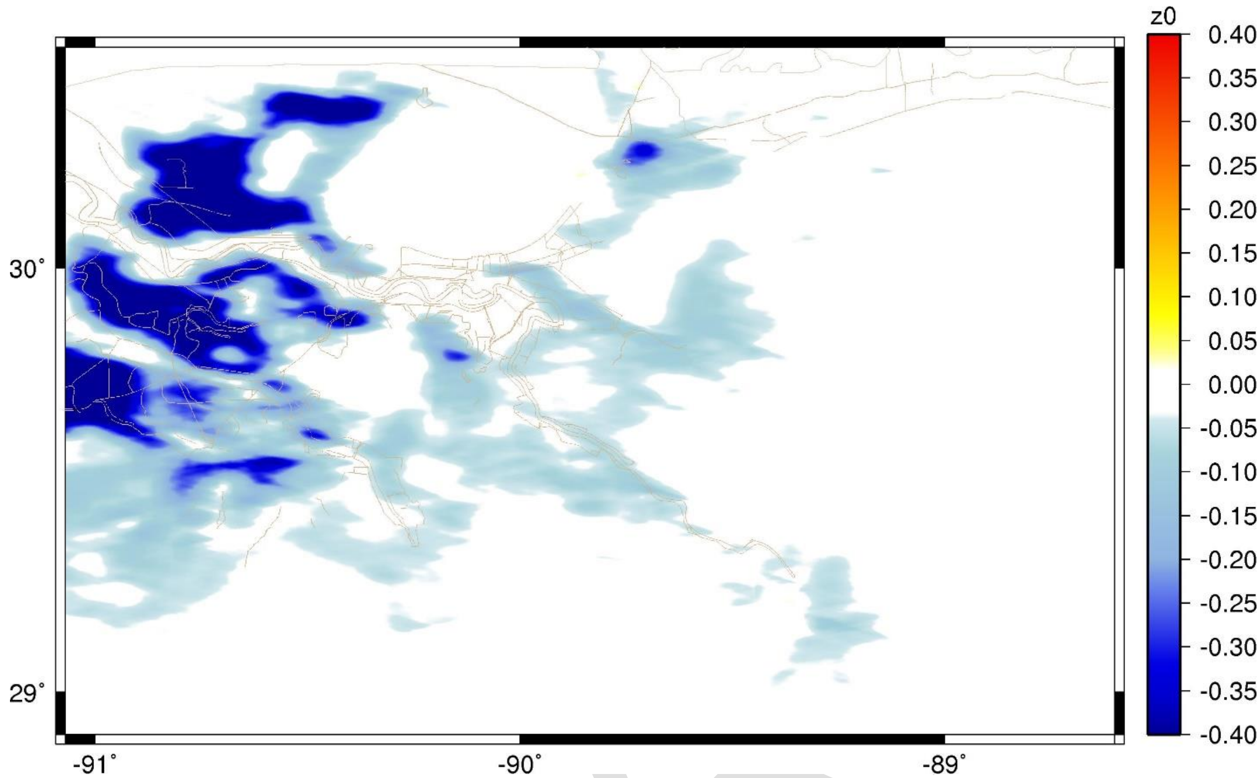

Figure 26: Example QA/QC Image to Observe Model Input Changes to Directional Roughness Length.

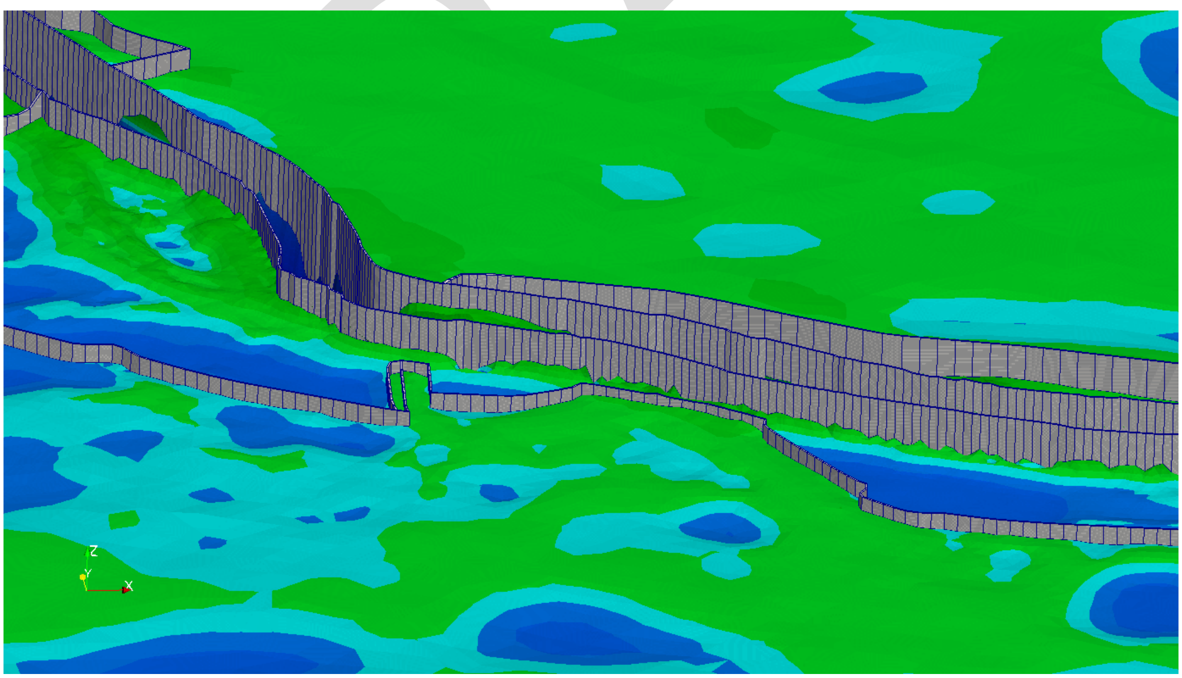

Figure 27: Example QA/QC Image Showing Elevations of the Mississippi River Levees (Image is Shown With Vertical Exaggeration).

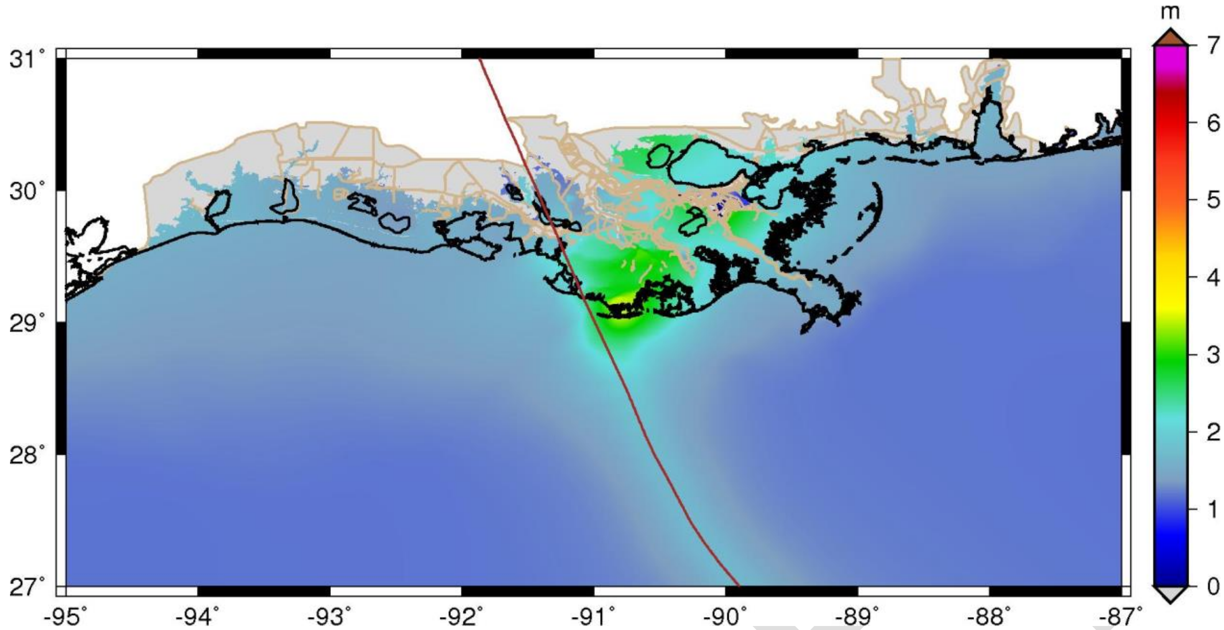

Figure 28: Example QA/QC Image Showing the Maximum Water Surface Elevation (m, NAVD88 2008.55) During a Simulation (Red Line Depicts Storm Track).

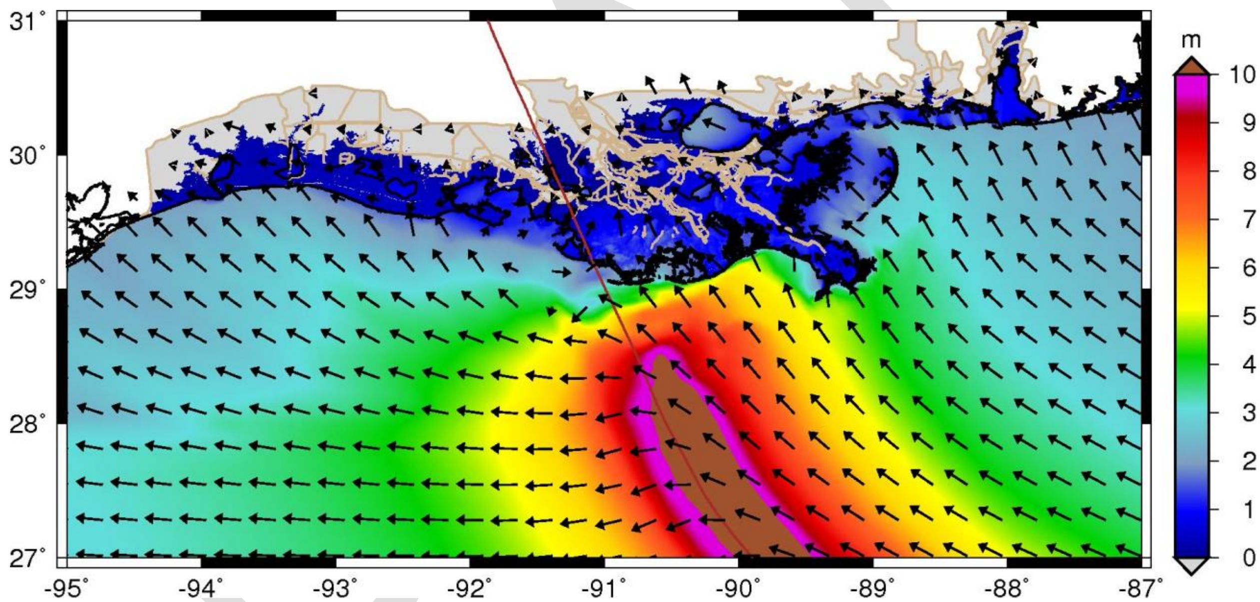

Figure 29: Example QA/QC Image Showing the Maximum Calculated Wave Height (m) and Associated Wave Direction (Red Line Depicts Storm Track).

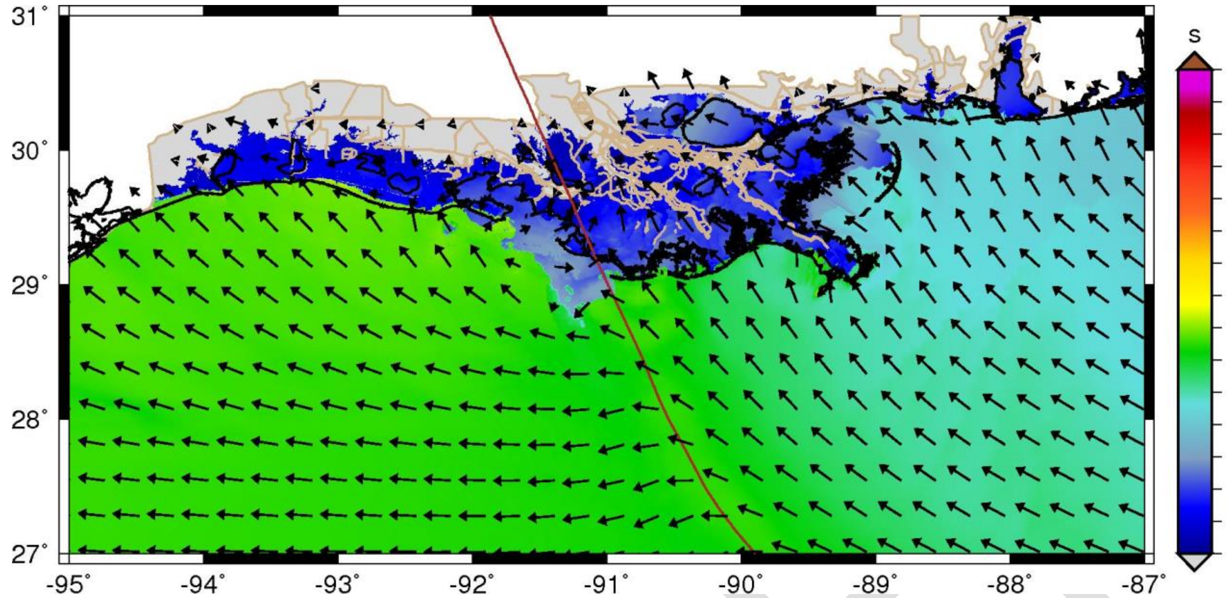

Figure 30: Example QA/QC Image Showing the Peak Wave Period (Seconds) and Direction Associated With the Maximum Wave Height (Red Line Depicts Storm Track).

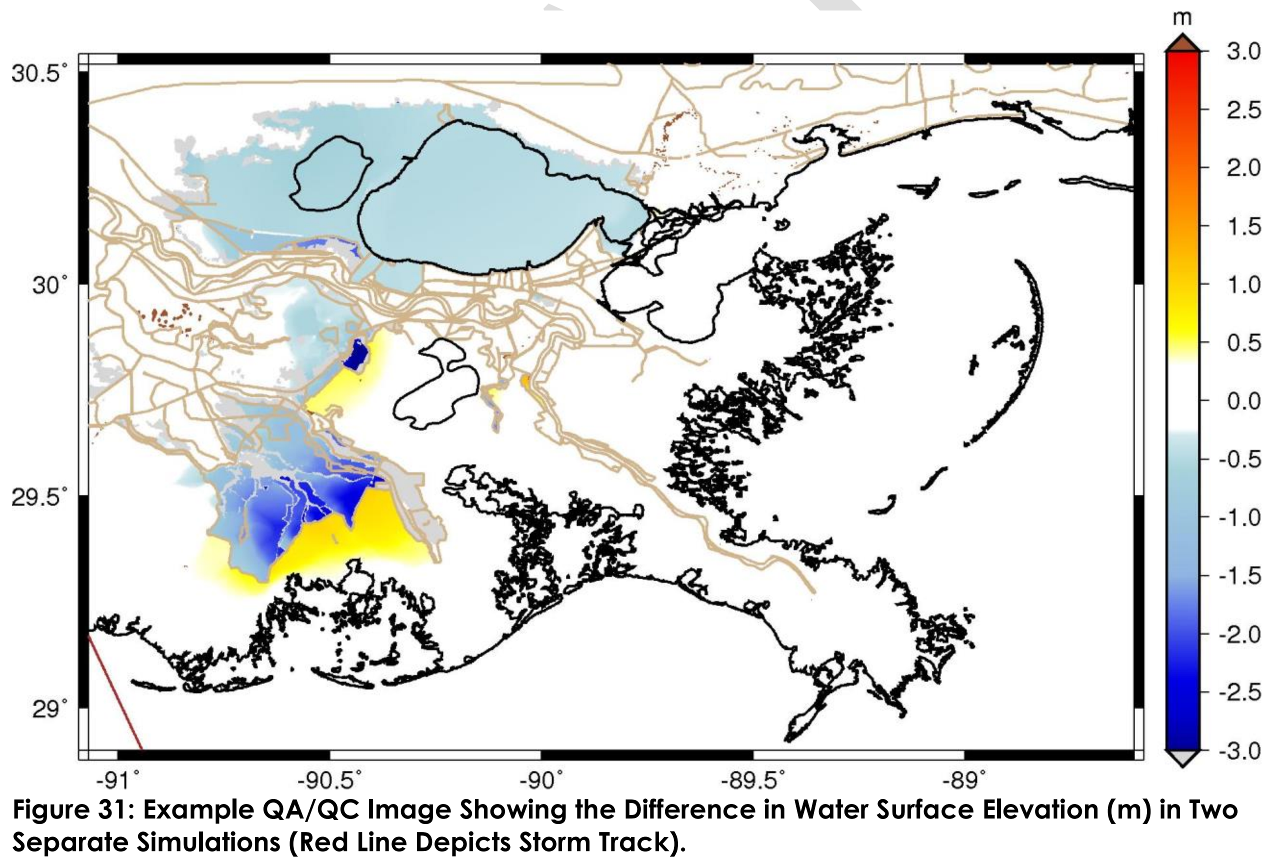

Figure 31: Example QA/QC Image Showing the Difference in Water Surface Elevation (m) in Two Separate Simulations (Red Line Depicts Storm Track).

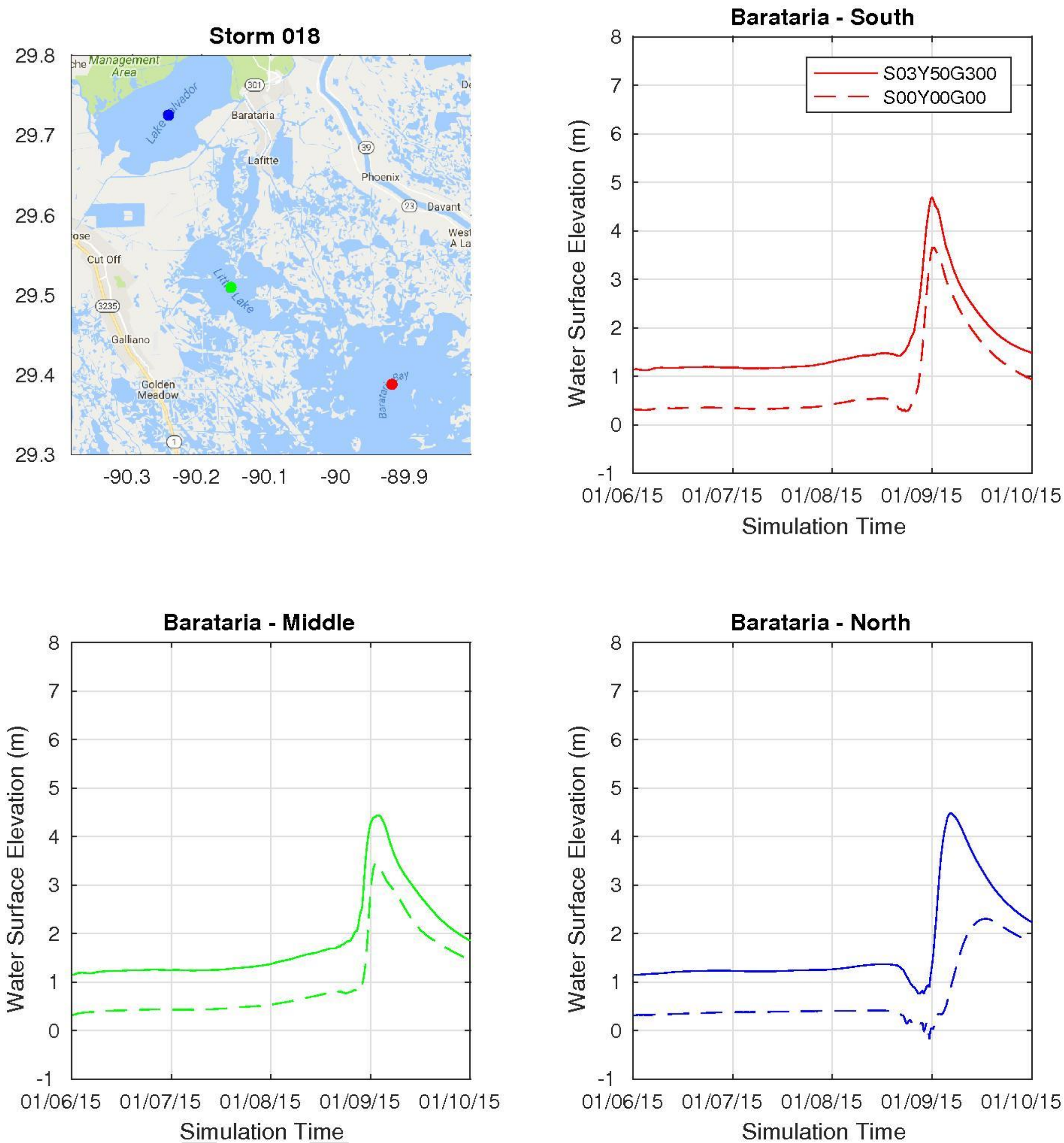

Figure 32: Example QA/QC Image Showing the Time Series of Water Surface Elevation at Three Locations in Barataria Bay and the Comparison to Initial Conditions.

4.0 Coastal Louisiana Risk Assessment (CLARA) Model

This section describes the policies and procedures followed by the CLARA development team for the purpose of assuring the quality of all results derived from CLARA and used in support of the 2017 Coastal Master Plan.

4.1 Input Data

CLARA relies on a variety of data sources in order to estimate flood depths and economic damage. To ensure data accuracy prior to initiating model production runs, the CLARA team reviewed input data sets that have not undergone prior quality assurance checks. Datasets reviewed by the team include, for example:

- CLARA enclosed protection system reach point elevations;
- Surge and wave input points for enclosed protected systems; and
- Asset inventory counts for all asset classes (structures inventory, historical sites, and critical infrastructure).

The CLARA team created a spreadsheet that lists input data sets and provides spaces for individual team members to both affirm that they have reviewed input data sets and to write down notes on each dataset. The CLARA Principal Investigator, technical lead, and lead model developer are all authorized to sign off on a dataset. A dataset can be used within the CLARA model provided one of these three RAND team members has affirmed the quality of the data set. The spreadsheet is then stored on a RAND server.

4.2 Results: Flood Depths

CLARA was run repeatedly, each time using a unique combination of parameters representing scenario, grid, and year. Each CLARA run produced a set of results that were used both to support QA and for use in the master plan analysis. These results included probability distribution functions for flood depths at grid points distributed across the study area. For instance, to ensure the quality and consistency of flood depth estimates produced during this process, maps of flood depth at the 10-, 50-, 100-, and 500-year exceedances were developed using the Tableau visualization software to aid with review and quality checks (see Figure 33 for example).

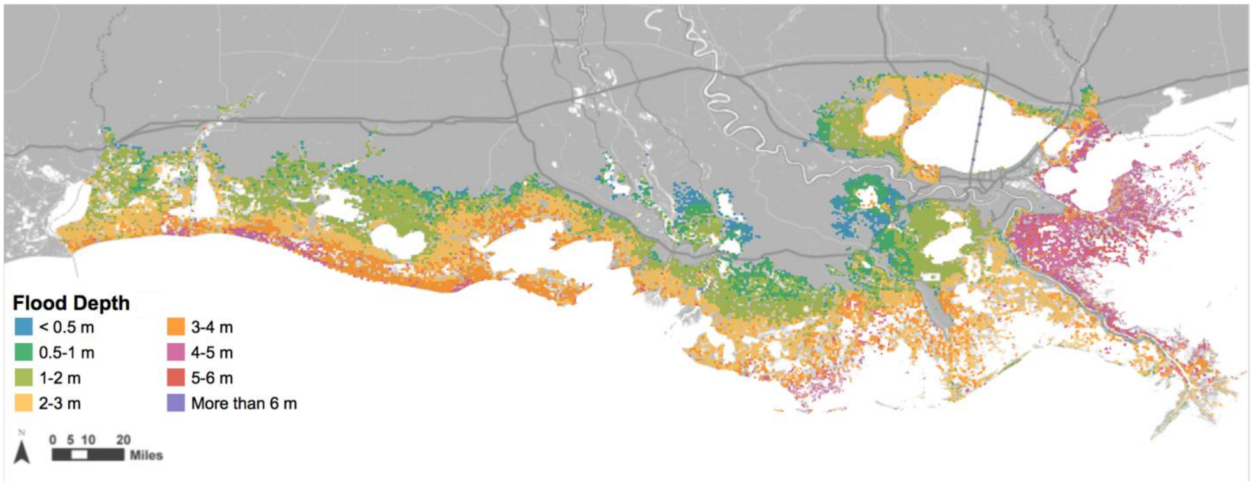

Figure 33: Example Screenshot of Flood Depth QA Tableau Visualizations.

Specific map-based results related to flood depths that were reviewed during QA include:

- **Absolute flood depth (meters)** at the 10-, 50-, 100-, and 500-year exceedance levels for each combination of scenario, grid, and year and at 10th, 50th, and 90th percentiles representing the range of parametric uncertainty;
- Differences in flood depths over time (across years within a single scenario) and differences between environmental scenarios within a given year and over time;
- Statistical summaries of **stillwater storm surge** and **significant wave height** at points exterior to enclosed protection systems at the 10-, 50-, 100-, and 500-year exceedance levels, for each combination of scenario, grid, and year and at 10th, 50th, and 90th percentiles;
- **Overtopping rate** at each levee or structure point surrounding enclosed protected systems. Maximum rates by synthetic storm are shown, as well as difference points along the probability distribution within a given storm simulation; and
- Maps that show the **differences between flood depths found for the FWOA project map versus for each other grid in turn**, for each combination of scenario, grid, year, and percentile. When considering individual project effects, reviewers focus on the area of influence for each project within a grid.

CLARA team and external reviewers perform the quality reviews. The order in which the reviewers evaluated model output follows:

- Initial review was performed by one of the following: the Principal Investigator, the technical lead, or the lead model developer. The primary reviewer assembled any comments or questions to address and provided them to the model developer, along with access to the appropriate Tableau workbook;
- **A second, different reviewer from the set mentioned above then selectively reviewed results** and resolved any key questions or issues from the first review. Comment responses were provided in written form as well as for quality assurance archiving. When the first

reviewer was satisfied with the responses, the reviewers notified the Principal Investigator; and

- **Technical staff at the engineering and consulting firm ARCADIS reviewed the results** using web-based interactive visualizations after they have passed internal quality reviews at RAND.

When examining the maps as described above, reviewers filled out an online comment matrix with versioning tracked on an internal RAND server site. The site tracks the name of the reviewer and the date the reviewer entered comments. The site also aggregates results to allow the technical lead and model developer to work off one another's notes and to allow the Principal Investigator to compare notes with the technical lead and model developer. The comment matrix was filled out for each grid.

The CLARA development team discussed any counterintuitive and/or incorrect results identified by reviewers and, if needed, adjusted and reran CLARA. Once the team was satisfied with the CLARA results, the technical lead performed a final check and then posted results to a server accessible to CPRA and others working in support of the 2017 Coastal Master Plan. The CLARA team also provided appropriate outputs to the 2017 Coastal Master Plan Planning Tool team. Interim results were shared with CPRA and the Planning Tool team during each phase and once the QA/QC process was completed on a case-by-case basis.

4.3 Results: Economic Damage

The preceding section of this document focused on quality reviews for CLARA results estimating flood depths under future conditions. Similar quality reviews were performed to check CLARA results estimating economic damage.

The same reviewers and review process was used to examine economic damage results. Damage results reviewed include the following outcome metrics:

- Damage by annual exceedance probability at the 10-, 50-, 100- and 500-year return periods;
- Expected annual damage (EAD);
- Counts of flooded critical infrastructure (at least 0.3 m of flood depth at the median 50-year flood depth exceedance; critical infrastructure exposure); and
- Counts of flooded historically significant properties (at least 0.3 m of flood depth at the median 50-year flood depth exceedance; historical property exposure).

These results were generally summarized for each of the 54 risk regions outlined in the 2017 Coastal Master Plan see Attachment C3-25, Sec. 8.3. The review workbook includes (see Figure 34):

- Maps and other summary figures that show results for each metric for each combination of scenario, grid, year, percentile, and population growth scenario;
- Maps and other summary figures showing differences over time (within scenario) and across scenarios (within a given year) for all metrics noted above;
- Maps and other summary figures that show the differences between economic damage and flood exposure found for the FWOA grid versus for each other grid, for each combination of scenario, year, percentile, and population growth scenario; and

- Summary figures describing the difference in EAD, as well as the flood exposure metrics, between specific projects and FWOA results (project-level benefit assessment).

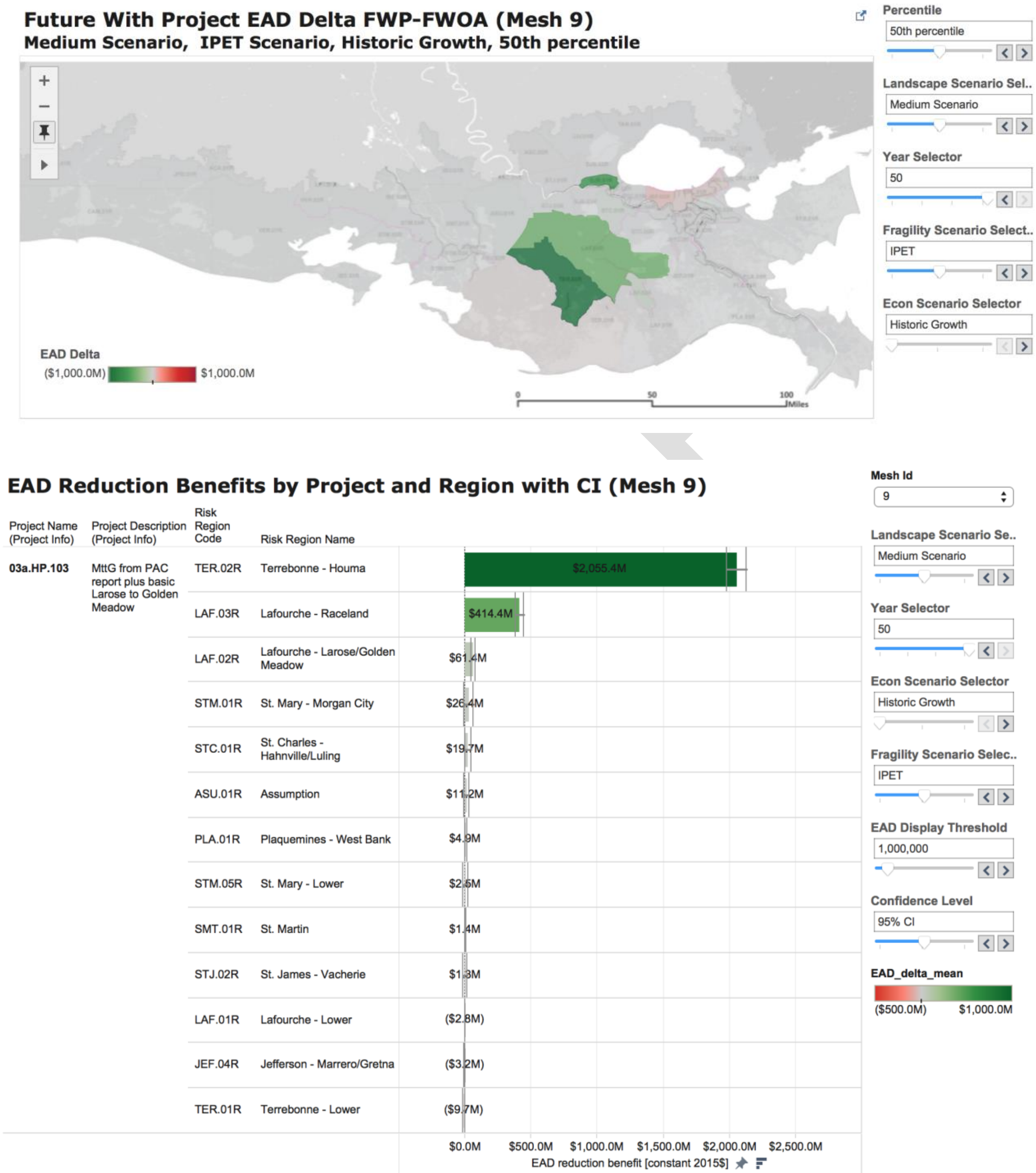

Figure 34: Example Screenshots of Economic Damage QA Tableau Visualizations.

As with flood depths, reviewers filled out an online comment matrix with versioning tracked on an internal RAND server site. The site tracks who filled out the comment matrix and when they filled it out. The site also aggregated results to allow the technical lead and model developer to work off one another's notes and to allow the Principal Investigator to compare notes with the technical lead and model developer. The comment matrix was filled out for each grid.

As with flood depth, the CLARA development team discussed issues identified by reviewers and adjusted and reran CLARA as needed. After QA/QC was complete for each case, the technical lead posted damage and exposure results to a server accessible to others working in support of the 2017 Coastal Master Plan and directly passed appropriate outputs to the Planning Tool team.

4.4 Results: Nonstructural Risk Reduction Projects

Quality reviews were performed to check the CLARA results, estimating the costs and implications of nonstructural projects for flood mitigation, including the elevation, acquisition, and flood proofing of properties in flood prone areas.

The same reviewers and review process were again used to examine results related to nonstructural projects, with the exception that ARCADIS staff did not review these results. Nonstructural outputs reviewed include the following data:

- Costs of each nonstructural project, broken down by asset class and mitigation type (elevation, acquisition, and flood proofing);
- Counts of the number of structures mitigated for each project, also broken down by asset class and policy;
- Data summarized for each of the 54 nonstructural project areas – corresponding to the 2017 risk regions – in which these mitigation efforts are applied, including other vulnerability-related criteria such as the proportion of low-to-moderate income households (LMI), count of repetitive loss or severe repetitive loss (RL/SRL) properties, and median 100-year flood depths; and
- Reduction in EAD from each nonstructural project area and project variant.

These results were summarized for each nonstructural project area or by other appropriate summary spatial units. A Tableau workbook of results developed for QA included maps and tables that illustrate the data described above for various combinations of projects and conditions.

Key comparisons that were made include:

- Does the spatial distribution of nonstructural costs and structures mitigated match intuition? Is more being done in more flood prone areas?
- Are structures mitigated count data consistent with nonstructural cost data?
- Looking across projects, does more spending lead to additional structures mitigated and damage reduction? Is there evidence of diminishing returns on investment in cases where the most cost effective actions are performed first?
- Looking across conditions, do changes in nonstructural results in areas where there may be new structural protection systems in place match intuition?

- Looking across conditions, do changes in nonstructural results as flood risks change, for example due to landscape changes, match intuition?

The CLARA development team again discussed and reviewed results and reran CLARA and/or the damage module within CLARA as needed. The CLARA team directly passed appropriate outputs to the Planning Tool team as results were finalized from the review process.

5.0 References

U.S. Army Corps of Engineers (USACE). (2008a). Flood Insurance Study: Southeastern Parishes, Louisiana. Intermediate Submission 2: Off-shore Water Levels and Waves. Vicksburg, Mississippi: USACE, p. 152.

U.S. Army Corps of Engineers (USACE). (2008b). Flood Insurance Study: Southwestern Parishes, Louisiana. Intermediate Submission 2. Vicksburg, Mississippi: USACE, p. 697.