2023 COASTAL MASTER PLAN

ALTERNATIVE ENVIRONMENTAL SCENARIOS - RISK

ATTACHMENT H5

REPORT: VERSION 02

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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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EXECUTIVE SUMMARY

This report describes the simulation modeling results projecting coastal flood risk and damage in the year 2070. Results are presented for three additional environmental scenarios representing different rates of future sea level rise (SLR) and/or coastal land subsidence over the 50-year period 2020-2070. This is based on comparisons between scenarios in a Future Without Action (FWOA) landscape as well as a landscape in which only the 2023 Coastal Master Plan's structural risk reduction projects have been implemented; no restoration projects are present, and protection projects are assumed to be implemented in keeping with the master plan's recommended implementation schedule (Future With Risk Only, or FWRO). The scenarios shown represent additional plausible conditions beyond those used for master plan development, but nevertheless are only a subset of many possible futures for the Louisiana coast and should be interpreted as plausible projections rather than likely predictions for future flood risk outcomes.

Results described in this analysis were simulated with the Coastal Louisiana Risk Assessment (CLARA) model to inform the development of Louisiana's 2023 Coastal Master Plan. The CLARA model was originally created by researchers at RAND Corporation to support development of Louisiana's 2012 Coastal Master Plan and has been updated and improved with each subsequent planning effort. It is designed to estimate flood depth exceedances, direct economic damage exceedances, and expected annual damage in dollars (EADD) and expected annual structural damage (EASD) in the Louisiana coastal zone. The model uses high-resolution hydrodynamic simulations of storm surge and waves as inputs. Monte Carlo simulation is used to estimate risk under a range of assumptions about future environmental and economic conditions and with different combinations of structural and nonstructural risk reduction projects on the landscape.

FWOA results from the additional environmental scenarios considered in this report generally show extensions of patterns previously observed from the master plan's lower and higher scenarios by Year 50. Although risk and damage estimates extend either below or above the 2023 analysis, depending on scenario, they suggest similar storylines to those documented in detail in support of the 2023 Coastal Master Plan. However, results from the highest SLR scenario more consistently push up against the CLARA model's northward coastal boundary, suggesting that this boundary should be revisited and likely moved further inland for the next phase of modeling to inform the 2029 Coastal Master Plan.

As with the FWOA analysis, the comparison of the 2023 Coastal Master Plan's risk reduction-only projects between the master plan's higher scenario (S08) and a scenario with additional assumed SLR by Year 50 (S09) largely shows an extension of patterns noted previously for S08. FWRO projects collectively provide a similar level of asset exposure and damage reduction in S09 compared to S08. However, this risk reduction occurs against a much higher baseline in terms of both depth and damage, leading to a high level of residual (remaining) risk even after these projects are implemented.

Given similarities to S08 results, this limited sensitivity analysis appears to reinforce the utility of the higher scenario as applied through the 2023 Coastal Master Plan analysis.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

AEP .... ANNUAL EXCEEDANCE PROBABILITY
ADCIRC .... ADVANCED CIRCULATION
CLARA .... COASTAL LOUISIANA RISK ASSESSMENT
CPRA .... COASTAL PROTECTION AND RESTORATION AUTHORITY
EADD .... EXPECTED ANNUAL DAMAGE IN DOLLARS
EASD .... EXPECTED ANNUAL STRUCTURAL DAMAGE
FFE .... FIRST FLOOR ELEVATION
FWOA .... FUTURE WITHOUT ACTION
FWRO .... FUTURE WITH RISK ONLY
FWIP .... FUTURE WITH IMPLEMENTATION PERIOD
HSDRRS .... HURRICANE STORM DAMAGE AND RISK REDUCTION SYSTEM
ICM .... INTEGRATED COMPARTMENT MODEL
IPCC .... INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE
IPET .... INTERAGENCY PERFORMANCE EVALUATION TASKFORCE
NOAA .... NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NOV .... NEW ORLEANS TO VENICE
RCP .... REPRESENTATIVE CONCENTRATION PATHWAY
RSLR .... RELATIVE SEA LEVEL RISE
SLR .... SEA LEVEL RISE
SWAN .... SIMULATING WAVES NEARSHORE
USACE .... U.S. ARMY CORPS OF ENGINEERS

1.0 INTRODUCTION

1.1 PURPOSE OF THIS REPORT

This report describes the simulation modeling results projecting coastal flood risk and damage in a series of different environmental scenarios for coastal Louisiana in the year 2070. The report builds on results presented in Louisiana's 2023 Coastal Master Plan and its supporting appendices (Fischbach et al., 2023; Johnson et al., 2023c) with a focus on simulations of additional environmental scenarios not considered as part of the master plan decision analysis. Results described in this analysis were simulated with same version of the Coastal Louisiana Risk Assessment (CLARA) model used to inform the development of Louisiana's 2023 Coastal Master Plan.

Results are presented for three additional environmental scenarios representing different rates of future sea level rise (SLR) and/or coastal land subsidence over the 50-year period 2020-2070. This is based on comparisons between scenarios in a Future Without Action (FWOA) landscape as well as a landscape in which only the 2023 Coastal Master Plan's structural risk reduction projects have been implemented; no restoration projects are present, and protection projects are assumed to be implemented in keeping with the Coastal Master Plan's recommended implementation schedule (Future With Risk Only, or FWRO). Flood damage results reflect a single scenario of projected future population change in Louisiana's coastal parishes. The focus of this report is to consider and describe the effect of higher or lower rates of SLR and subsidence on future Louisiana flood depths and damage as part of additional exploratory analysis conducted after 2023 plan development to inform future model improvement as well as scenario development and selection (CPRA, 2023).

This report should be of interest to the Coastal Protection and Restoration Authority (CPRA) and technical professionals and researchers in the field of flood risk assessment.

1.2 THE CLARA MODEL

The CLARA model was originally created by researchers at RAND Corporation to support development of Louisiana's 2012 Coastal Master Plan. It is designed to estimate flood depth exceedances, direct economic damage exceedances, and expected annual damage in dollars (EADD) and expected annual structural damage (EASD) in the Louisiana coastal zone. The model uses high-resolution hydrodynamic simulations of storm surge and waves as inputs. Monte Carlo simulation is used to estimate risk under a range of assumptions about future environmental and economic conditions and with different combinations of structural and nonstructural risk reduction projects on the landscape.

The CLARA model is well described in prior peer-reviewed and published literature, so this report does not include detailed descriptions of the basic methodological approach and assumptions. For interested readers, an introduction to the model can be found in Fischbach et al. (2012) and Johnson et al. (2013). Model improvements for the 2017 Coastal Master Plan are described in Fischbach et al. (2017), and published examples of CLARA model results can be found in Fischbach et al. (2019), Meyer & Johnson (2019), and Fischbach et al. (2017). Model improvements for Louisiana's 2023 Coastal Master Plan are described in Fischbach et al. (2021). Finally, an overall summary of the CLARA methodology as applied in the 2023 analysis can be found in Johnson et al. (2023a).

CLARA estimates flood depths at different annual exceedance probabilities (annual exceedance probabilities [AEPs]; e.g., 1% annual chance or 1 in 100-year flood depth) for grid cells across the Louisiana coast. In addition to depth results, two primary metrics are presented for flood exposure and damage estimates from the CLARA model in this report: 1) the exposure of single-family residences to flooding at one of three severity thresholds; and 2) projected flood damage across all asset types summarized as EADD or EASD, an alternate metric designed to be less sensitive to high-value assets in comparatively wealthier areas. The exposure thresholds are based on flood depths with a 2% (1 in 50-year) chance of occurring, and the comparisons are based on a structure inventory estimated for Year 0 that does not vary over time.[1] The thresholds include:

- **Structures Where Flooded**: CLARA model projections show non-zero flood depths for the grid cell in which the structure is located.
- **Moderate Exposure:** CLARA model projections show flood depths above the first-floor elevation (FFE) of the structure — a threshold beyond which moderate to major damage is expected to occur.
- **Severe Exposure**: CLARA model projections show flood depths that are 2 or more feet above the FFE of the structure — major damage to structure and contents would be expected.

Results are mapped for each community and summarized across the Louisiana coast. Mapped exposure results highlight the percent of homes at or above the moderate exposure threshold. Methods used for estimating EADD and EASD with CLARA are described in separate reports (Fischbach et al., 2021; Johnson et al., 2023a).

1.3 ORGANIZATION OF THIS REPORT

This report first provides a brief description of the additional environmental scenarios considered for this analysis (Section 2). It next summarizes CLARA simulation results in Year 50 for the three additional scenarios and compares these results to the lower and higher environmental scenario

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[1] CLARA damage estimates take into account population change over time (see Hauer et al., 2022), but these changes are not directly incorporated into the inventory of structures. As a result, structure exposure is based on the inventory at Year 0, and the number of structures remains fixed over the period of analysis. For more information, see Fischbach et al. (2021).

outputs used to develop the 2023 Coastal Master Plan. Section 3 provides coastwide comparisons in a FWOA, while Section 4 similarly summarizes results for the FWRO landscape. The report concludes with a brief summary of findings in Section 5.

2.0 METHODS AND DATA SOURCES

2.1 ENVIRONMENTAL SCENARIOS CONSIDERED

The Master Plan Development Team went through an extensive process to identify a plausible range of future scenario conditions that could influence morphology, ecology, and flood risk across the Louisiana coast. This process is detailed in Appendix B to the 2023 Coastal Master Plan (Coastal Protection and Restoration Authority, 2023) along with a series of supporting attachments (e.g., Pahl et al., 2023).

A key uncertain driver included in each future environmental scenario is SLR driven by global climate change. CPRA reviewed a range of SLR projections from different sources (e.g., 2017 Coastal Master Plan, Intergovernmental Panel on Climate Change, National Oceanic and Atmospheric Administration) to support 2023 Coastal Master Plan development and identified an initial suite of 27 50-year projections to consider. After further analysis, two curves were ultimately selected to include as the master plan's lower and higher environmental scenarios, respectively. The lower scenario curve was selected to be consistent with IPCC's RPC 4.5 and yields 1.65 feet (0.49 m) of SLR by Year 50. The higher scenario curve yields 2.5 feet (0.77 m) of SLR by Year 50 and falls within the plausible range of RCP 8.5 projections. Figure 1 provides a summary of recent historical observed SLR, the range of IPCC projections, and the ensemble of SLR curves considered for the 2023 Coastal Master Plan analysis.

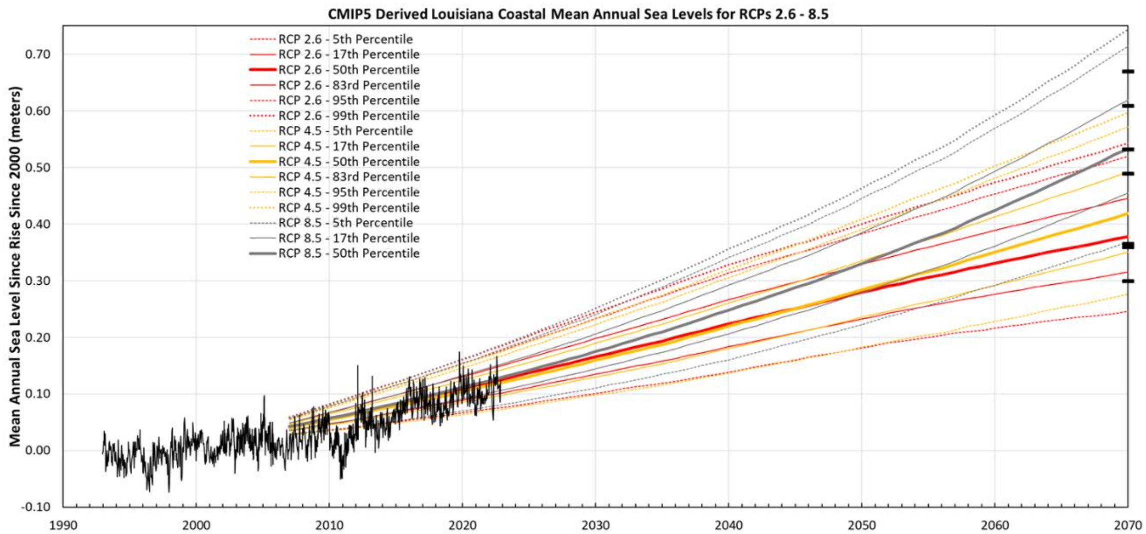

Figure 1. Sea level rise scenarios considered for the 2023 Coastal Master Plan — scenarios selected for the master plan or considered in this analysis highlighted.

Building on the results from the lower and higher scenarios, CPRA selected three additional scenarios from the list above for the sensitivity analysis described in this report, with specific driver values listed in Table 1 below.

Scenario 6 (S06) is the same as the lower scenario (S07) in its assumptions about meteorological factors and land subsidence, but it includes a lower projection of SLR (1.25 feet [0.38 m] by 2070 compared to S07's 1.64 feet [0.50 m]). Scenario 19 (S19) uses the same SLR assumption as the higher scenario (S08; 2.53 feet [0.77 m]), but instead assumes a lower subsidence assumption consistent with the first quartile of regional rate estimates rather than the median estimate. In effect, this means combining the S07 subsidence assumption with the S08 SLR assumption. Finally, Scenario 9 (S09) is the same as S08 except that it applies a higher rate of SLR, 3.58 feet [1.09 m], than any of those previously considered in the 2023 Coastal Master Plan analysis.

For convenience of comparison, the master plan's lower scenario will be referred to as S07 and the higher scenario as S08 through the remainder of this document.

Table 1. Environmental scenarios considered in this analysis

SCENARIO ID	SLR (M BY 2070)	TEMP	ET	PRECIP	TRIBS	MS RIVER	SUBSIDENCE
S06	0.38	RCP 4.5 50TH	RCP 4.5 50TH	RCP 4.5 50TH	RCP 4.5 50TH	RCP 4.5	DEEP + 1ST QT
S07	0.50	RCP 4.5 50TH	RCP 4.5 50TH	RCP 4.5 50TH	RCP 4.5 50TH	RCP 4.5	DEEP + 1ST QT
S08	0.77	RCP 8.5 50TH	RCP 8.5 50TH	RCP 8.5 50TH	RCP 8.5 50TH	RCP 4.5	DEEP + MEDIAN

S19	0.77	RCP 8.5 50^{TH}	RCP 8.5 50^{TH}	RCP 8.5 50^{TH}	RCP 8.5 50^{TH}	RCP 4.5	DEEP + 1^{ST} QT
S09	1.09	RCP 8.5 50^{TH}	RCP 8.5 50^{TH}	RCP 8.5 50^{TH}	RCP 8.5 50^{TH}	RCP 4.5	DEEP + MEDIAN

2.2 ADDITIONAL MODEL RUNS AND SCENARIO COMPARISONS

The comparisons described in this report are based on simulations of Year 50 (i.e., 2070) in each of the modeled scenarios. For the FWOA, all three additional scenarios were evaluated. For the FWRO, by contrast, only one additional case (S09) was evaluated to consider the effect of a higher rate of SLR on the performance of structural risk reduction projects selected for the 2023 Coastal Master Plan.

A coupled ADCIRC+SWAN model was used to simulate the same 90 storms in each of the alternative environmental scenario cases that were run through S07 and S08 to support plan development (Cobell & Roberts, 2021; Fischbach et al., 2021). The variations on SLR and land subsidence in S06 and S19 have modest impacts on topographic and bathymetric elevations (topobathy), while S09's greater SLR leads to noticeable differences in the land-water interface by 2070. Figure 2 illustrates the difference in topobathy between S06 and S07, while Figure 3 and Figure 4 depict the differences between S09 and S08 and between S19 and S08, respectively.

CLARA grid cell elevations were recalculated for each alternative case using the same procedure as in other scenarios, wherein elevations are assigned corresponding to the median topographic elevation of land pixels from the landscape's land-water raster. Open water grid cells are assigned an elevation equal to the landscape's mean sea level assumption.

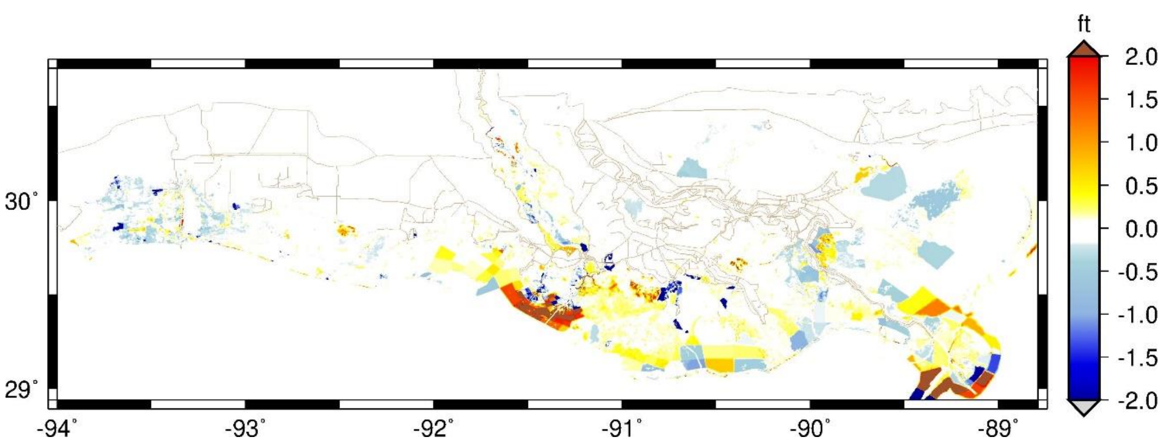

Figure 2. Topobathy differences between S06 and S07 for Year 50.

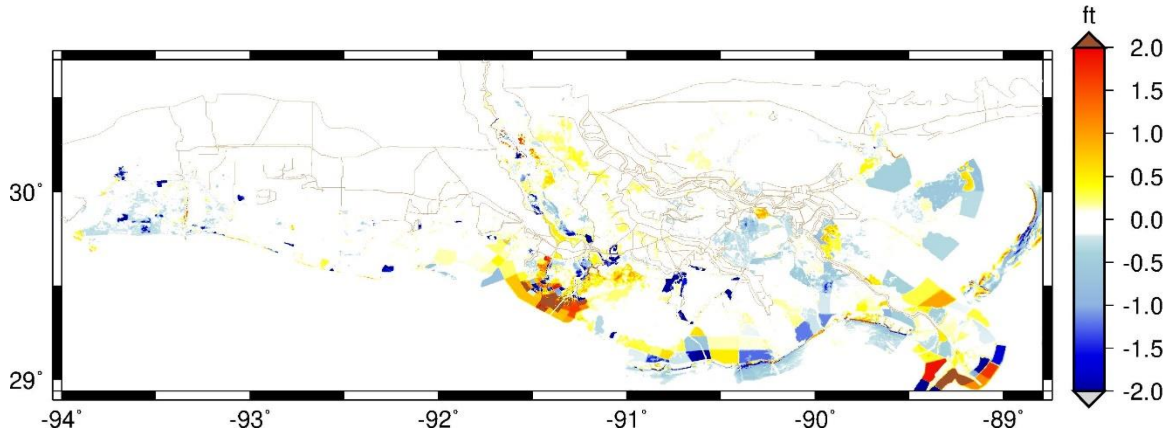

Figure 3. Topobathy differences between S09 and S08 for Year 50.

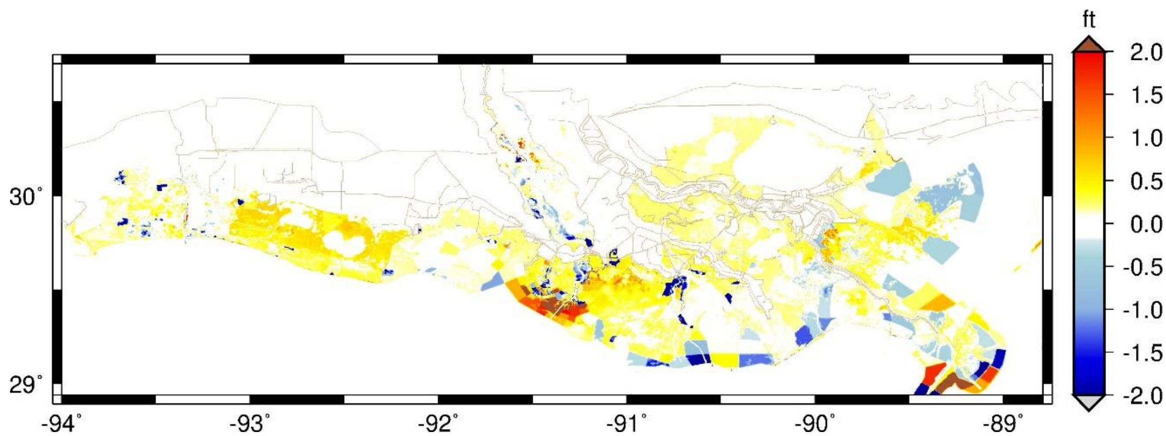

Figure 4. Topobathy differences between S19 and S08 for Year 50.

3.0 FUTURE WITHOUT ACTION COMPARISONS

3.1 FLOOD DEPTHS

Flood depths in Year 50 were simulated with ADCIRC/SWAN and CLARA and summarized across a range of AEPs. Depth results for the 1% (1 in 100-year) AEP are shown coastwide for S06 and S07 in Figure 5 below. In general, 1% AEP flood depth patterns for S06 are similar to those in S07, with a substantial portion of the coast estimated to have at least a 1% annual chance of being exposed to 10 or more feet of flooding by Year 50.

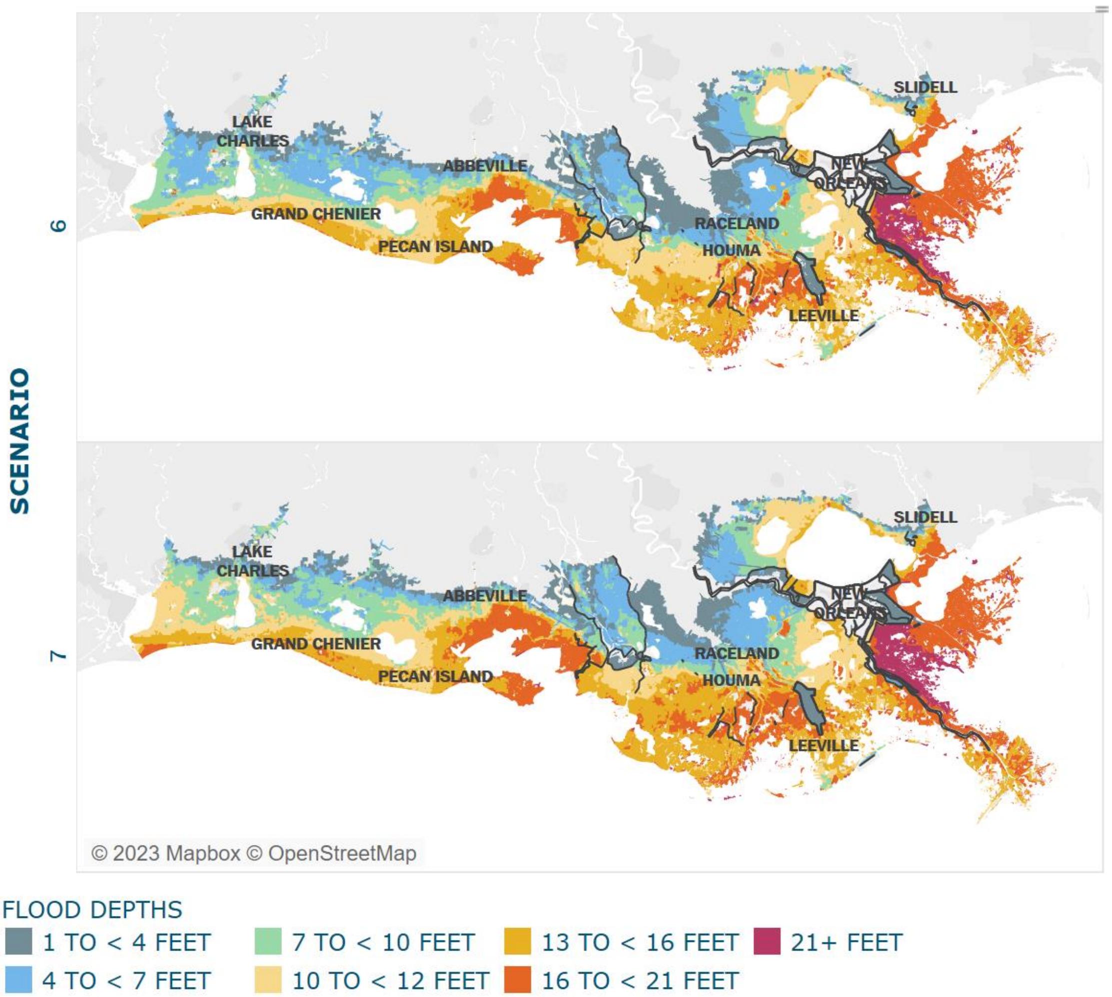

Figure 5. Coastwide FWOA 1% (1 in 100-year) AEP flood depths in Year 50 S06 and S07 — Interagency Performance Evaluation Taskforce (IPET) fragility, 50% pumping scenario, 50th percentile.

Spatial differences between these two scenarios are summarized in Figure 6, which maps the depth difference between S06 and S07 (brown shades indicate lower flood depths; green shades indicate higher flood depths). This figure shows that across much of the Barataria and Terrebonne basins and the central and southwestern portion of the coast, 1% AEP flood depths are between 1 and 2 feet lower in S06 compared to S07 in Year 50. Differences are smaller in the Pontchartrain basin, with most locations seeing less than a foot of difference between the two scenarios.

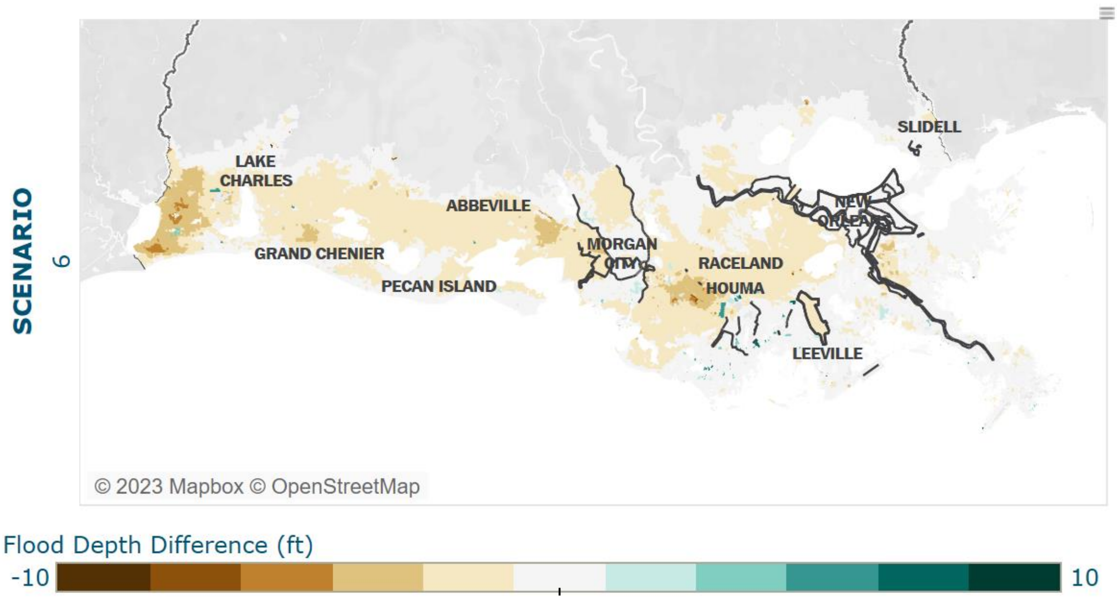

Figure 6. Change in coastwide FWOA 1% (1 in 100-year) AEP flood depths in Year 50 for S06 compared to S07 — IPET fragility, 50% pumping scenario, 50th percentile.

Several areas, including the southwestern boundary of the study region in Cameron Parish and portions of Terrebonne west of Houma show regions of greater differences between scenarios, generally ranging from 3-4 feet with small areas where S06 depth exceedances are 4-5 feet lower than in S07. Similar patterns of difference can be observed when considering higher likelihood (e.g., 10% AEP) and lower likelihood (e.g., 0.2% AEP) flood events (not shown).

1% AEP flood depths for S19 and S09 are similarly shown with S08 (higher scenario) in Figure 7. Figure 8 instead shows depth difference for S19 and S09 compared to S08 to better highlight the spatial patterns of difference. S19 assumes the same SLR in Year 50 as S08 but a lower rate of subsidence; this difference is most notable in upland areas of the southwest coastal region. In these areas, 1% AEP depths are generally 1-2 feet lower than in S08, with some areas around Grand Lake (north of Grand Chenier) closer to 3 feet lower. By contrast, there are scattered areas further coastward across the Chenier Plain, Central Coast, Terrebonne, and Barataria where 1% flood depths in S19 are slightly higher than in S08, generally ranging from 0-2 feet. Depth estimates at 10% and 0.2% AEPs (not shown) suggest similar spatial patterns of difference.

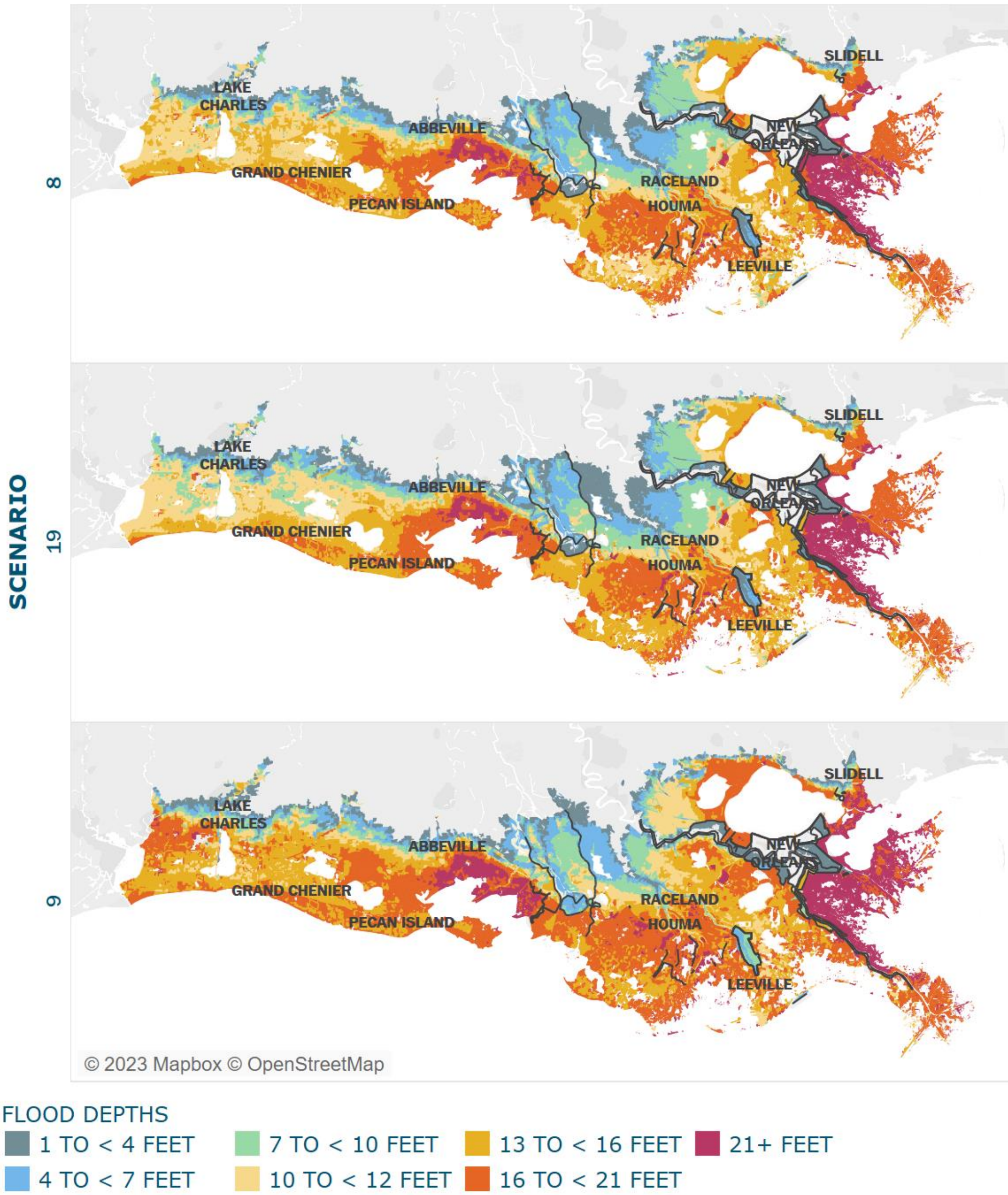

Figure 7. Coastwide FWOA 1% (1 in 100-year) AEP flood depths in Year 50 for S08, S19, and S09 —IPET fragility, 50% pumping scenario, 50th percentile.

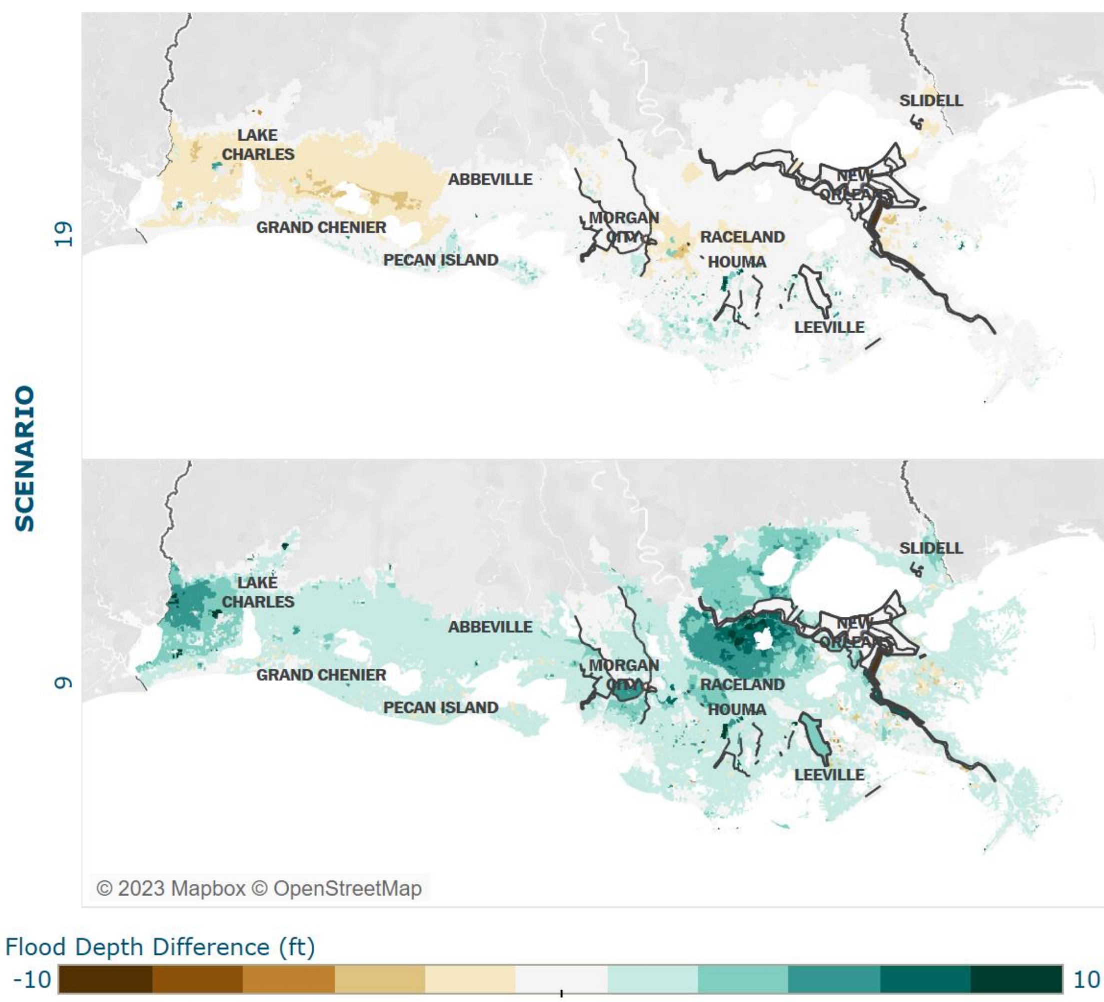

Figure 8. Change in coastwide FWOA 1% (1 in 100-year) AEP flood depths in Year 50 for S19 and S09 compared to S08 —IPET fragility, 50% pumping scenario, 50th percentile.

S09 uniformly shows higher 1% AEP flood depths compared to S08 for nearly the entire coast. In many areas, the difference in depth roughly tracks the higher SLR assumption, with an additional 1.08 feet of SLR compared to S08, leading to 0.5–2.0 feet of additional flood depth in the 1% AEP estimates. However, several regions show larger nonlinear increases in flood depth, including northwest Cameron Parish and western Pontchartrain around and west of Lake Maurepas in the Amite River basin. S09 1% AEP flood depths are generally 3-4 feet higher in these regions compared to S08. A large portion of the Upper Barataria basin shows yet further increases, ranging from 5 feet to more than 9 feet of additional 1% AEP flooding when compared to S08. This could have notable effects on asset exposure and damage in these regions, discussed in the next section of this report.

Finally, S09 results show several enclosed protected areas with substantially higher 1% AEP flooding than in S08, including the Berwick polder west of Morgan City, the Larose to Golden Meadow system, and portions of protected upper Plaquemines Parish in the New Orleans to Venice (NOV) system. These differences are due to the levee and floodwall systems overtopping at more frequent intervals in S09 compared to S08 with an additional foot of SLR adding to the storm surge and wave levels outside of these systems. The additional overtopping, and corresponding increase in the risk of levee failure, shifts the exceedance curve so that at the 1% AEP these interior areas jump from little flooding to major flooding in Year 50 of the more extreme SLR scenario.

Similar results can be observed for the Greater New Orleans Hurricane Storm Damage and Risk Reduction System (HSDRRS) at less frequent levels of likelihood (i.e., AEPs below 1%). For instance, Figure 9 compares Year 50 depth results at three AEPs (1%, 0.2%, and 0.1%) for S08, S19, and S09 within the HSDRRS system only. This figure shows similar results at the 1% AEP across scenarios, with flooding largely driven by rainfall as noted in Fischbach et al. (2023) except for S09 in the West Bank of Jefferson Parish. At the 0.2% AEP in S09, however, large portions of both East and West Bank HSDRRS show 4 or more feet of flooding, suggesting that the combination of low likelihood storm surge and waves and the additional increment of SLR in this S09 are sufficient to overtop large portions of the risk reduction system by Year 50.

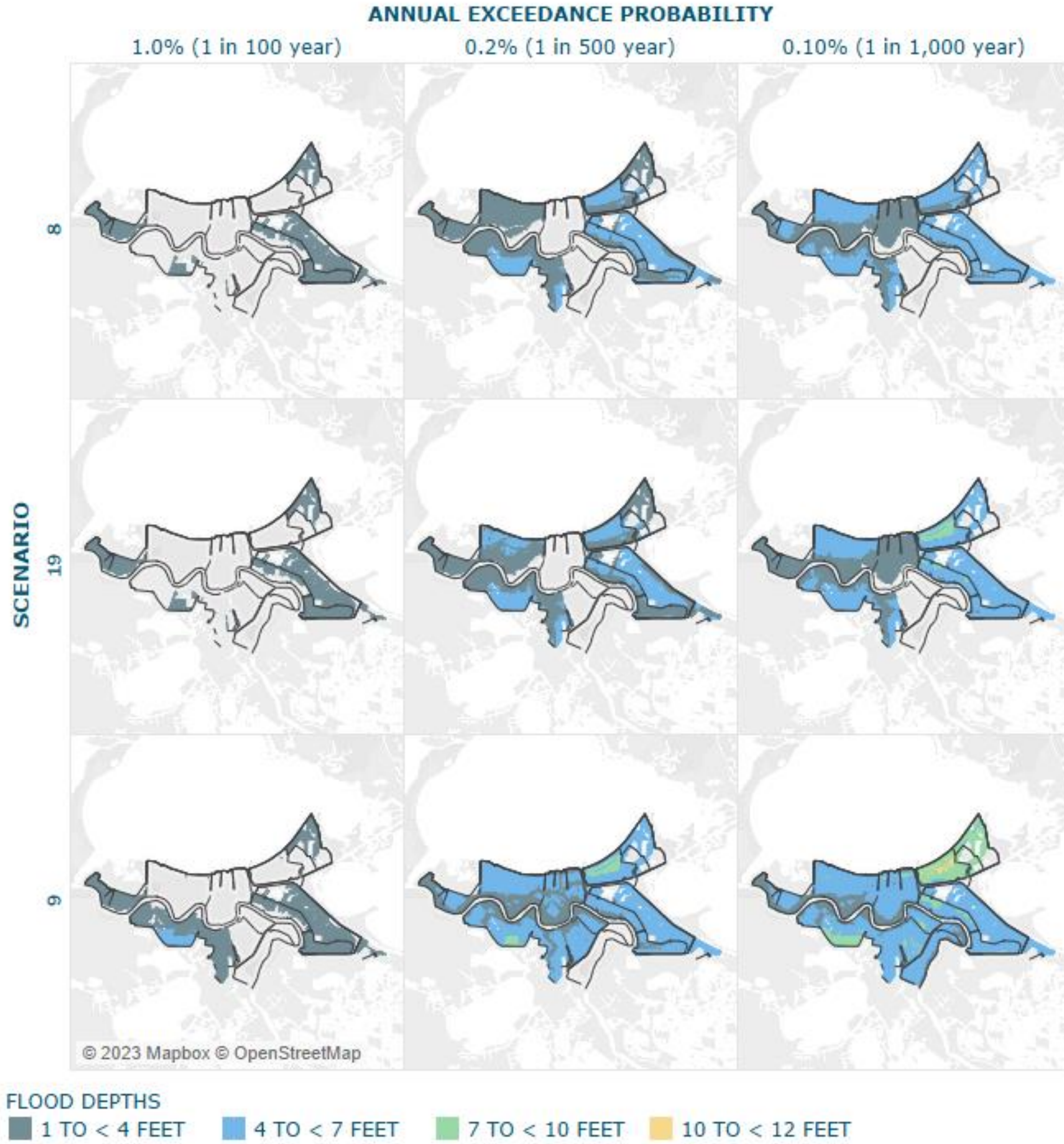

Figure 9. FWOA flood depths in the HSDRRS system at three AEPs in Year 50 for S08, S19, and S09 —IPET fragility, 50% pumping scenario, 50th percentile.

3.2 ASSET EXPOSURE AND FLOOD DAMAGE

Turning next to FWOA asset exposure, Figure 10 summarizes the exposure of small residential structures (single-family detached homes, duplexes, and manufactured homes) across all environmental scenarios in Year 50 (2% AEP). Summary results show that S06 residential exposure is similar coastwide to S07, with approximately 15,000 (2%) fewer residences exposed to flood depths above their FFEs (i.e., moderate or severe exposure) at the 2% AEP. However, the number of homes facing moderate exposure is similar in both scenarios, meaning the most notable reduction from S07 to S06 is in the severe exposure category. Moderate exposure and the number of structures in flooded areas are little changed in the summary results, while approximately 12,000 structures are considered "not exposed" at the 2% AEP in S06. Additional structures shifting to the "not exposed" category generally indicates a difference in the extent of the 2% AEP floodplain between scenarios. As a result, residences on the boundary of flooded areas in S07 are then outside of the flooded area under S06.

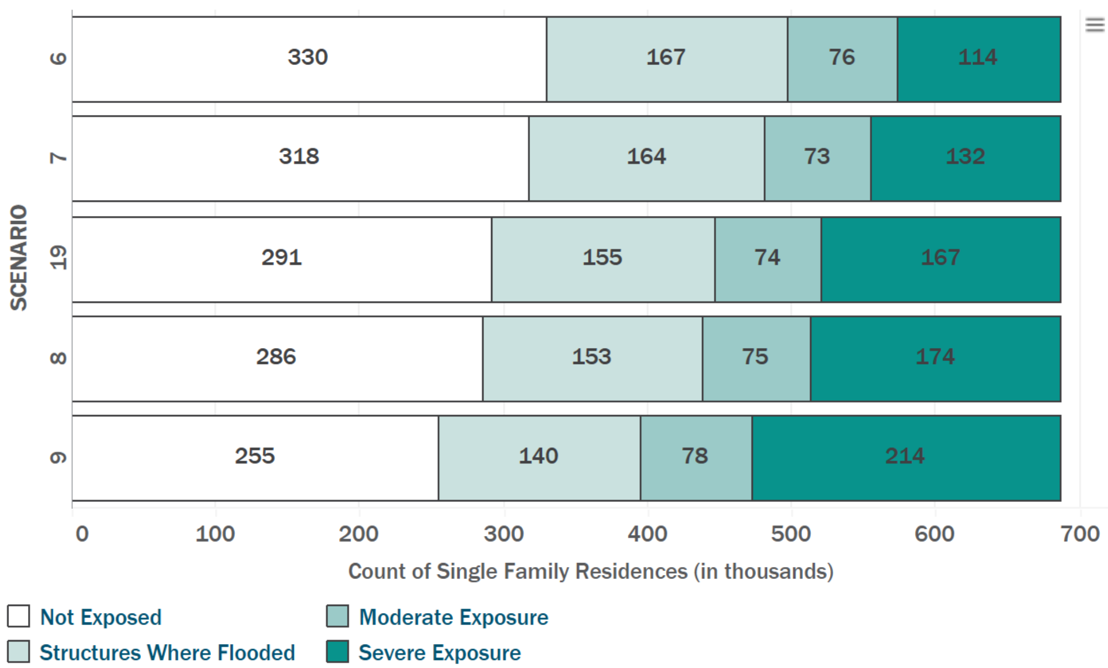

Figure 10. Coastwide single family residence structure exposure comparison by scenario in Year 50 — 2% AEP, IPET fragility, 50% pumping scenario, 50th percentile.

Given modest differences in flood depth exceedances, coastwide residential exposure in S19 Year 50 is very similar to that simulated previously in S08 (Figure 10). Exposure is somewhat lower in S19 with a lower assumed rate of subsidence in different regions, though again much of the difference observed is in the severe exposure (7,000 fewer residences) and not exposed (5,000 more residences) categories.

Residential exposure increases dramatically, however, in S09. With a higher rate of SLR, by Year 50 the number of homes exposed to flood depths well above their FFEs (severe exposure) at a 2% AEP increases by more than 40,000 (23%). The moderate exposure category increases slightly, while the count of residential structures either in flooded areas or not exposed declines. This can be explained by many areas seeing more substantial flood depths in S09, pushing 2% AEP depths well above FFEs together with homes previously facing zero or lower exposure jumping into higher exposure categories. The increased number of severe exposure residences when comparing S09 to S08 is nearly as large as the increase seen in this category when comparing the 2023 Coastal Master Plan lower (S07) and higher (S08) scenarios.

Coastwide flood damage results presented in terms of EADD (left pane) or single family residential EASD (right pane) for all environmental scenarios are shown in Figure 11 below. Patterns of EASD summarized coastwide closely track EADD, consistent with the scenario results presented in the 2023 Coastal Master Plan and other supporting technical appendices. In general, the consistently lower flood depths in S06 translate to 15% lower EADD estimates in S06 ($12.2 billion) compared to S07 ($15.2 billion). Year 50 S06 residential EASD is correspondingly 20% lower (2,655 fewer structure equivalents) than the master plan's S07 projection.

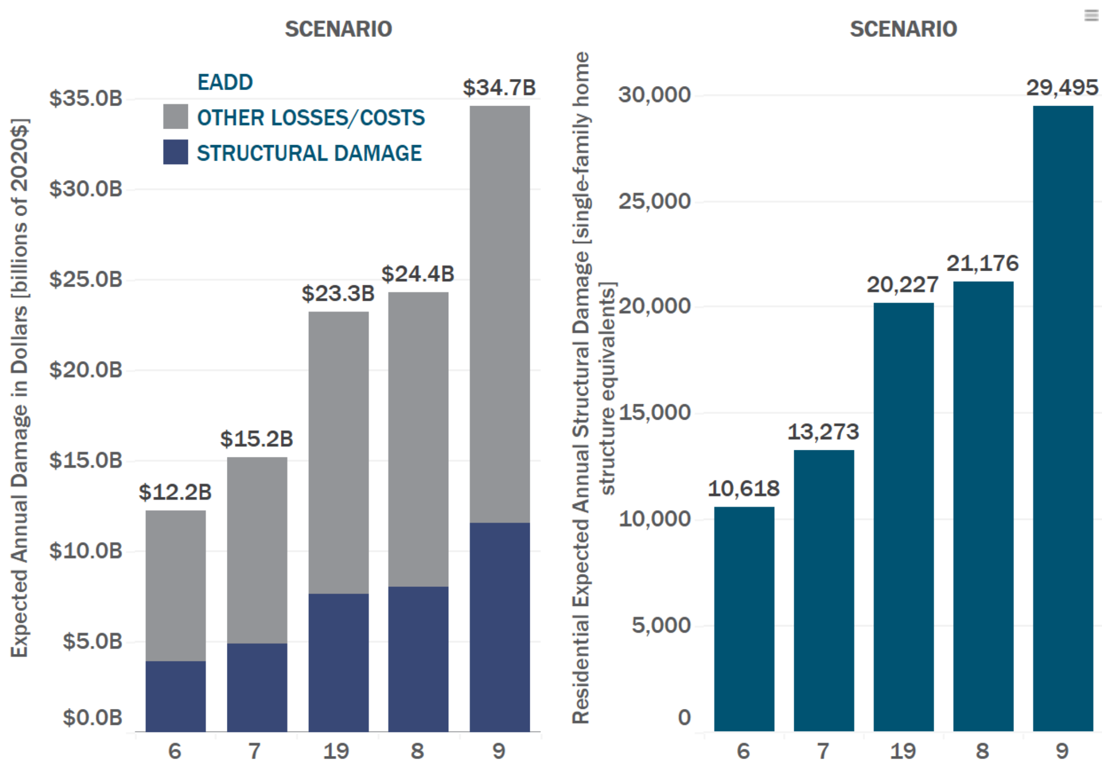

Figure 11. Coastwide EADD and residential EASD environmental comparison scenario in Year 50 — IPET fragility, 50% pumping scenario, 50th percentile.

EADD patterns across different communities are similar between S06 and S07 (Figure 12). EADD is proportionally lower in S06 in communities with a higher density of assets such as Slidell, Houma, and Lake Charles (Figure 13). These coastwide comparisons suggest generally lower EADD in S06 rather than focused areas where EADD change is observed, consistent with the depth comparisons noted earlier (Figure 6).

S19 EADD and residential EASD estimates are modestly lower than S08 estimates, with a difference of approximately 4.5% in both metrics (Figure 11). By contrast, both metrics jump significantly coastwide in S09 in Year 50, with an increase of $10.3 billion (EADD) and over 8,000 structure equivalents (residential EASD) compared to the 2023 Coastal Master Plan higher scenario. By Year 50, the higher rate of SLR in S09 and corresponding increase in depth and extent of flooding lead to a significant expansion in asset damage compared to S08—an increase of 42% and 39% for EADD and residential EASD, respectively.

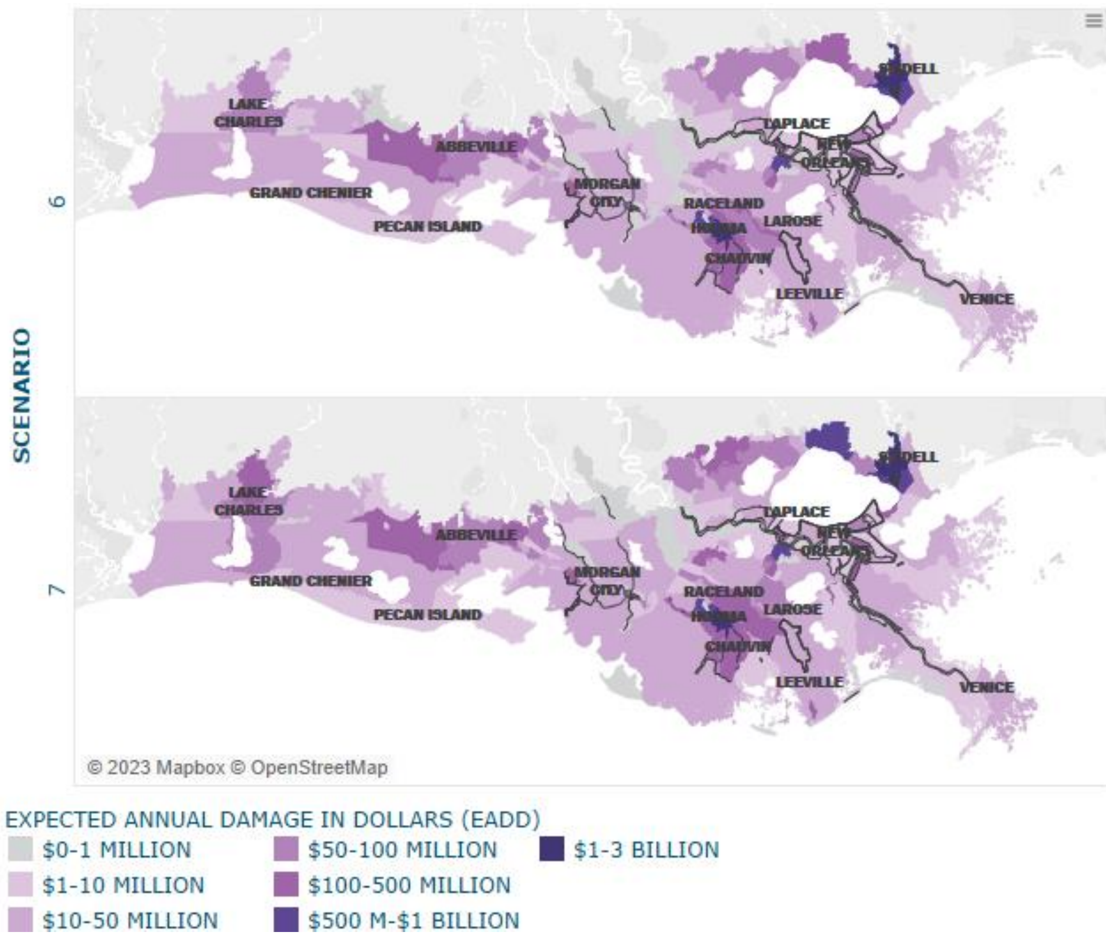

Figure 12. Coastwide EADD in Year 50 for S06 and S07 — IPET fragility, 50% pumping scenario, 50th percentile.

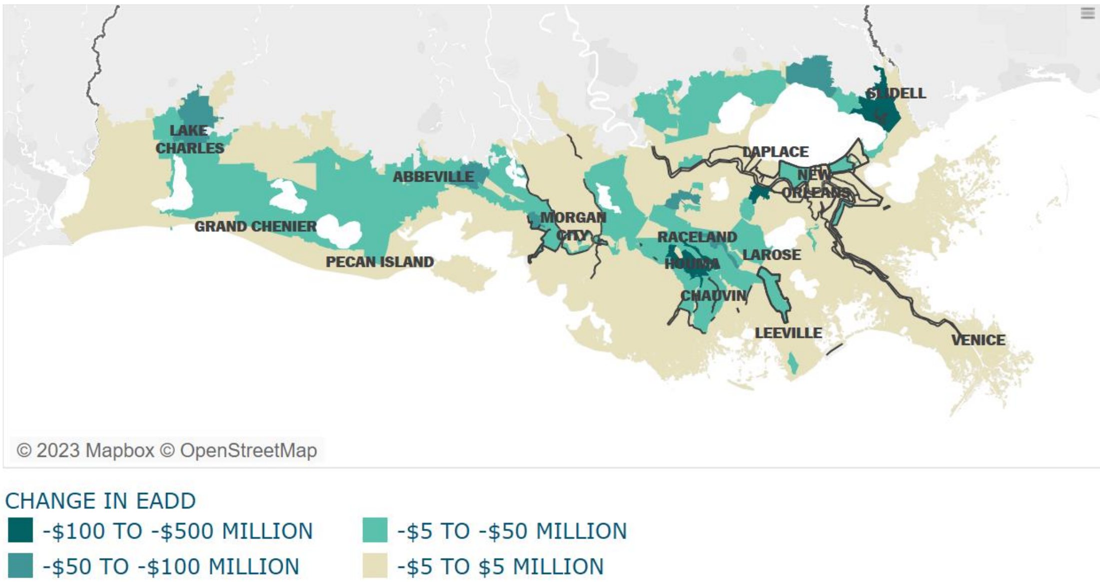

Figure 13. Difference in coastwide EADD in Year 50 between S06 and S07 —IPET fragility, 50% pumping scenario, 50th percentile.

Year 50 spatial EADD patterns by community for S19, S08, and S09 are shown in Figure 14, while Figure 15 shows the difference in EADD comparing S19 (top) and S09 (bottom) to S08 (not shown). As with the lower SLR scenario comparisons, differences are generally higher in areas with a higher density of assets at risk. However, several communities on the boundary of the floodplain with higher asset density show greater sensitivity to the SLR scenario when comparing S08 and S09. For example, EADD in the Gonzales/Prairieville community west of Lake Maurepas increases by over $1.1 billion between S08 and S09, while EADD in Lake Charles more than doubles (from $372 million in S08 to $692 million in S09).

The Greater New Orleans HSDRRS system also shows storm surge and wave overtopping from low probability, high consequence storms in S09 compared to S08, leading to EADD increases of approximately $800 million (East Bank) and $352 million (West Bank), respectively.

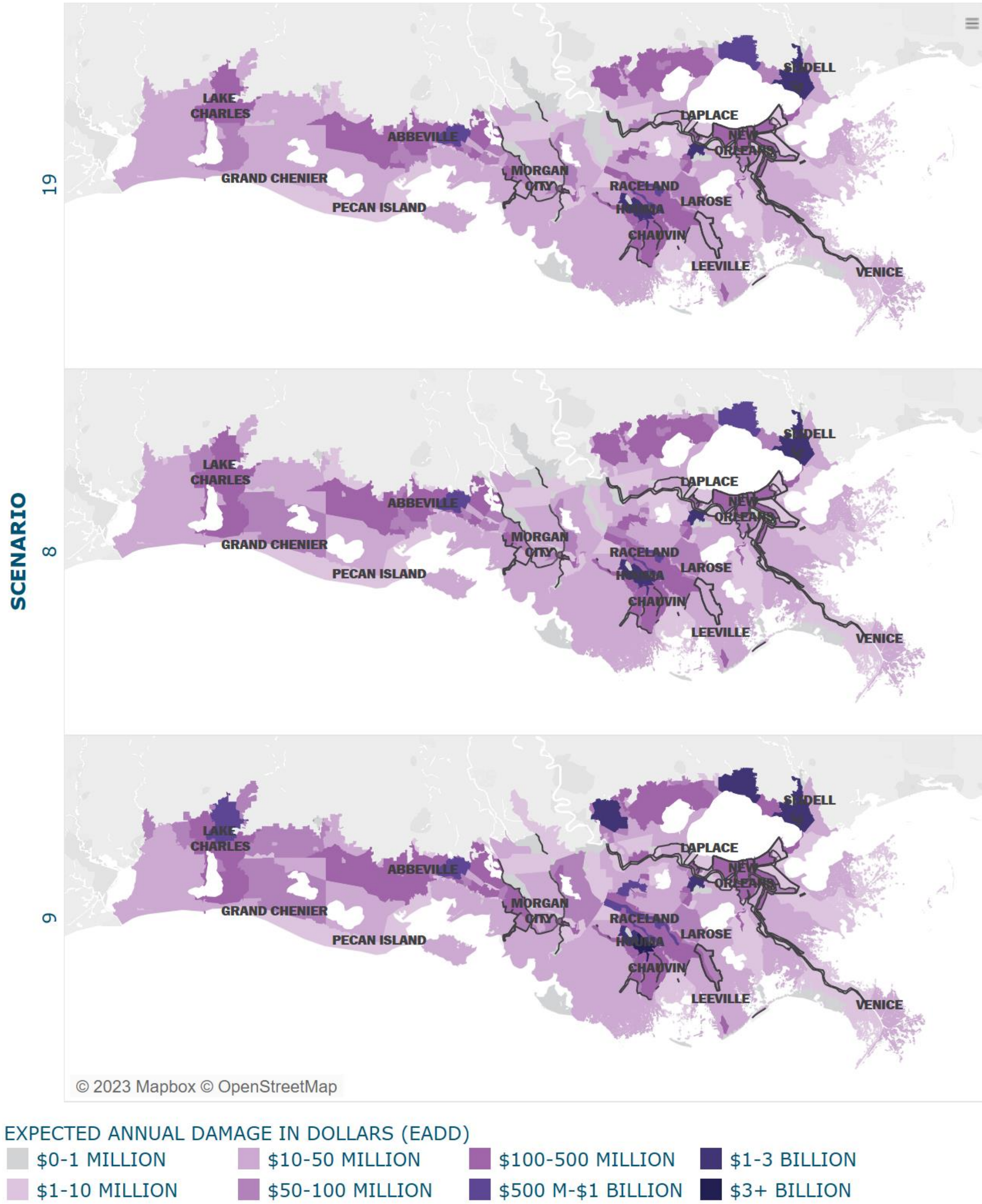

Figure 14. Coastwide EADD in Year 50 for S19, S08, and S09 —IPET fragility, 50% pumping scenario, 50th percentile.

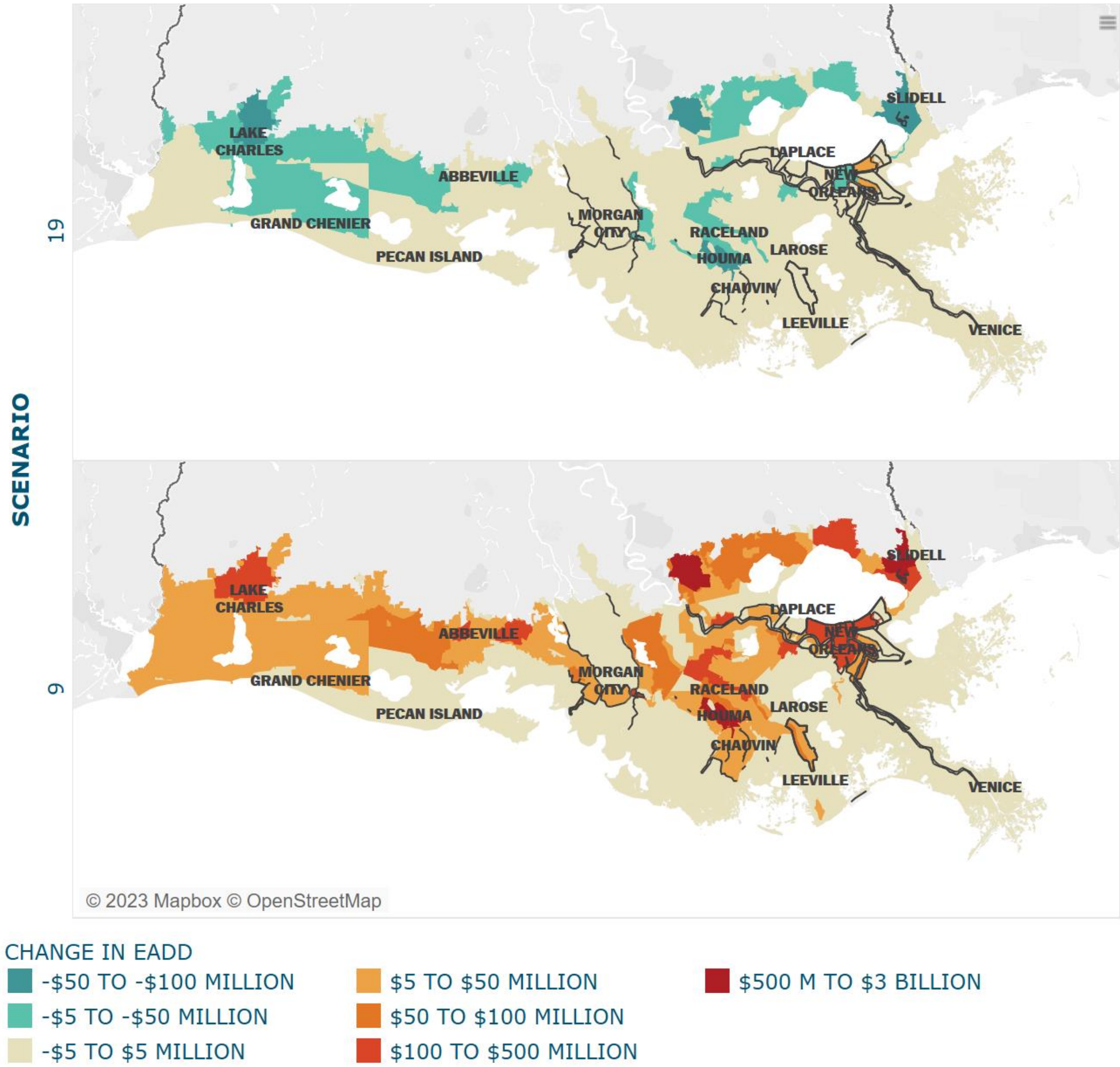

Figure 15. Difference in coastwide EADD in Year 50 comparing S19 and S09 to S08 — IPET fragility, 50% pumping scenario, 50th percentile.

3.3 DISCUSSION

FWOA results from the additional environmental scenarios considered in this report generally show extensions of patterns previously observed from the master plan's lower and higher scenarios by Year 50. Both the extent and depth of flooding decreases in S06 relative to S07, but the spatial patterns of both depth and damage are largely comparable to the lower scenario. FWOA S19 risk results are very similar to S08, with nearly identical damage results due to the subsidence differences largely affected less densely populated areas of the coast. S09 depths are consistently higher than S08 and the inland extent of flooding increases, both leading to notable jumps in exposure and damage, but the geographic distribution of depth and damage is nevertheless comparable to that previously observed in higher scenario estimates. However, the S09 results more consistently push up against the CLARA coastal boundary previously established in the 2017 Coastal Master Plan analysis, suggesting that this boundary should be revisited and pushed further inland for the next phase of modeling to inform the 2029 Coastal Master Plan. This also implies that risk estimates for S09 are likely biased downwards given the limitations of the spatial domain.

4.0 MASTER PLAN RISK REDUCTION PROJECTS COMPARISON

This section builds on the previous analysis to consider how risk and damage results from the structural risk reduction projects selected for the 2023 Coastal Master Plan might vary with one additional environmental scenario. In contrast to the previous section, only the higher SLR case (S09) was considered in this additional FWRO sensitivity analysis.

Twelve structural risk reduction projects were selected for communities across the Louisiana coast in the 2023 Coastal Master Plan at an estimated cost of $14 billion (Figure 16). Project implementation is split across two future with implementation periods (FWIP1 and FWIP2), but all projects are assumed to be in place by Year 50 as the single year of focus in this sensitivity analysis.

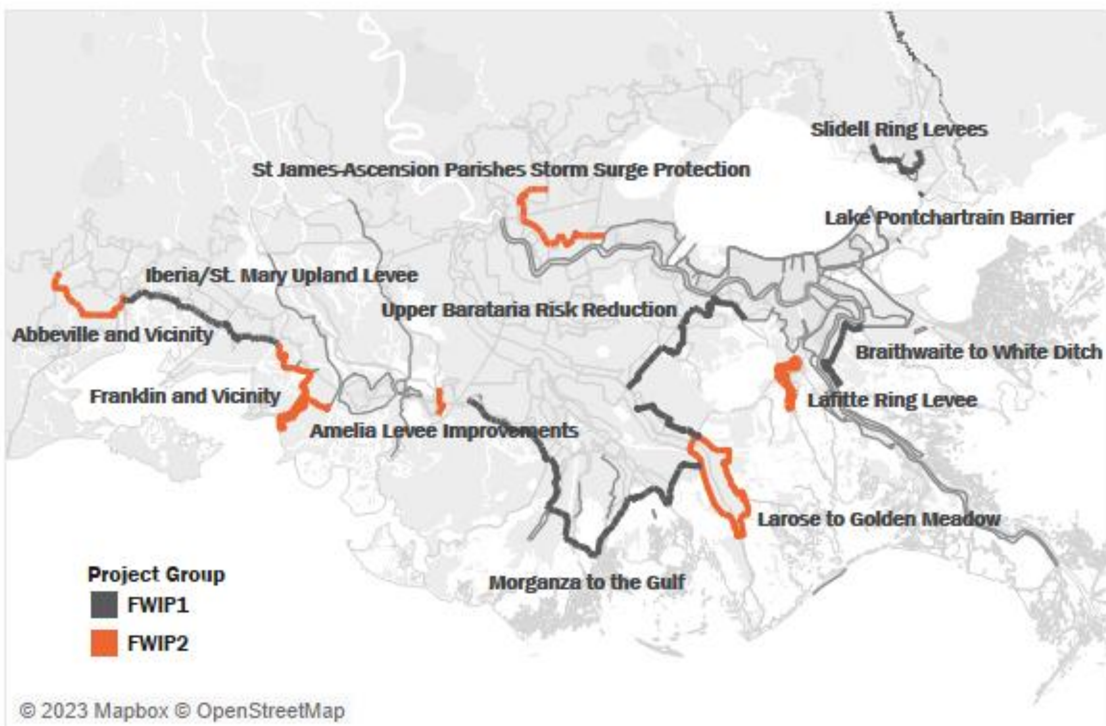

Figure 16. Structural risk reduction projects selected for the 2023 Coastal Master Plan by implementation period.

The sections below present summary FWRO results in S09 Year 50. These results are then compared to two different cases of interest: FWOA S09 (see Section 3) and FWRO in S08, the higher scenario previously selected for master plan project selection and communication. Detailed results from the FWRO S08 analysis are presented in a separate technical appendix to the master plan (Johnson et al., 2023b).

Note that this section focuses on the Pontchartrain, Barataria, Terrebonne, and Central Coast regions where FWRO projects would be located. Cross-scenario comparisons in additional areas away from these regions (e.g., Chenier Plain) would be the same as those described in the previous section.

4.1 FLOOD DEPTHS

Figure 17 shows a comparison of Year 50 FWRO flood depth results from S08 (top) and S09 (bottom) at the 1% AEP. Mapped results show that the risk reduction projects selected for the 2023 Coastal Master Plan would continue to provide substantial depth reduction for areas behind the levees in the higher SLR scenario. Consistent depth reduction is noted in areas behind major risk reduction alignments, such as Morganza to the Gulf and the Iberia/St. Mary Upland Levee. Higher 1% AEP depths are noted in S09 in many locations, both coastward and landward of the new or upgraded levee alignments, but the depth pattern is consistent between scenarios when accounting for the additional increment of SLR in S09.

Another way to compare scenario results is to calculate whether FWRO projects are providing similar levels of depth reduction in both S08 and S09. Figure 18 shows a mapped comparison of the change in Year 50 flood depths between the FWRO and FWOA in both S08 (top) and S09 (bottom). This figure shows that, despite the consistently greater coastwide flood depths in S09, the structural risk reduction projects selected for the master plan provide a similar level of depth reduction for both scenarios. Morganza to the Gulf and Abbeville and Vicinity, for example, yield more than 6 feet of depth reduction at the 1% AEP for a large area behind the new levees in both scenarios. Of course, in S09 this flood depth reduction occurs against a higher baseline, leading to the final differences in depth noted in Figure 17.

Depth reduction in S09 is more limited in selected regions targeted by 2023 Coastal Master Plan risk reduction projects (Figure 18). These include Slidell, portions of Iberia near Jeanerette, and Braithwaite to White Ditch, where the upgraded levee leads to higher 1% AEP flood depths in S09 Year 50 due to extensive overtopping at this recurrence level and a “deeper bowl” in which to flood. By contrast, additional depth reduction is noted in S09 compared to S08 in areas surrounding and west of Lac Des Allemands, including communities such as South Vacherie and Chackbay.

Finally, Figure 19 shows a mapped comparison of Year 50 FWRO flood depths between S09 and S08 at three AEP levels (10%, 1%, and 0.2%). This figure helps to clarify that, even with risk reduction projects in place, S09 flood depths are consistently higher across geographic area and probability.

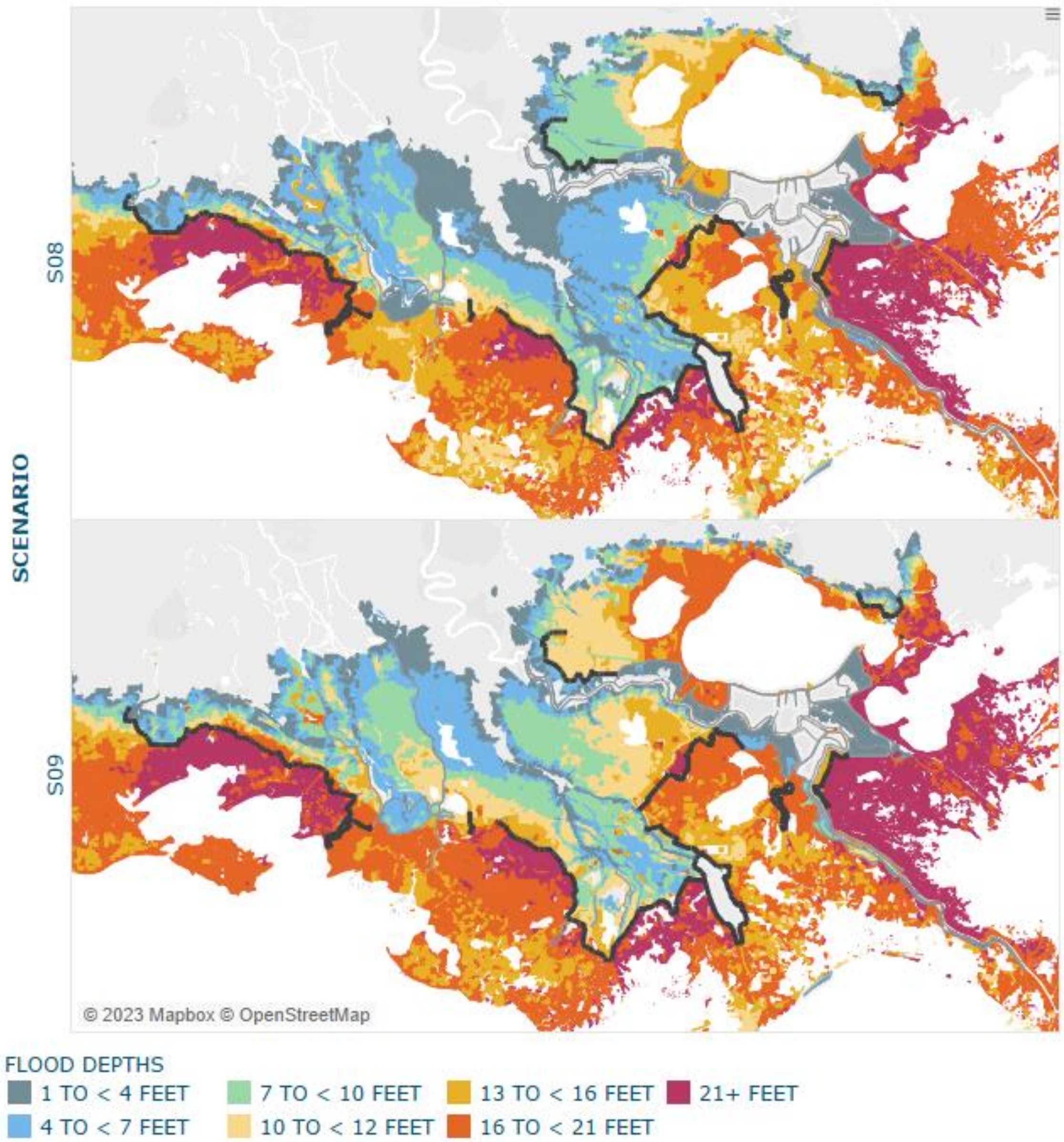

Figure 17. Future with risk only 1% (1 in 100-year) AEP flood depths in Year 50 for S08 and S09 — IPET fragility, 50% pumping scenario, 50th percentile.

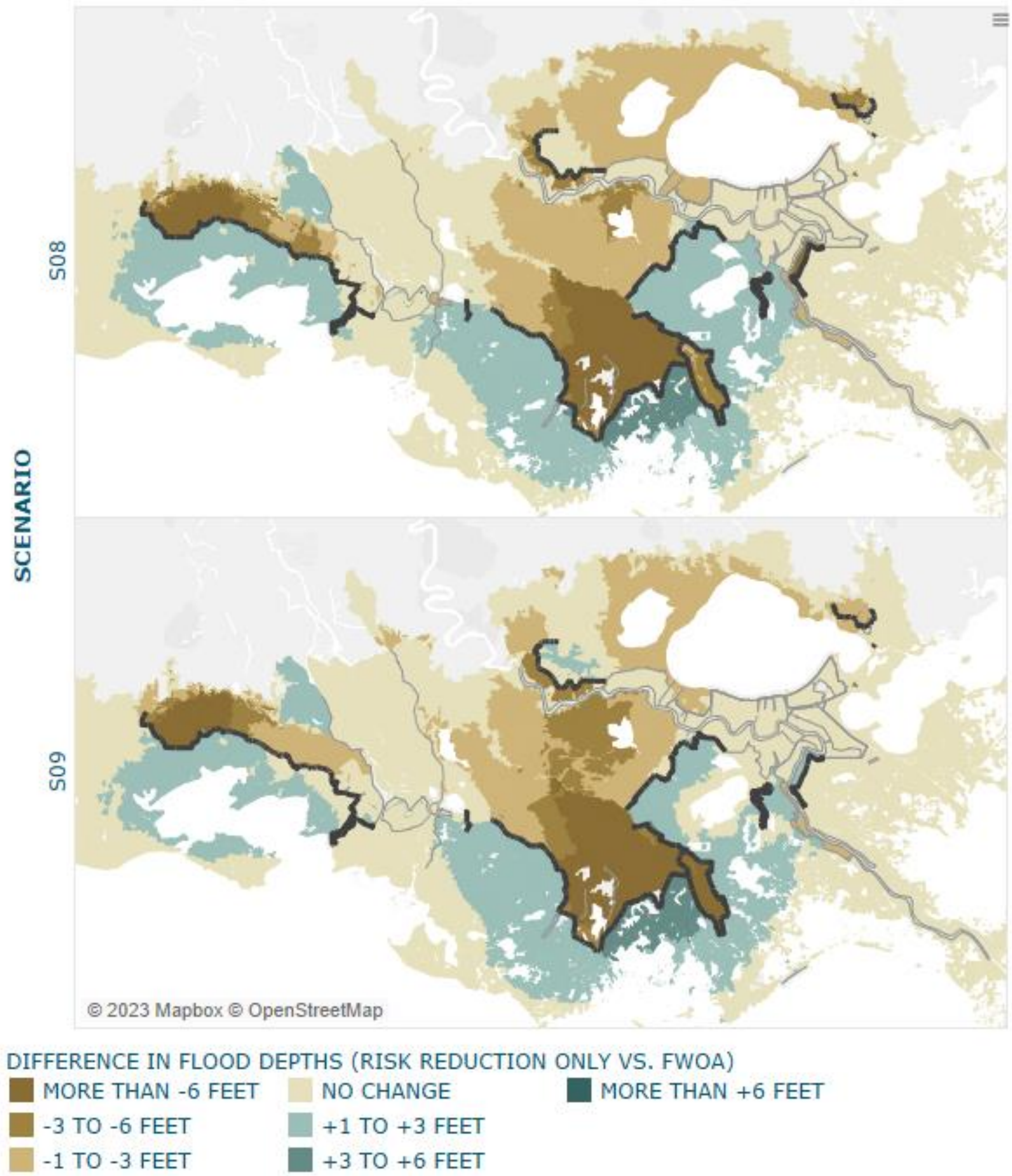

Figure 18. Change in Year 50 1% (1 in 100-year) AEP flood depths with risk only projects in place for S08 and S09 — IPET fragility, 50% pumping scenario, 50th percentile.

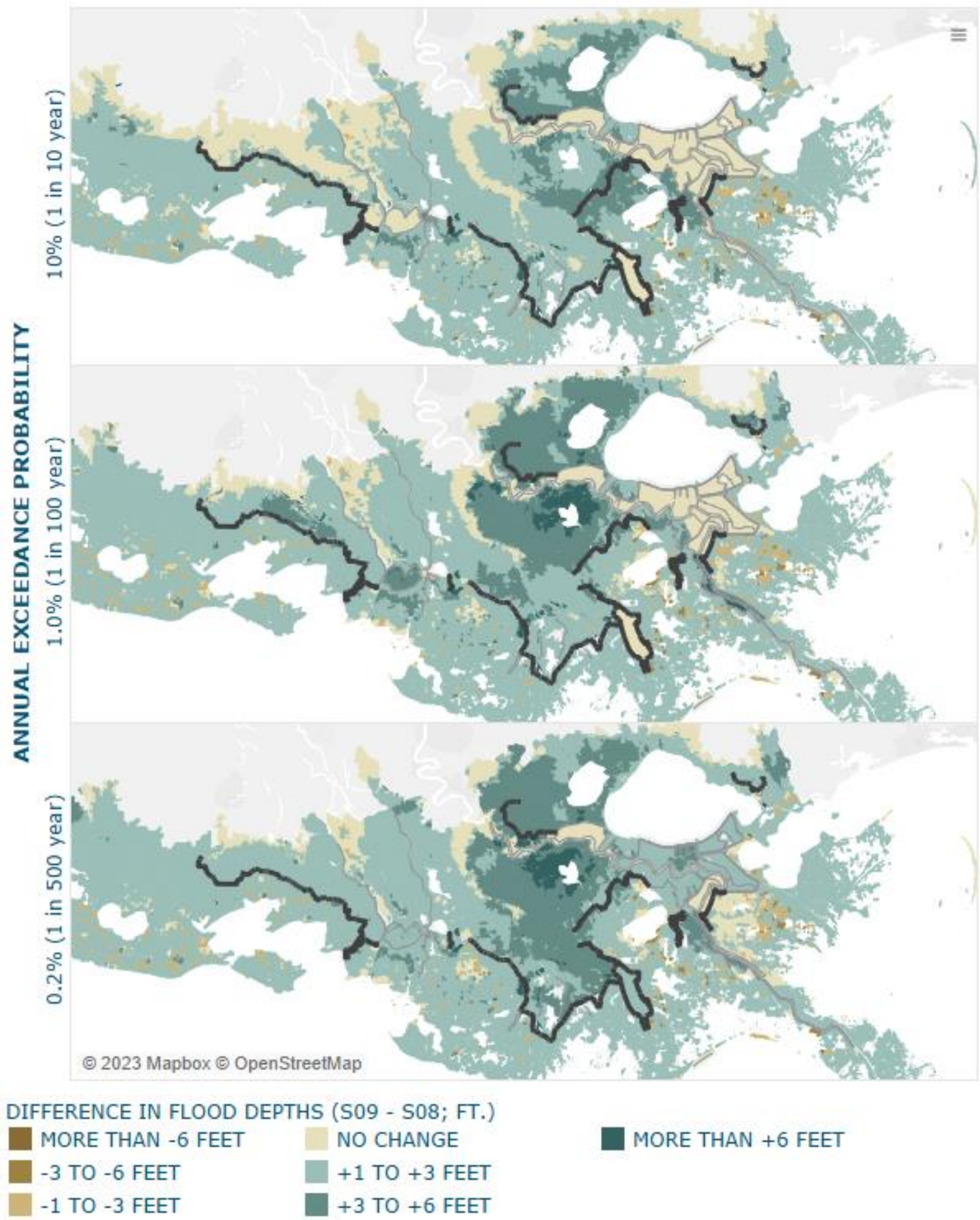

Figure 19. Difference in coastwide future with risk only flood depths at three AEPs in Year 50 comparing S08 and S09 — IPET fragility, 50% pumping scenario, 50th percentile.

4.2 ASSET EXPOSURE AND FLOOD DAMAGE

As discussed in Section 3, higher flood depths lead to consistently greater exposure of residential asset exposure in S09 compared to S08 (Figure 20, top pane). With risk reduction projects in place, residential exposure is reduced in both scenarios (Figure 20, bottom pane). This is notable in the highest category of exposure: nearly 57,000 fewer single-family residences face severe exposure (2 or more feet above FFE) in the FWRO compared to a FWOA in S09 (2% AEP). However, as with S08, many of these residences are still exposed at lower levels, with the marginal count of structures in the moderate category or in flooded areas increasing from the FWOA to FWRO. In addition, in S08 the proportional reduction in severely exposed residences is approximately 40% (reduction of 70,000); in S09, only 26% of residences in this category see a similar level of exposure reduction.

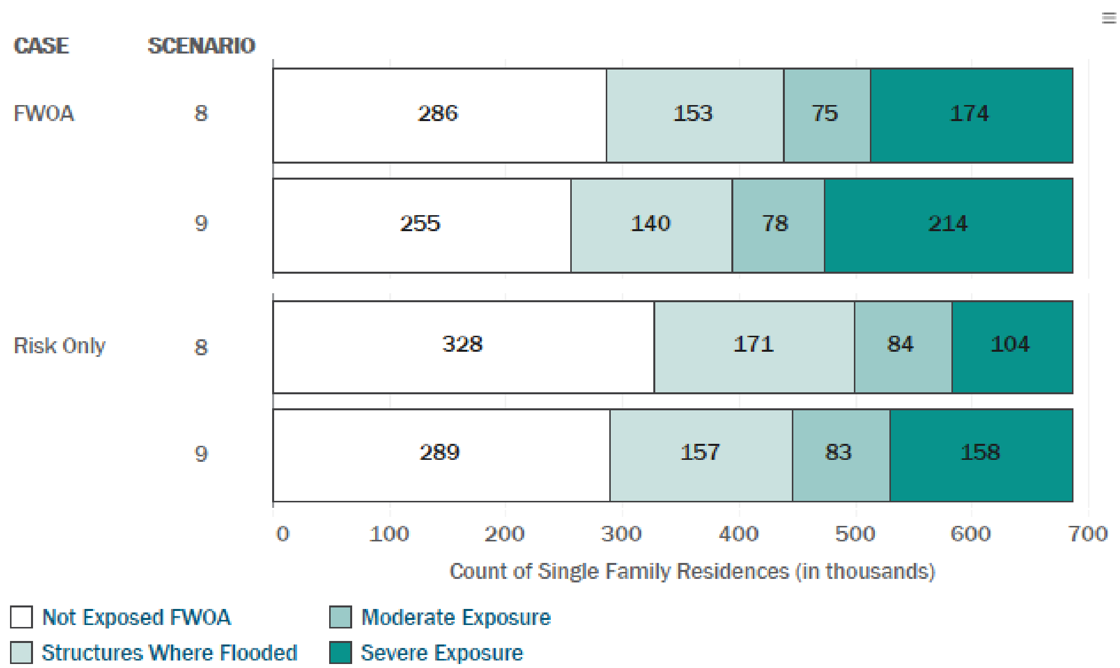

Figure 20. Single family residence structure exposure comparison at the 2% AEP by scenario in Year 50 — IPET fragility, 50% pumping scenario, 50^{th} percentile.

Damage results are summarized coastwide for S08 and S09 in both EADD (left pane) and EASD (right pane) terms in Figure 21. Orange bars show the FWOA results, while grey bars show the coastwide FWRO results for comparison. Starting from a $34.7 billion Year 50 FWOA baseline in S09, the FWRO projects reduce coastwide EADD by $11.8 billion (34%). This is comparable to the EADD reduction in S08 in dollar terms ($10.1 billion EADD reduced in Year 50 S08) but smaller in percentage terms (34% in S09 versus 41% in S08). Notably, even with substantial risk reduction, Year 50 EADD is nearly as high in S09 FWRO ($22.9 billion) as it is in S08 FWOA ($24.4 billion).

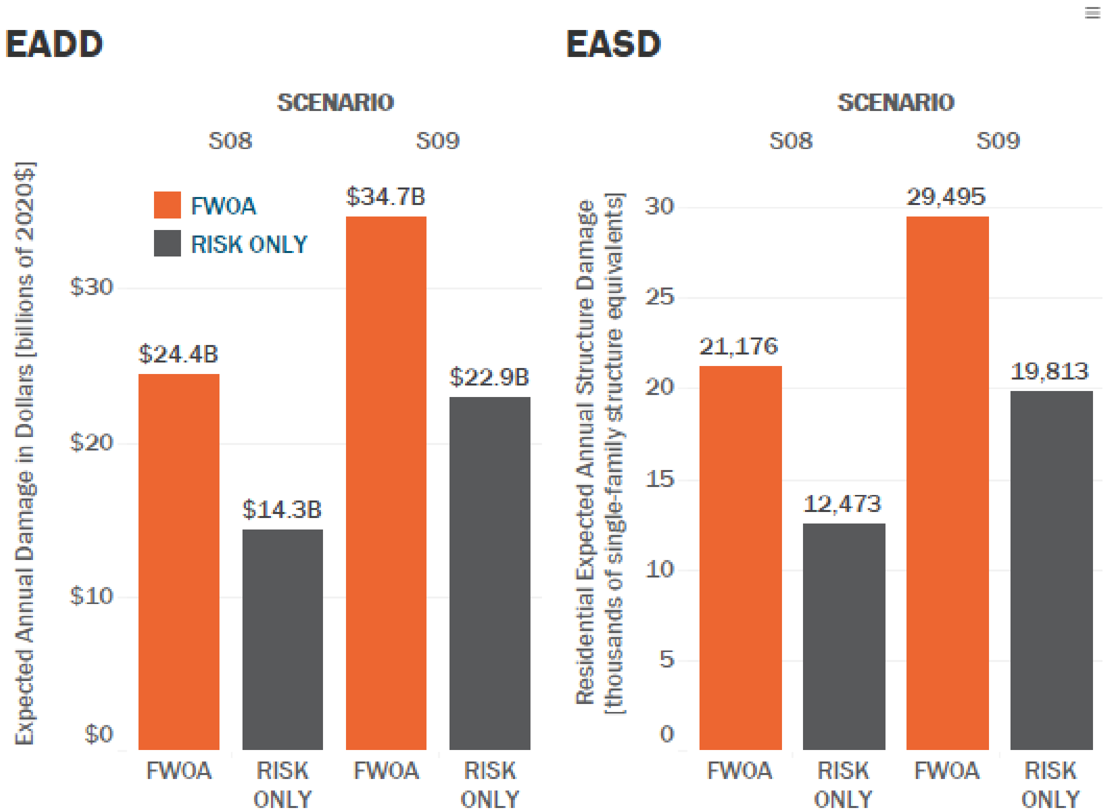

Figure 21. Coastwide EADD and residential EASD in a FWOA and FWRO for S08 and S09 in Year 50 — IPET fragility, 50% pumping scenario, 50th percentile.

Coastwide residential EASD shows a similar pattern when comparing scenario results: risk reduction projects lead to an estimated reduction of 9,682 structure equivalents (33%) in S09, compared to 8,703 reduced in S08 (41%).

Year 50 EADD results by community in a FWRO are shown for both S08 and S09 in Figure 22 below. Spatial patterns are very similar across both scenarios, with higher EADD in more densely populated areas. Significant residual damage is noted in S09 as with S08, with Slidell, Mandeville/Covington, and the Houma region each showing at least $1 billion in EADD even with projects in place. Notably, the Gonzales/Prairieville community joins this list in S09 (EADD of $165 million in S08, $1.08 billion in S09).

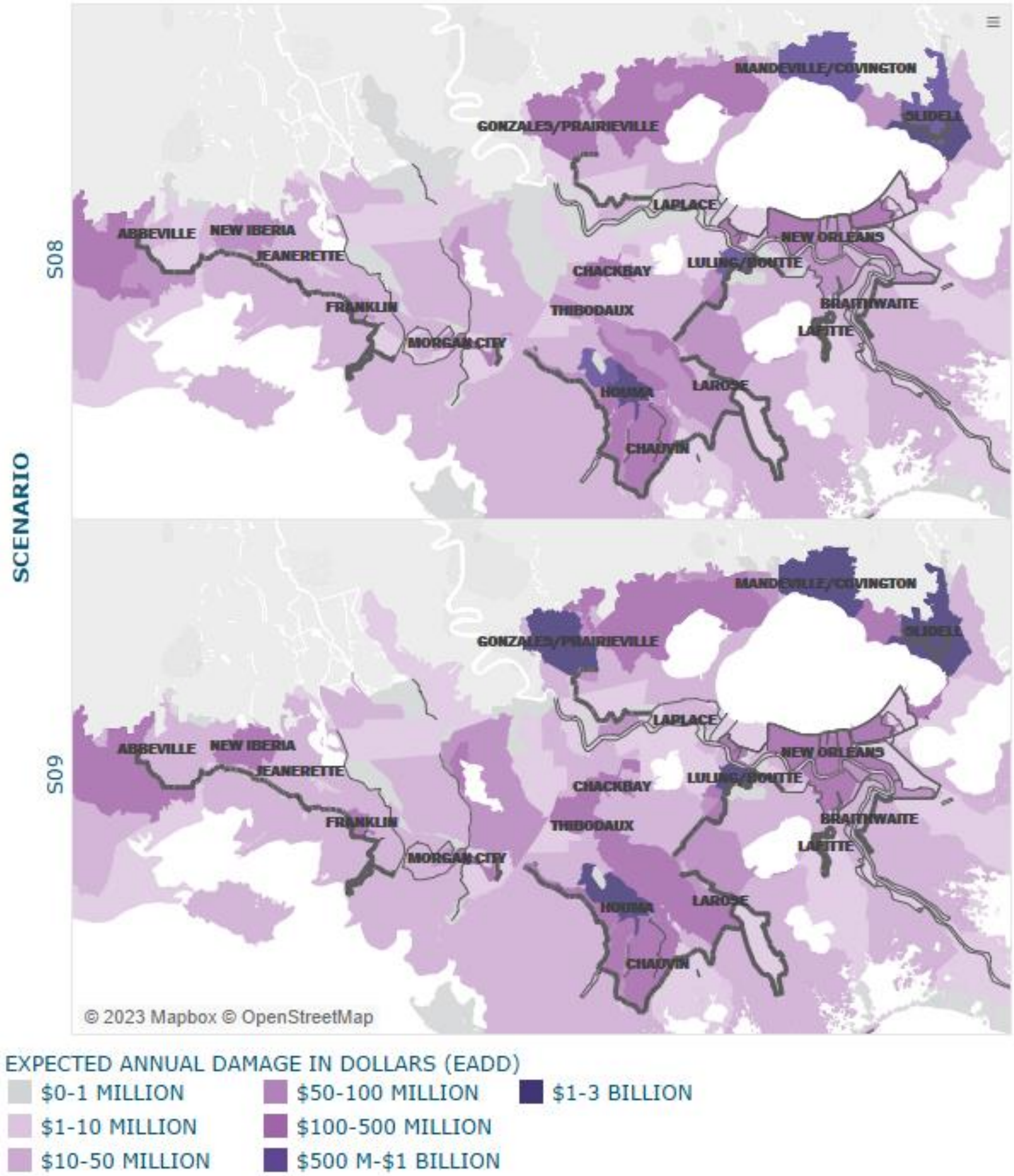

Figure 22. Coastwide FWRO EADD in Year 50 for S08 and S09 — IPET fragility, 50% pumping scenario, 50th percentile.

Damage reduction patterns when comparing FWRO and FWOA are also similar when comparing S08 and S09 (Figure 23). The scale of damage reduction is similar by community, with marginally greater damage reduction noted in some communities in S09 (e.g., Houma, Braithwaite) with others showing declines (e.g., Luling/Boutte, Mandeville/Covington).

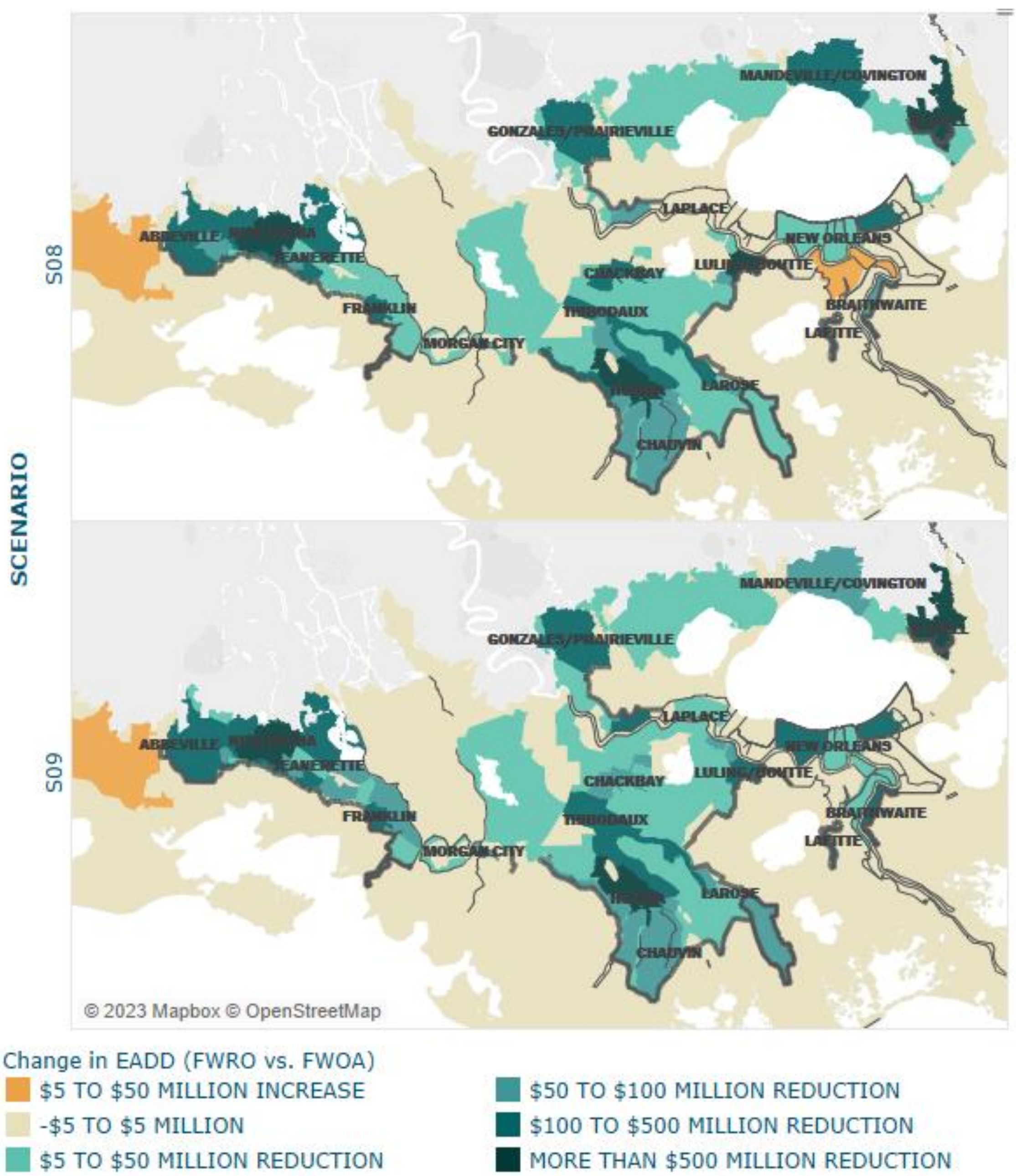

Figure 23. Change in EADD with FWRO projects EADD in Year 50 by environmental scenario — IPET fragility, 50% pumping scenario, 50th percentile.

The Lake Pontchartrain Barrier is designed to reduce water levels from storm surge into the lake. While both scenarios show damage reduction on the East Bank of Greater New Orleans from the barrier, damage reduction in this polder is greater in S09 because it reduces the overtopping at more frequent AEPs as noted previously (see Figure 9 and Figure 19).

As a final comparison, Figure 24 shows just the difference in total EADD by community between S09 and S08. The mapped results highlight the notably higher EADD in FWRO S09 relative to S08 in more densely populated areas, particularly those with assets further inland from the coastal region (e.g., Gonzales/Prairieville, Chackbay/Thibodaux).

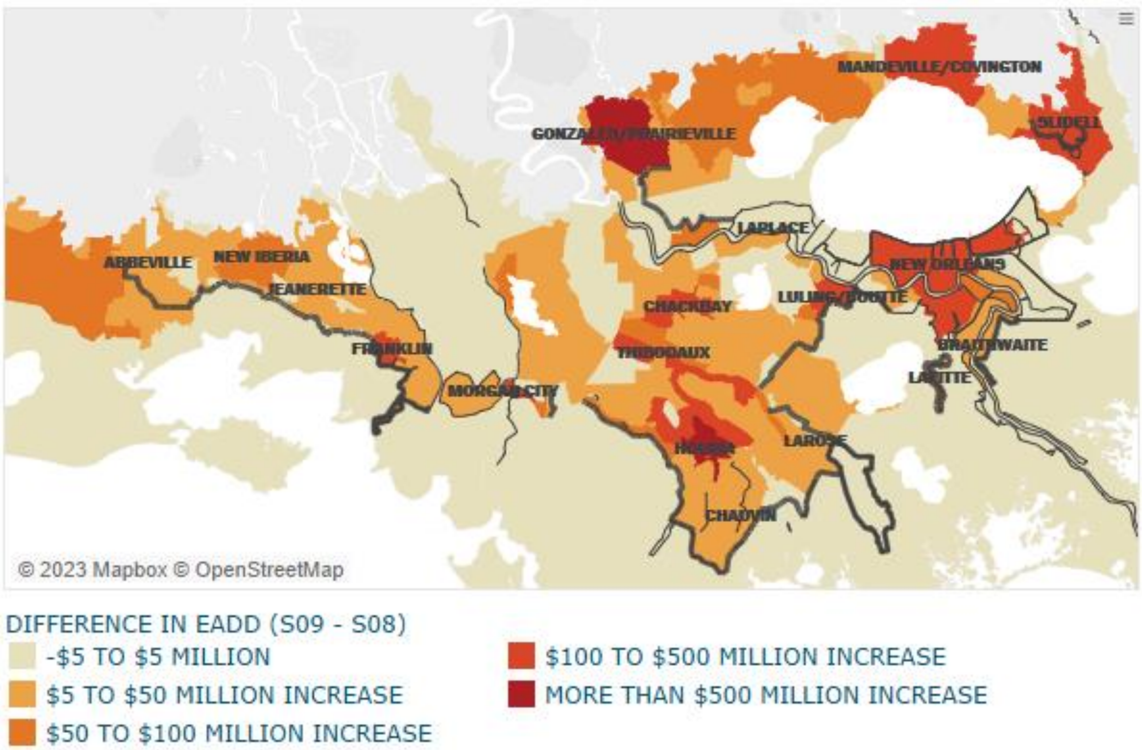

Figure 24. Difference in FWRO coastwide EADD in Year 50 between S09 and S08 — IPET fragility, 50% pumping scenario, 50th percentile.

4.3 DISCUSSION

As with the FWOA analysis, the comparison of the 2023 Coastal Master Plan's risk reduction-only projects between S08 and S09 largely shows an extension of patterns noted previously for the higher scenario. FWRO projects collectively provide a similar level of asset exposure and damage reduction in

S09 compared to S08. However, this risk reduction occurs against a much higher baseline in terms of both depth and damage, leading to a high level of residual (remaining) risk even after these projects are implemented. In the FWRO, spatial patterns of residual damage show particular increases in communities with higher asset densities and/or those close to the study boundary. However, given similarities to S08 results, it is unclear if or how project prioritization among the structural risk reduction projects might have been meaningfully different based on S09 results. As a result, this limited sensitivity analysis appears to reinforce the utility of the higher scenario as applied through the 2023 Coastal Master Plan analysis.

5.0 CONCLUSION

This report presented a sensitivity analysis of simulation modeling results projecting coastal flood risk and damage over a 50-year period in three additional environmental scenarios. Results described in this analysis were simulated with the ADCIRC, SWAN, and CLARA models to build on Louisiana's 2023 Coastal Master Plan analysis and inform next steps for modeling and scenario selection in advance of the 2029 Coastal Master Plan. The document described projected FWOA and FWRO flood depths, exposure of single-family residences, and flood damage across coastal Louisiana.

FWOA results from the additional environmental scenarios considered in this report generally show extensions of patterns previously observed from the master plan's lower and higher scenarios by Year 50. Although risk and damage estimates extend either below or above the 2023 analysis, depending on scenario, they suggest similar storylines to those documented in detail in support of the 2023 Coastal Master Plan. However, results from the highest SLR scenario more consistently push up against the CLARA model's northward coastal boundary, suggesting that this boundary should be revisited and likely moved further inland for the next phase of modeling to inform the 2029 Coastal Master Plan. Risk estimates in that scenario are also likely lower than the true value as a result.

As with the FWOA analysis, the comparison of the 2023 Coastal Master Plan's risk reduction-only projects between the master plan's higher scenario and a scenario with additional assumed SLR by Year 50 (S09) largely shows an extension of patterns noted previously for the higher scenario. FWRO projects collectively provide a similar level of asset exposure and damage reduction in S09 compared to S08. However, this risk reduction occurs against a much higher baseline in terms of both depth and damage, leading to a high level of residual (remaining) risk even after these projects are implemented. Given similarities to S08 results, this limited sensitivity analysis appears to reinforce the utility of the higher scenario as applied through the 2023 Coastal Master Plan analysis.

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