US Army Corps of Engineers ®
Jacksonville District

# SAN JUAN METRO AREA, PUERTO RICO

## COASTAL STORM RISK MANAGEMENT STUDY
## DRAFT INTEGRATED FEASIBILITY STUDY AND ENVIRONMENTAL ASSESSMENT

JULY 2020

## APPENDIX F: PLAN FORMULATION

This page was intentionally left blank.

TABLE OF CONTENTS

1.1 Summary Of Management Measures ..... 2
1.1.1 Identification Of Management Measures ..... 2
1.2 Screening Of Management Measures ..... 10
1.2.1 Preliminary Screening ..... 10
1.2.2 Formulation Strategy ..... 22
1.3 Comparison & Evaluation Of The Focused Array Of Alternatives ..... 23
1.3.1 Planning Criteria Evaluation ..... 28
1.3.2 Economic Evaluation (Costs & Benefits) ..... 34
1.3.1 Environmental Quality ..... 34
1.4 Screening Of Alternatives ..... 36
1.5 The Tentatively Selected Plan ..... 37

# 1.1 SUMMARY OF MANAGEMENT MEASURES

This appendix gives a full account of the plan formulation analysis. **Chapter 3** of the main report can be referenced for an excerpt.

Plan formulation is the process of developing alternative plans to address a given problem. The first step in plan formulation involves identifying all potential management measures for the given problems. A management measure is an action that can be implemented at a specific geographic site to address one or more planning objectives.

An alternative plan includes one or more management measures to address the problem. Alternative plans can differ by types of measures, or how measures are combined or defined, including dimensions, quantities, materials, locations or implementation time frames.

Coastal storm risk management measures consist of three basic types: structural, nonstructural, and natural or nature-based features. The plan formulation process will result in an array of feasible coastal storm risk management alternatives that may consist of a variety of structural, nonstructural, and natural/nature-based measures.

## 1.1.1 IDENTIFICATION OF MANAGEMENT MEASURES

Management measures were selected to accomplish at least one of the planning objectives for this study, which were formulated based on the problems. All possible measures were considered, including those beyond the authority of USACE to implement. The following is a summary of the management measures considered.

**Structural** coastal storm risk management measures are man-made, constructed measures that counteract a flood event in order to reduce the hazard or to influence the course or probability of occurrence of the event. This includes gates, levees, and seawalls that are implemented to reduce risk of damage to infrastructure and to reduce risk to public safety.

**Nonstructural** coastal storm risk management measures are permanent measures applied to a structure and/or its contents that prevent or provide resistance to damage from flooding. Nonstructural measures differ from structural measures in that they focus on reducing the consequences of flooding instead of focusing on reducing the probability of flooding. Relocation, floodproofing (wet and dry), home elevation, and flood warning systems are examples of nonstructural measures.

**Natural and nature-based** coastal storm risk management measures work with or restore natural processes with the aim of wave attenuation and storm surge reduction. Examples are submerged

breakwaters that can also act as an artificial reef, elevated living shorelines and addition of vegetation for redundancy of coastal risk reduction functions.

The following measures are identified and considered for all 6 planning reaches (WSJB-1a, WSJB-1b, WSJB-2, WSJB-3, WSJB-4, and CL-1). As detailed analysis continues in this report, measures are then screened out or carried forward for sub-reaches delineated by direction of the water flow hazard within each reach. Objectives for both reaches include reduction of risk to infrastructure due to flooding from storm surge combined with sea level rise. In WSJB-3, an additional objective is to reduce risk to infrastructure due to wave attack during hurricanes and storms. Measures appropriate to address these objectives are outlined in the discussions below.

MEASURES – TO REDUCE STORM SURGE (SS) RISK (WSJB-1, 2, 3, 4, CL-1)

*STRUCTURAL*

These measures serve the purpose of raising up the elevation of existing strategic low points, to reduce the risk of flooding from a respective water elevation as a result of storm surge combined with sea level rise.

S-1 (SS): No-action: The no-action plan represents future conditions without the implementation of a project. Although this measure does not address any specific problems, it provides a comparison for all other measures. Information to describe this measure was collected during the inventory of existing conditions. The storm surge frequencies would be expected to continue over the 50-year period of analysis. Present structures and replacement costs will be used into the future. The No Action alternative would see no additional federal involvement in storm damage reduction as outlined within this study.

S-2 (SS): Seawall/Floodwall: Seawalls and floodwalls are interchangeable at this phase of the study in terms of the function they provide, and will generally be referred to as seawalls in order to be conservative in costs and real estate footprint assumptions. Seawalls and floodwalls will be delineated further in the final report in terms of design footprint (i.e.: Seawalls use a slightly wider footprint than floodwalls). Seawalls could be constructed at a position seaward of the structures which they are designed to protect. These structures in general have a smaller bottom width footprint and could be beneficial in areas which do not have a large footprint of available real estate, such as in urban settings which are developed. It is assumed that seawall structures in the study area would be constructed seaward of existing seawalls, to protect historic value as well as to avoid disruption of engineering structural integrity of the existing seawall function. Seawalls could be designed as walls or with broader tops allowing for recreation on top of the wall. Both options are considered with this measure. COMBINEABILITY: This measure would

need to be combined with S-7[1] and could combined with other measures.

S-3 (SS): Levee: Levees are embankments constructed along a waterfront to reduce the risk of flooding in relatively large areas, with typical slopes ranging from 1V:2H to 1V:5H, depending on construction material. They are typically constructed by compacting soil into a large berm that is wide at the base and tapers toward the top. Grass or some other type of non-woody vegetation is usually planted on the levee to add stability to the structure. Levees may be constructed in urban areas; however, large tracts of real estate are usually required due to the levee width and required setbacks. COMBINEABILITY: This measure would need to be combined with S-7 and could combined with other measures.

S-4 (SS): Storm Surge Barrier, Large: In most cases, the barrier consists of a series of movable gates that stay open under normal conditions but are closed when storm surge is expected to exceed a certain predetermined level. Storm surge barriers are often chosen as a preferred alternative to closing off waterways completely and may also reduce the required length of flood risk management measures adjacent to and/or behind the barriers. Storm surge barriers range in scale from small/local sluice gates reducing risk to a small coastal inlet to very large barrier systems that are designed to reduce risk to a large estuary or bay and consist of a series of coastal dikes, gates, and in some cases navigation locks. Storm surge barriers must be tied into high ground, whether it be existing high ground, a seawall, levee or other. Specifically, a storm surge barrier of this magnitude would be placed across San Juan Harbor and across the inlet of Condado Lagoon. COMBINEABILITY: This measure would need to be combined with S-2 or S-3 due to a requirement to tie into high ground, and assuming there will not be naturally existing high ground available.

S-5 (SS): Storm Surge Gate, Small: This measure refers to a smaller storm gate, or sluice gate, to close off risk of storm surge in smaller canals. Specifically, this type of gate could be used in the Mosquito Canal/Malaria Canal or Northern Canal. COMBINEABILITY: This measure would need to be combined with S-2 or S-3 due to a requirement to tie into high ground, and assuming there will not be naturally existing high ground available.

S-6 (SS): Pump Stations: Pump stations can be used to redirect water in low lying elevations to more appropriate locations. They generally have a sustained operation and maintenance commitment as well as associated costs. This measure represents larger pump stations that would be used to prevent storm surge, rather than smaller pumps that would be used in combination with structural measures to assist in outflow of runoff. COMBINEABILITY: This could be a stand- alone alternative, but would not be very effective given the large expanse of low lying

[1] Structural measures, such as seawalls and levees tend to trap rainfall runoff associated with storms on the landward side. S-7 represents culverts or pumps and would allow outflow of water from behind the landward side of the structure to carry the water to seaward sides, ensuring that functions to meet appropriate rainfall runoff needs are met.

elevations.

S-7 (SS): Inland Hydrology: Structural measures, such as seawalls and levees tend to trap rainfall runoff associated with storms on the landward side. Gravity outlets, such as culverts, in some cases can be installed along the length of the structure. In cases where significant runoff may be trapped behind the structure, ponding areas and pump stations may be required. This measure must be come combined with other structures such as levees and seawalls to allow outflow of water from behind the landward side of the structure to carry the water to seaward sides, ensuring that functions to meet appropriate rainfall runoff needs are met. While currently undefined, this measure will address the need for adequate rainfall runoff with other measures, and will be developed further and refined as needed for planning purposes. COMBINEABILITY: This measure is intended to be combined with S-2, S-3, NNBF-2 and NNBF-3.

S-8 (SS): Retention basin: This measure would involve land buyout to create a water retention basin in low areas to temporarily impound water and offset flooding impacts elsewhere. COMBINEABILITY: This measure would need to be combined with S-7 to also address inland hydrologic needs for rainfall runoff.

*NON-STRUCTURAL*

NS-1 (SS): Improved evacuation plan: The Puerto Rico Hurricane Evacuation Study was released in October 2018, and references evacuation zones. Conclusions from surveys conducted in the Puerto Rico Hurricane Evacuation Study, Behavioral Study, Final Report March 2014 generally indicated that residents would be more likely to evacuate out of the evacuation zone to higher ground if directed to do so. This would be a measure implemented by the non-federal sponsor. COMBINEABILITY: This measure alone would not meet the objective to reduce risk since coastal flooding would still occur and many communities would still be affected whether they evacuate or not; it would need to be combined with other structural or NNBF measures that would reduce coastal flooding in order to be effective.

NS-2 (SS): Improved public notification systems: Warning systems can limit damages of an event due to increased preparedness and ensure evacuation directives are messaged to the community. This would be a measure implemented by the non-federal sponsor. COMBINEABILITY: This measure alone would not meet the objective to reduce risk since coastal flooding would still occur and many communities would still be affected whether they receive the public notification or not; it would need to be combined with other structural or NNBF measures that would reduce coastal flooding in order to be effective.

NS-3 (SS): Improved public outreach about coastal flooding risk: Measures to convey storm surge risk to communities could help community better understand how it could affect them during a storm. An example used in other areas is storm surge posts, which visually show the

storm surge stages which could be expected in various areas associated with category 1-5 storms. This would be a measure implemented by the non-federal sponsor. COMBINEABILITY: This measure alone would not meet the objective to reduce risk since coastal flooding would still occur and many communities would still be affected even if they are aware of the risks; it would need to be combined with other structural or NNBF measures that would reduce coastal flooding in order to be effective.

NS-4 (SS): Re-Zoning: Re-zoning could apply to phasing out development low lying areas over time. This would be a measure implemented by the non-federal sponsor. COMBINEABILITY: This measure alone would not meet the objective to reduce risk since coastal flooding could still occur in areas which are not re-zoned; it would need to be combined with other structural or NNBF measures that would reduce coastal flooding in order to be effective.

NS-5 (SS): Floodproofing (Dry): Dry floodproofing involves making building and site modifications to prevent water from entering during a flooding event. Dry floodproofing methods would be to seal flood prone structures from water with door and window barriers, small scale rapid deployable floodwalls, or sealants. Dry floodproofing is generally feasible up to 3 feet and is prohibited in FEMA VE zones. COMBINEABILITY: Due to limited risk reduction (only up to 3 feet), this measure would need to be combined with other measures.

NS-6 (SS): Floodproofing (Wet): Wet floodproofing involves making a series of modifications to a structure to allow an enclosed area below the base flood elevation to flood. The method of floodproofing reduces risk to the building but not to the contents of the building. COMBINEABILITY: This measure could be a stand-alone alternative or could be combined with other measures.

NS-7 (SS): Acquisition of land and structures (Buyout): This measure would allow storm surge to flood into low lying elevations. Structures within the area vulnerable to damage would be identified for acquisition. Structures on the acquired parcels would be demolished and natural areas restored. Such parcels would become public property and would reduce the number of structures vulnerable to storm damages. COMBINEABILITY: This measure could be a stand-alone alternative or could be combined with other measures.

NS-8 (SS): Elevate critical infrastructure: This measure, in combination with other measures, could reduce damages to critical infrastructure by building them to higher elevations. COMBINEABILITY: This measure alone would not meet the objective to reduce risk since coastal flooding would still occur and many communities would still be affected; it would need to be combined with other structural or NNBF measures that would reduce coastal flooding in order to be effective.

NS-9 (SS): Elevate infrastructure: This measure, in combination with other measures, could

reduce damages to infrastructure by building them to higher elevations. COMBINEABILITY: This measure could be a stand-alone alternative or could be combined with other measures.

NS-10 (SS): Relocation of Critical Infrastructure: This measure would allow the area to continue to flood from storm surge, while relocating critical infrastructure to a higher elevation to reduce risk of critical damage. Structures vulnerable to storm damage in the study are would be identified, and where feasible, such structures would be moved further landward on their parcels to escape the vulnerable area. COMBINEABILITY: This measure would need to be combined with other measures.

NS-11 (SS): Relocation of critical evacuation route: This measure would allow the area to continue to flood from storm surge, while relocating infrastructure to a higher elevation to reduce risk of critical damage. Structures vulnerable to storm damage in the study are would be identified, and where feasible, such structures would be moved further landward on their parcels to escape the vulnerable area. COMBINEABILITY: This measure alone would not meet the objective to reduce risk since coastal flooding would still occur and many communities would still be affected; it would need to be combined with other structural or NNBF measures that would reduce coastal flooding in order to be effective.

NS-12 (SS): Elevate local roads: This measure, in combination with other measures, could reduce damages to roadways by building them to higher elevations. This measure would be especially applicable in the Condado Lagoon area, where tidal flooding impacts road access often. COMBINEABILITY: This measure alone would not meet the objective to reduce risk since coastal flooding would still occur and many communities would still be affected; it would need to be combined with other structural or NNBF measures that would reduce coastal flooding in order to be effective.

*NATURAL AND NATURE-BASED FEATURES*

NNBF-1 (SS): Greenways: Use undeveloped land or purchase land which is susceptible to flooding to function as additional natural storage/retention during coastal storm and/or heavy rain events. COMBINEABILITY: This measure alone would not meet the objective to reduce risk since coastal flooding would still occur and many communities would still be affected; it would need to be combined with other structural or NNBF measures that would reduce coastal flooding in order to be effective.

NNBF-2 (SS): Elevated Living Shoreline: This measure would be similar to a levee, however it would have two transitional berms at lower elevations. It would include placement of fill, stone, and vegetation, to reduce risk of storm surge flooding depths by providing a more natural raised elevation. It could provide additional benefits to create an effective buffer, provide valuable habitat and improve water quality. This measure is envisioned to be better suited for areas with less space and would be planted with vegetation suited for brackish/salt water

habitats/environments. COMBINEABILITY: This measure would need to be combined with S-7 to also address inland hydrologic needs for rainfall runoff.

NNBF-3 (SS): Horizontal Levee ("Tiered Levee"): This measure would be similar to the elevated living shoreline, however it would have three transitional berms at lower elevations. It would include placement of fill, stone, and vegetation, to reduce risk of storm surge flooding depths by providing a more natural raised elevation. It could provide additional benefits to create an effective buffer, provide valuable habitat and improve water quality. This measure is envisioned to be better suited for areas with more space and would be planted with vegetation suited for freshwater/marsh habitats/environments. COMBINEABILITY: This measure would need to be combined with S-7 to also address inland hydrologic needs for rainfall runoff.

## MEASURES – TO REDUCE WAVE ATTACK (WA) RISK (PLANNING REACH WSJB-3)

### *STRUCTURAL*

S-1: No-action: The no-action plan represents future conditions without the implementation of a project. Although this measure does not address any specific problems, it provides a comparison for all other measures. Information to describe this measure was collected during the inventory of existing conditions. The storm surge frequencies would be expected to continue over the 50-year period of analysis. Present structures and replacement costs will be used into the future. The No Action alternative would see no additional federal involvement in storm damage reduction as outlined within this study.

S-2: Seawall (WA): In addition to the function of a seawall for risk reduction as a result of storm surge, a seawall also can function for wave attack. Reference the description for seawall (SS). COMBINEABILITY: This measure would need to be combined with S-7 (SS) to address rainfall runoff. This is a duplicative measure that can cover both SS and WA.

S-3: Revetment (WA): This measure would involve placement of large rock, designed to withstand the wave environment, seaward of structures which are most vulnerable to storm damages which may result from shoreline erosion. The engineered structure would have a sloped profile designed to dissipate wave energy before it reaches the protected structures. The revetment could be covered by a dune or some degree of beach fill for additional protection and for aesthetic reasons. Construction would be from the beach, with intermittent access from roads. Impacts to the nearshore resources during construction would be avoided. COMBINEABILITY: This could be a stand-alone alternative.

### *NON-STRUCTURAL*

NS-1 (WA): Acquisition of land and structures (Buyout): Structures within the area vulnerable to damage would be identified for acquisition. Structures on the acquired parcels would be demolished and natural areas restored. Such parcels would become public property and would

reduce the number of structures vulnerable to storm damages. COMBINEABILITY: This measure alone would not meet the objective to reduce risk since coastal flooding would still occur and many communities would still be affected; it would need to be combined with other structural or NNBF measures that would reduce coastal flooding in order to be effective.

NS-2 (WA): Relocation of Critical Infrastructure: This measure would allow the area experience wave attack while relocating infrastructure to a higher elevation to reduce risk of critical damage. Structures vulnerable to storm damage in the study are would be identified, and where feasible, such structures would be moved further landward on their parcels to escape the vulnerable area. COMBINEABILITY: This measure alone would not meet the objective to reduce risk since coastal flooding would still occur and many communities would still be affected; it would need to be combined with other structural or NNBF measures that would reduce coastal flooding in order to be effective.

NS-3 (WA): Improved public outreach: Measures to convey risk from the wave action risk to communities could help community better understand how it could affect them during a storm. Signs in the area could be a means to convey information. This would be a measure implemented by the non-federal sponsor. COMBINEABILITY: This measure alone would not meet the objective to reduce risk since coastal flooding would still occur and many communities would still be affected; it would need to be combined with other structural or NNBF measures that would reduce coastal flooding in order to be effective.

*NATURAL AND NATURE-BASED FEATURES*

NNBF-1 (WA): Submerged/Emergent Breakwaters: Offshore breakwaters reduce the amount of wave energy reaching the shoreline, and in this case, would reduce risk of damage to the storm surge measure. The breakwaters would be constructed of large rock with foundation materials to prevent subsidence. The breakwaters would be trapezoidal in profile and would be placed parallel to the shoreline in shallow water. The breakwater would be constructed in segments, separated from each other, to prevent infilling between the beach and the breakwater. The elevation and length of each breakwater segment and the distance between segments would be designed considering the local wave and sediment transport characteristics. This measure could benefit the environmental resources in the area, with the rock mimicking natural reefs adjacent to the study area, and potentially creating foraging habitat for benthic species. Mangroves could grow on top of the breakwaters as well for additional habitat and foraging opportunities for birds. COMBINEABILITY: This measure would need to be combined with other storm surge measures to fulfill both the storm surge and wave attack reduction objectives.

NNBF-2 (WA): Emergent Island: This type of island would be elevated from the water and would act as a barrier island to the shoreline area. It would serve the same function as a breakwater, but it would be engineered with appropriate earthen materials. This measure could benefit the environmental resources in the area, with the rock on the outer face of the island potentially

creating foraging habitat for benthic species. Mangroves and other plant species could grow on top of the islands as well for additional habitat and foraging opportunities for birds. COMBINEABILITY: This measure would need to be combined with other storm surge measures to fulfill the storm surge and wave attack objectives.

NNBF-3 (WA): Mangrove/Vegetation Fringe: Mangroves have been shown to reduce wave action during coastal storm events, however, it is not measureable in terms of stand-alone benefits for the purposes of this analysis. Therefore, this measure would need to be combined with another measure which is measureable in terms of benefits, and would provide additional benefit/redundancy to that measure. Mangroves provide additional habitat and foraging opportunities for birds. COMBINEABILITY: This measure would need to be combined with other wave attack and storm surge measures to fulfill the storm surge and wave attack objectives.

## 1.2 SCREENING OF MANAGEMENT MEASURES

Screening is the ongoing process of eliminating measures which will no longer be considered, based on evaluation criteria.

### 1.2.1 PRELIMINARY SCREENING

Criteria to evaluate study measures was derived from the specific project objectives, ability to meet long term considerations, the four P&G accounts, as well as constraints. During this process, the interdependency, as well as the exclusivity of measures, is identified. This process serves to eliminate some measures from further consideration. Costs and benefits are not calculated at this stage.

In order to provide a metric for appraisal of the various management measures, a numeric score was applied by judging a measure's ability to meet planning objectives, meet long term considerations, avoid constraints, and to contribute to each of the four P&G accounts. The management measures were evaluated and rated as follows: 0 = does not meet criteria, 1 = partially meets criteria, and 2 = fully meets criteria. If the total rating equals a number greater than 11, the measure partially meets, at least, over half of the objectives and constraints and is carried forward for further analysis. If the total rating is equal to or less than 11, the measure is not considered further. Planning criteria is shown in **Figure 1.** Results of the screening are summarized in **Figure 2** and shown in more detail in **Table 1.**

**Figure 1. Planning Criteria for Screening of Measures.**

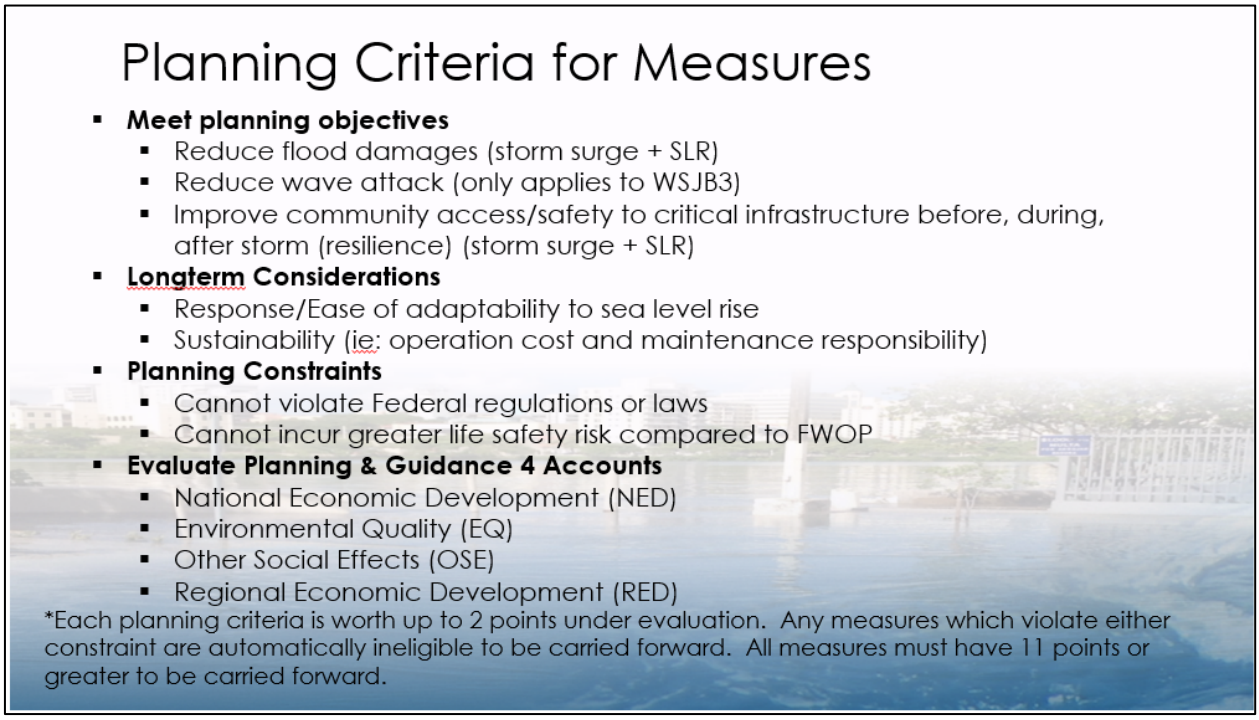
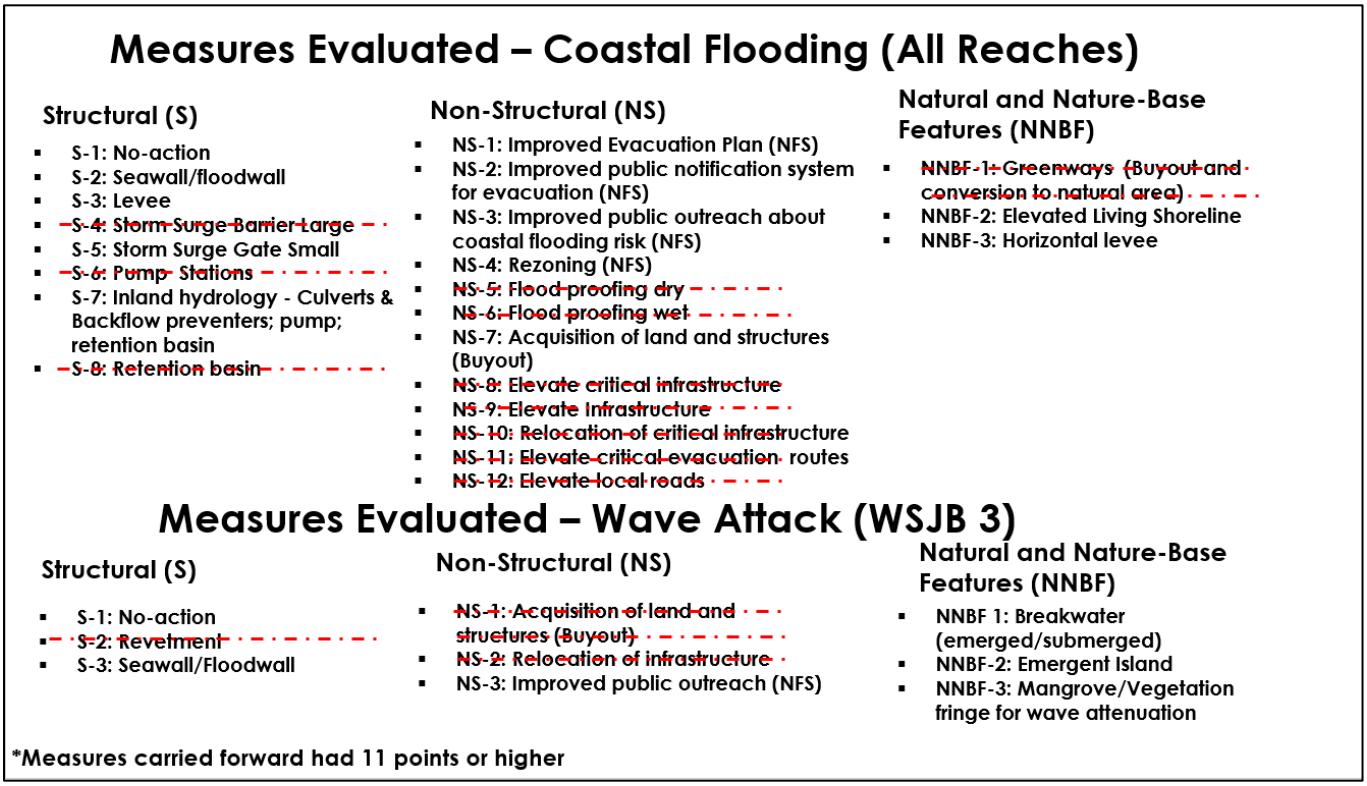


**Figure 2. Measures Considered and Evaluated, with Screening Results (Coastal Flooding and Wave Attack).**




## MEASURES SCREENED OUT

### *STRUCTURAL*

- S-4 (SS): Larger Storm Surge Barrier – This measure was screened out because the costs would not outweigh the benefits, resulting in a BCR<1. Additionally, it carries significant operation and maintenance responsibilities and cost. The barrier carries risk as it would need to be closed in order to capture benefits, and it also not contribute to reduction in risk as a result of sea level rise.
- S-6 (SS): Pump Stations – This measure was screened out since it scored less than 11 points on the criteria evaluation. Key reasons are that pump stations as stand-alone items would not be effective. First, they would be unable to reduce the storm surge impacts to infrastructure, and after storm surge impacted the area, it would not be effective at pumping out water over the large expanse of low elevation. Additionally, it carries significant operation and maintenance responsibilities and cost. Finally, they would not contribute to reduction in risk as a result of sea level rise.
- S-3 (WA): Revetment – This measure was screened out since it scored less than 11 points on the criteria evaluation. A key reason is that it would not sufficiently reduce wave action in conjunction with storm surge measures.

*NON-STRUCTURAL*

- NS-5 (SS): Floodproofing (Dry) - This measure was screened out since it scored less than 11 points on the criteria evaluation. A key reason is that most of the structures are concrete, one-story, slab on grade construction in low lying elevations. Since dry floodproofing is only sufficient to protect against 3 feet, sea level rise alone in the next 50 years could quickly exceed this threshold. Additionally, some areas are in FEMA zone VE (dry floodproofing is prohibited.)
- NS-6 (SS): Floodproofing (Wet) - This measure was screened out since it scored less than 11 points on the criteria evaluation. A key reason is that most of the structures are concrete, one-story, slab on grade construction in low lying elevations. To create a wet floodproofing opportunity, at least a two story building would be needed, or the concrete structures would need to be raised. This would be extremely cost prohibitive, as well as extremely long and difficult in terms of construction.
- NS-8 (SS): Elevate critical infrastructure - This measure was screened out since it scored less than 11 points on the criteria evaluation. A key reason is that most of the structures are concrete, one-story, slab on grade construction in low lying elevations, and critical infrastructure is not consolidated into focused areas. Elevating critical infrastructure would be extremely costly, and additionally, all other infrastructure would still be flooded and would likely be unable to access critical infrastructure.
- NS-9 (SS): Elevate infrastructure - This measure was screened out since it scored less than 11 points on the criteria evaluation. A key reason is that most of the structures are concrete, one-story, slab on grade construction in low lying elevations. This would be extremely cost prohibitive, as well as extremely long and difficult in terms of construction.
- NS-10 (SS): Relocation of Critical Infrastructure - This measure was screened out since it scored less than 11 points on the criteria evaluation. A key reason is that the critical infrastructure is not consolidated into focused areas. Relocation of critical infrastructure would be extremely costly, and additionally, all other infrastructure would still be flooded and would likely be unable to access critical infrastructure.
- NS-11 (SS): Relocation of critical evacuation routes - This measure was screened out since it scored less than 11 points on the criteria evaluation. A key reason is that the critical evacuation routes are generally elevated to sufficient heights. Additionally, it is key to note that even if evacuation plans are followed, residents are still limited to remaining on the island and infrastructure would still be damaged.
- NS-12 (SS): Elevate local roads - This measure was screened out since it scored less than 11 points on the criteria evaluation. A key reason is that this would involve most roads. This would be extremely costly, and additionally, all other infrastructure would still be flooded.
- NS-2 (WA): Relocation of Critical Infrastructure - This measure was screened out since it scored less than 11 points on the criteria evaluation. A key reason is that the critical infrastructure is not consolidated into focused areas. Relocation of critical infrastructure

would be extremely costly, and additionally, all other infrastructure would still be flooded and would likely be unable to access critical infrastructure.

*NATURAL AND NATURE-BASED FEATURES*

- NNBF-1 (SS): Greenways- This measure has merit but at this point no areas have been identified to make this measure feasible.

## MEASURES CARRIED FORWARD

*STRUCTURAL*

- S-1 (SS/WA): No-action
- S-2 (SS/WA): Seawall
- S-3 (SS): Levee
- S-5 (SS): Storm Surge Gate, Small
- S-6 (SS): Outflow Structures

*NON-STRUCTURAL*

- NS-1 (SS): Improved evacuation plan
- NS-2 (SS): Improved public notification systems
- NS-3 (SS/WA): Improved public outreach about coastal flooding risk
- NS-4 (SS): Re-Zoning
- NS-7 (SS): Acquisition of land and structures (Buyout)

*NATURAL AND NATURE-BASED FEATURES*

- NNBF-2 (SS): Elevated Living Shoreline
- NNBF-3 (SS): Horizontal Levee
- NNBF-5 (SS) Beneficial Use of Material
- NNBF-1 (WA): Submerged/Emergent Breakwaters
- NNBF-2 (WA): Emergent Island
- NNBF-3 (WA): Mangrove/Vegetation Fringe

## Table 1. Structural Measures – Coastal Flooding.

| | Management | Reaches that Apply | | | | | 50-year Planning Objectives | | Longterm Considerations | | Constraints | | Principles and Guidelines Accounts | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Structural Measures (NS) | WSJB1A/1B | WSJB2 | WSJB3 | WSJB4 | CL | Reduce risk of damages to infrastructure storm surge effects combined with sea level rise (intermediate scenario) over the next 50 years | Reduce flood stages/durations along evacuation routes and to critical infrastructure to improve accessibility, as well as maintain public health and safety, to community before, during and after storm surge events in combination with sea level rise. (resilience) | Longterm ease of use/adaptability to sea level rise. | Sustainability (ie:Lower operation and Maintenance) | Avoid conflict with Federal and State Regulations | Cannot increase life loss compared to the FWOP conditions | National Economic Development (NED) | Environmental Quality (EQ) | Other Social Effects (OSE) (to include local acceptability) | Regional Economic Development (RED) | Rank | Carried Forward |
| S-1 | No-Action | Y | Y | Y | Y | Y | no | no | no | Likely other partial and ineffective solutions would be built | yes | no | no | would likely continue at status quo, but certain areas would continue to become worse after major storms | Likely other partial and ineffective solutions would be built | would likely continue at status quo | 5 | Y |
| | | | | | | | 0 | 0 | o | 0 | 2 | o | 0 | 1 | 1 | 1 | | |
| S-2 | Floodwall/seawall | Y | Y | Y | Y | Y | In certain strategic areas, coulld be effective at protecting infrastructure. | Could prevent backflow into communities to allow accessibility to roads, as well as maintain health and safety. | Certain types of floodwalls/seawalls are better for height adaptation. | inspections would be required. | Meets. | Would need to install culverts with flapgates with this measure to ensure outflow as needed. | Potential to have moderate cost and high benefits. | some effects during construction. It is assumed the seawall/floodwall would be installed slight offset from existing seawalls/floodwalls (If culturally significant) | larger heights could be considered to be not aestheticically pleasing | could protect existing econmic businesses along this area and could become part of tourism in the area if done properly | 14 | Y |
| | | | | | | | 2 | 2 | 1 | 1 | 2 | 2 | 1 | 1 | 1 | 1 | | |
| S-3 | Levee (applies only in areas with enough space) | Y | Y | N | N | N | In certain strategic areas, coulld be effective at protecting infrastructure | Could prevent backflow into communities and restore health and safety | Storm surge would be prevented from entering and therefore roads, etc would not be as affected. | inspections would be required. | Meets. | Would need to install culverts with flapgates with this measure to ensure outflow as needed. | Potential to have moderate cost and high benefits. | some effects during construction | larger heights could be considered to be not aestheticically pleasing | slight RED during construction | 14 | Y |
| | | | | | | | 2 | 2 | 2 | 1 | 2 | 2 | 1 | 1 | 1 | 0 | | |
| S-4 | Storm Surge Barrier Gates, Large | Y | N | N | N | Y | 3 gates would be needed. Cost is extremely high - NED beenfits can be achieved to gain same ebenfits for lesser cost. | Could potentially accomplish. Would only work if closed. | Would not work for sustained sea level rise (unless permantely closed). Adaptability for higher elevations could be acheived but would likely be costly and time intensive. | Large operation and mainteance. It would need to be closed prior to a storm and kept opened during non-storm events. | Meets. | Meets | High cost will outwigh benefits | gates would be open except for prior to and during storms. Could be effects to marine species during closures and/installation | smaller gates would be less intrusive to communities. | slight RED during construction | 8 | N |
| | | | | | | | 0 | 1 | 0 | 0 | 2 | 2 | 0 | 1 | 1 | 1 | | |
| S-5 | Storm Surge Gates, Small | Y | Y | N | N | N | could apply to Aqua Frias (WSJB 1)or mosquito canal (Malaria Canal) WSJB-2. Could potentially reduce some or all damages to WSJB1/WSJB2 during storm events in both locations. Cost is likely to be high - unclear if NED benefits could be achieved. | Could accomplish. Would only work if closed. | Meets. | Some operation and mainteance on the smaller gates but not as much as larger sector gates. It would need to be closed prior to a storm and kept opened during non-storm events. | Meets. | Meets. | Smaller gates could have low cost and high benefits. | Gates reduce the need for hard structures, leading top potentially less effects | smaller gates would be less intrusive to communities. | slight RED during construction | 13 | Y |
| | | | | | | | 1 | 1 | 2 | 1 | 2 | 2 | 1 | 1 | 1 | 1 | | |
| S-6 | Pumps Stations | N | N | N | N | N | Pump statiions would be unable to pump out needed strom surge and sufficiently reduce flooding, due to sizing and low elevations. | Could prevent backflow into communities for access and to maintain health and safety | Adaptable but could be costly and would require resizing/replacing as needed | big operation and maintenance cost and commitment to maintain for proper function | Meets. | Meets. | High cost and operation cost, cannot reduce flooding - | cannot reduce flooding - | Unclear if this option would be well received by communities. | slight RED during construction | 6 | N |
| | | | | | | | 0 | 0 | 1 | 0 | 2 | 2 | 0 | 0 | 0 | 1 | | |
| S-7 | Inland Hydrology | Y | Y | Y | Y | Y | Would not redcue damages on its own, but required to prevent rainfall runoff flooding behind strutures | would prevent backflow into communities to maintain health and safety | Could be adpted as needed | inspections would be required. | Meets. | Meets. | Potential to have moderate cost and high benefits. | could prevent damaging storm surge to surrounding environement | likely would be acceptable to communities | slight RED during construction | 14 | Y |
| | | | | | | | 2 | 2 | 2 | 1 | 2 | 2 | 1 | 1 | 1 | 0 | | |
| S-8 | Retention basin | Y | Y | N | N | N | If used in multiple areas in combination with desination of areas at igher elevation and other measures, it can offset damages to infrastructure by designating areas which are designed to flood. | Water impounded at a designatred location(s) would allow other areas to return to business as usual sooner. | Moderate | Maintenance would be required for inflow/outflow structures. | Meets. | Meets. | Cost of land and creation of retention basin with associated structures would have very high cost. This would likely not be economically justified. | Low ipoundment area could be created as wetlands (4 feet, etc), and could potentially contribute benefits. | Unclear if this option would be well received by communities. Land likely not available. | Could create short term economic benefits during construction. | 10 | N |
| | | | | | | | 1 | 1 | 1 | 0 | 2 | 2 | 0 | 1 | 1 | 1 | | |

**Table 2. Non-Structural Measures (NS 1 to NS 7)– Coastal Flooding.**

| | Measures | Reaches that Apply | | | | | 50-year Planning Objectives | | Longterm Considerations | | Constraints | | Principles and Guidelines Accounts | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Non-Structural Measures (NS) | WSJB1A/1B | WSJB2 | WSJB3 | WSJB4 | CL | Reduce risk of damages to infrastructure storm surge effects combined with sea level rise (intermediate scenario) over the next 50 years | Reduce flood stages/durations along evacuation routes and to critical infrastructure to improve accessibility, as well as maintain public health and safety, to community before, during and after storm surge events in combination with sea | Longterm ease of use/adaptability to sea level rise. | Sustainability (ie:Lower operation and Maintenance) | Avoid conflict with Federal and State Regulations | Cannot increase life loss compared to the FWOP conditions | National Economic Development (NED) | Environmental Quality (EQ) | Other Social Effects (OSE) (to include local acceptability) | Regional Economic Development (RED) | Rank | Carried Forward |
| NS-1 | Improved Evacuation plan | Y | Y | Y | Y | Y | evaucation plan improvements will help undertanding of risk and protocols to reduce risk | evaucation plan improvements will help undertanding of risk and protocols to reduce risk | evaucation plan improvements will help undertanding of risk and protocols to reduce risk | evaucation plan improvements will help undertanding of risk and protocols to reduce risk | Meets | Meets | evaucation plan improvements will help undertanding of risk and protocols to reduce risk | evaucation plan improvements will help undertanding of risk and protocols to reduce risk | evaucation plan improvements will help undertanding of risk and protocols to reduce risk | evaucation plan improvements will help undertanding of risk and protocols to reduce risk | | Y |
| | | | | | | | 1 | 1 | 1 | 1 | 2 | 2 | 1 | 1 | 1 | 1 | 12 | |
| NS-2 | Improved public notification systems for evacuation | Y | Y | Y | Y | Y | notifcation system improvement will help understanding of timing, need and risk prevention | notifcation system improvement will help understanding of timing, need and risk prevention | notifcation system improvement will help understanding of timing, need and risk prevention | notifcation system improvement will help understanding of timing, need and risk prevention | Meets | Meets | notifcation system improvement will help understanding of timing, need and risk prevention | notifcation system improvement will help understanding of timing, need and risk prevention | notifcation system improvement will help understanding of timing, need and risk prevention | notifcation system improvement will help understanding of timing, need and risk prevention | | Y |
| | | | | | | | 1 | 1 | 1 | 1 | 2 | 2 | 1 | 1 | 1 | 1 | 12 | |
| NS-3 | Improved public outreach about coastal flooding | Y | Y | Y | Y | Y | education through outreach will help undertanding of risk | education through outreach will help undertanding of risk | education through outreach will help undertanding of risk | education through outreach will help undertanding of risk | Meets | Meets | education through outreach will help undertanding of risk | education through outreach will help undertanding of risk | education through outreach will help undertanding of risk | education through outreach will help undertanding of risk | | Y |
| | | | | | | | 1 | 1 | 1 | 1 | 2 | 2 | 1 | 1 | 1 | 1 | 12 | |
| NS-4 | Re-zoning (possibly in phases) | Y | Y | Y | Y | Y | this could help to phase out repairs or new construction after a certain time in flood prone areas | this could help to phase out repairs or new construction after a certain time in flood prone areas | this could help to phase out repairs or new construction after a certain time in flood prone areas | this could help to phase out repairs or new construction after a certain time in flood prone areas | Meets | Meets | this could help to phase out repairs or new construction after a certain time in flood prone areas | this could help to phase out repairs or new construction after a certain time in flood prone areas | this could help to phase out repairs or new construction after a certain time in flood prone areas | this could help to phase out repairs or new construction after a certain time in flood prone areas | | Y |
| | | | | | | | 1 | 1 | 1 | 1 | 2 | 2 | 1 | 1 | 1 | 1 | 12 | |
| NS-5 | Floodproofing (dry) | N/ | Y | N | Y | Y | only works to 3 feet | unlikely | does nothing for roads, acces s | no | no | not in VE areas | unlikely to achive needed benefits | no sign effect either way | unlikely to help communities or be supported | small RED during process | | N |
| | | | | | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | |
| NS-6 | Floodproofing (wet) | Y | Y | Y | Y | Y | In combination with other measures, this could reduce damages to infrastructure by taking them to higher elevations. However, most homes are concrete block on grade and this type of measure is not practicle or realistic for homes. Applying this to entire study are is not feasibile. Cost almost certainly outweigh benefit | roads would have to be elevated to see these benefits | Once built, this could reduce damages to infrastructure by taking them to higher elevations. However, too many homes to do this for enitre community. | potentially low maintenance once built; However, too many homes to do this for enitre community. | Meets | Meets | would be very costly - would need to buyout first floors of buildings, etc or make adaptations to allow areas up to a certain point to flood | no sign effect either way | could help coummnities but unlikely to be acceptable or practical | RED during process | | N |
| | | | | | | | 0 | 0 | 1 | 1 | 2 | 2 | 0 | 0 | 0 | 1 | 7 | |
| NS-7 | Acquistion of land and structures (buyout) | Y | Y | Y | Y | Y | This would reduce risk to structures by removing them from the high risk areas. Likely to be high cost. | Would not accomplish for roads, other areas experiencing some lower damages | More homes would need to be aquired as sea level rises. | tradeoff with sustainanoloty of area bought out but likely constantly assessing buyouts | Meets | Meets | Expected high cost and only benefits some | Could allow conversion back to natrual areas and no construction which could be beneficial. | may not be acceptabe to communities, or may be favorable assistance | RED during process | | Y |
| | | | | | | | 1 | 0 | 1 | 1 | 2 | 2 | 1 | 1 | 1 | 1 | 11 | |

**Table 3. Non-Structural Measures (NS 8 to NS 12)– Coastal Flooding.**

| | Measures | Reaches that Apply | | | | | 50-year Planning Objectives | | Longterm Considerations | | Constraints | | Principles and Guidelines Accounts | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Non-Structural Measures (NS) | WSJB1A/1B | WSJB2 | WSJB3 | WSJB4 | CL | Reduce risk of damages to infrastructure storm surge effects combined with sea level rise (intermediate scenario) over the next 50 years | Reduce flood stages/durations along evacuation routes and to critical infrastructure to improve accessibility, as well as maintain public health and safety, to community before, during and after storm surge events in combination with sea | Longterm ease of use/adaptability to sea level rise. | Sustainability (ie:Lower operation and Maintenance) | Avoid conflict with Federal and State Regulations | Cannot increase life loss compared to the FWOP conditions | National Economic Development (NED) | Environmental Quality (EQ) | Other Social Effects (OSE) (to include local acceptability) | Regional Economic Development (RED) | Rank | Carried Forward |
| **NS-8** | **Elevate critical infrastructure** | **Y** | **Y** | **Y** | **Y** | **Y** | In combination with other measures, this could reduce damages to infrastructure by taking them to higher elevations; however, this would not benefit all the other areas which exp problems | This would not improve accessibility for communities to the crit infrastructure from their homes/businesses | Elevation would have to be at appropriate height to avoid future raising. | unlikely to be sustainable if communities roads and infrastructure is not raised accordingly | yes | Meets | high upfront cost, only solves part of the problem and does not provide solution for the whole community, likely to result in low beneifts | no sign effect either way | if communities are still flooded, rasiing crit infrs does not help them | RED during construction | | N |
| | | | | | | | 0 | 0 | 1 | 1 | 2 | 2 | 0 | 0 | 0 | 1 | 7 | |
| **NS-9** | **Elevate infrastructure** | **Y** | **Y** | **Y** | **Y** | **Y** | In combination with other measures, this could reduce damages to infrastructure by taking them to higher elevations. However, most homes are concrete block on grade and this type of measure is not practical or realistic for homes. | In combination with other measures, this could reduce damages to infrastructure by taking them to higher elevations; however, would need to be combined with roads, evac routes too to see true benefits | In combination with other measures (such as road elevation), this could reduce damages to infrastructure by taking them to higher elevations | yes, elevated infrastructure would already be adapted to future SLR scenarios if at correct height | Meets | Meets | extremely high costs, unlikely to be justified | no sign effect either way | could help communities but would be constant construction for many years | RED during construction, could have tourism benefits if done properly | | N |
| | | | | | | | 1 | 1 | 1 | 1 | 2 | 2 | 0 | 0 | 1 | 1 | 10 | |
| **NS-10** | **Relocation of critical infrastructure** | **Y** | **Y** | **Y** | **Y** | **Y** | Moving infrastructure to higher ground would reduce risk of damages to those structures but it would not reduce damages for others which were not moved. It would be very costly and would likely not see the needed benefits for justification | Partially would improve accessibility to critical infrastructure for some but not all | Only for those structures which were moved to higher ground, and only if they were moved to high enough ground. Critical infrastructure is scattered and not consistently in one area. | Partially. Sustainable for structures moved but possibly not for all. | Meets | Meets | high cost of land and relocation could result in low benefits | not likely to affect environment positive or negative | if communities are still flooded, this would not help them | some RED during construction | | N |
| | | | | | | | 0 | 1 | 1 | 1 | 2 | 2 | 0 | 1 | 1 | 1 | 10 | |
| **NS-11** | **Elevate critiical evac routes** | **Y** | **Y** | **Y** | **Y** | **Y** | In combination with other measures, could allow communities to evac and return sooner. However, this would not benefit all the other areas which exp problems | This would not improve accessibility for communities to the crit infrastructure from their homes/businesses | This would not help communities | This would not improve accessibility for communities to the crit infrastructure from their homes/businesses | Meets | Meets | yes | Meets | high upfront cost, only solves part of the problem and does not provide solution for the whole community, likely to result in low beneifts | no sign effect either way | | N |
| | | | | | | | 0 | 0 | 0 | 0 | 1 | 1 | 2 | 2 | 0 | 0 | 6 | |
| **NS-12** | **Elevate local roads & sidewalks** | **Y** | **Y** | Y | **Y** | **Y** | In combination with other measures, this could reduce damages to infrastructure by taking them to higher elevations | In combination with other measures, this could reduce damages to infrastructure by taking them to higher elevations | In combination with other measures, this could reduce damages to infrastructure by taking them to higher elevations | yes, elevated roads would already be adapted to future SLR scenarios | Meets | Meets | high cost and would need to be combined for true benefits, high unlikely to be justified | no sign effect either way | if communities are still flooded, this would not help them | RED during construction, could have tourism benefits if done properly | | N |
| | | | | | | | 1 | 1 | 1 | 1 | 2 | 2 | 0 | 0 | 0 | 1 | 9 | |

**Table 4. Natural & Nature-Based Features – Coastal Flooding.**

| | Measures | Reaches that Apply | | | | | 50-year Planning Objectives | | Longterm Considerations | | Constraints | | Principles and Guidelines Accounts | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Natural and Nature & Based Features | WSJB1A/1B | WSJB2 | WSJB3 | WSJB4 | CL | Reduce risk of damages to infrastructure storm surge effects combined with sea level rise (intermediate scenario) over the next 50 years | Reduce flood stages/durations along evacuation routes and to critical infrastructure to improve accessibility, as well as maintain public health and safety, to community before, during and after storm surge events in combination with sea level rise. (resilience) | Longterm ease of use/adaptability to sea level rise. | Sustainability (ie:Lower operation and Maintenance) | Avoid conflict with Federal and State Regulations | Cannot increase life loss compared to the FWOP conditions | National Economic Development (NED) | Environmental Quality (EQ) | Other Social Effects (OSE) (to include local acceptability) | Regional Economic Development (RED) | Rank | Carried Forward |
| NNBF-1 | Greenways would be combined other measures (buyout/relocation, etc) | N | Y | N | N | N | can offset damages to infrastructure by designating natural areas (pervious vs impervious) which are designed to flood. | Provides natural greenspace which can provide water quality benefits and water attenuation. | This natural area would be used during storm events tas natural flooding area to allow other areas to continue to function. Provides redundancy to strutural measures. | This area could be succeptable to sustained increased water levels as sea level change, but would have been previously identified as non-critical infrastructure and not to be developed. | Meets | Meets | Would need to be paired with other measures to attain full benefits. Cost of land is unknown. | This would add native greenspace to urban areas; | This has potential for recreational opportunities during non-flooding events. | Could increase economic recreational and toruism opportunities. | | Y |
| | | | | | | | 1 | 1 | 2 | 1 | 2 | 2 | 1 | 2 | 2 | 2 | 16 | |
| NNBF-2 | Elevated Living Shoreline | N/Y | N | Y | N | Y | In certain strategic areas, could be effective at protecting infrastructure. | Could prevent backflow into communities to allow accessibility to roads, as well as maintain health and safety.Provides area which can provide water quality benefits and water attenuation. | very adaptable | inspections would be required. Design with nature allows for sustainability. | Meets | Meets | Potential to have moderate cost and high benefits. | This would add native additional habitat and water quality features. | This has potential for recreational opportunities during non-flooding events. | Could increase economic recreational and toruism opportunities. | | Y |
| | | | | | | | 2 | 2 | 2 | 2 | 2 | 2 | 1 | 2 | 2 | 2 | 19 | |
| NNBF-3 | Horizontal Levee | N/N | Y | N | N | N | In certain strategic areas, could be effective at protecting infrastructure. | Could prevent backflow into communities to allow accessibility to roads, as well as maintain health and safety.Provides area which can provide water quality benefits and water attenuation. | very adaptable | inspections would be required. Design with nature allows for sustainability. | Meets | Meets | Potential to have moderate cost and high benefits. | This would add native additional habitat and water quality features. | This has potential for recreational opportunities during non-flooding events. | Could increase economic recreational and toruism opportunities. | | Y |
| | | | | | | | 2 | 2 | 2 | 2 | 2 | 2 | 1 | 2 | 2 | 2 | 19 | |

**Table 5. Structural Measures – Wave Attack.**

| | Measures | Reaches that Apply | | | | | 50-year Planning Objectives | Longterm Considerations | | Constraints | | Principles and Guidelines Accounts | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Structural Measures (S) | WSJB1 A/1B | WSJB2 | WSJB3 | WSJB4 | CL | Reduce risk of damages to infrastructure from wave attack combined with sea level rise (intermediate scenario) over the next 50 years | Longterm ease of use/adaptability to sea level rise. | Sustainability (ie:Lower operation and Maintenance) | Avoid conflict with Federal and State Regulations | Cannot increase life loss compared to the FWOP conditions | National Economic Development (NED) | Environmental Quality (EQ) | Other Social Effects (OSE) (to include local acceptability) | Regional Economic Development (RED) | Rank | Carried Forward |
| S-1 | No-Action | N | N | Y | N | N | wave action will continue to cause damages along the shoreline. | adaptation would need to be done by local community or others | sustainable by doing nothing, but not truly sustainable as this would be attempted without a holistic plan | Meets | Meets | No benefits | would remain status quo | communities would continue to be affected during and after storms | no benefits | | Y |
| | | | | | | | 0 | 0 | 0 | 2 | 2 | 0 | 1 | 1 | 0 | 6 | |
| S-2 | Seawall (along Catano shoreline) | N | N | Y | N | N | would provide wave attack and flooding benefits | yes | potentially | Meets | Meets | could have potential to reduce wave enegy benefits for less than cost | no sign effects either way | could be acceptable ; could possibly block viewshed | some RED during construction and also for tourism | | Y |
| | | | | | | | 2 | 2 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 17 | |
| S-2 | Revetment (along Catano) shoreline | N | N | Y | N | N | To some degree, must be combined with flood reduction measures | To some degree, must be combined with flood reduction measures | yes, add more rock | Meets | Meets | could have lower cost and potential benefits | no sig effects either way | could be acceptable | no sig effects either way | | N |
| | | | | | | | 1 | 1 | 2 | 2 | 2 | 1 | 0 | 1 | 0 | 10 | |

**Table 6. Non-Structural Measures – Wave Attack.**

| | Measures | Reaches that Apply | | | | | 50-year Planning Objectives | Longterm Considerations | | Constraints | | Principles and Guidelines Accounts | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Nonstructural Measures (NS) | WSJB 1A/1B | WSJB2 | WSJB3 | WSJB4 | CL | Reduce risk of damages to infrastructure from wave attack combined with sea level rise (intermediate scenario) over the next 50 years | Longterm ease of use/adaptability to sea level rise. | Sustainability (ie:Lower operation and Maintenance) | Avoid conflict with Federal and State Regulations | Cannot increase life loss compared to the FWOP conditions | National Economic Development (NED) | Environmental Quality (EQ) | Other Social Effects (OSE) (to include local acceptability) | Regional Economic Development (RED) | Rank | Carried Forward |
| NS-1 | Acquisition of land and structures (buyout) | N | N | Y | N | N | This would reduce damages by removing infrastucture from high impact zones. | If communities moved to areas with more stability. | Potentially. | Meets | Meets | Likely to be extremely high cost to buy out all of the infrastructure in this area. | unlikely to affect | likely to be highly unpopular and unclear where communities would move to | none | | N |
| | | | | | | | 2 | 1 | 1 | 2 | 2 | 0 | 0 | 0 | 0 | 8 | |
| NS-2 | Relocation of critical infrastructure | N | N | Y | N | N | This would reduce damages by removing infrastucture from high impact zones. | If communities moved to areas with more stability. | Potentially. | Meets | Meets | Likely to be extremely high cost to move all of the infrastructure in this area. | unlikely to affect | likely to be highly unpopular and unclear where communities would move to | none | | N |
| | | | | | | | 2 | 1 | 1 | 2 | 2 | 2 | 0 | 0 | 0 | 10 | |
| NS-3 | improved public outreach about wave attack | N | N | Y | N | N | education through outreach will help undertanding of risk ; however, homes are not built up in this area as in a typical shoreline - mostly inductrial and community features. Not likely to fully address problem but could be helpful in conjunction with a feature | Partially meets. | Partially meets. | Meets | Meets | Partially meets. | Partially meets. | Partially meets. | Partially meets. | | Y |
| | | | | | | | 1 | 1 | 1 | 2 | 2 | 1 | 1 | 1 | 1 | 11 | |

**Table 7. Natural & Nature-Based Features – Wave Attack.**

| | Measures | Reaches that Apply | | | | | 50-year Planning Objectives | Longterm Considerations | | Constraints | | Principles and Guidelines Accounts | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | NNBF | WSJB 1A/1B | WSJB2 | WSJB3 | WSJB4 | CL | Reduce risk of damages to infrastructure storm surge effects combined with sea level rise (intermediate scenario) over the next 50 years | Longterm ease of use/adaptability to sea level rise. | Sustainability (ie:Lower operation and Maintenance) | Avoid conflict with Federal and State Regulations | Cannot increase life loss compared to the FWOP conditions | National Economic Development (NED) | Environmental Quality (EQ) | Other Social Effects (OSE) (to include local acceptability) | Regional Economic Development (RED) | Rank | Carried Forward |
| NNBF-1 | Emerged or Submerged breakwater | N | N | Y | N | N | yes | yes | yes, could build higher if needed | little to no maintenance | Meets | Potential NED benefits compared to cost | habitat could be promoted | community would likely find acceptable | could provide RED with economic recreational and toruism opportunities. | | Y |
| | | | | | | | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 18 | |
| NNBF-2 | Emergent island | N | N | Y | N | N | yes | yes | yes, could build higher if needed | little to no maintenance | Meets | Potential NED benefits compared to cost | habitat could be promoted | community would likely find acceptable | could provide RED with economic recreational and toruism opportunities. | | Y |
| | | | | | | | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 18 | |
| NNBF-3 | Mangrove/ Vegetation Fringe | N | N | Y | N | N | unproven but potential to lessen damages from wave attack | could improve conditions after storm | could work in tandem with seawall to not only reduce wave energy but also work towards future SLR adaptability | llittle O&M | Meets | potential NED benefits compared to minimal cost | habitat could be promoted with the shelves | community would likely find acceptable | little to no RED | | Y |
| | | | | | | | 1 | 1 | 2 | 2 | 2 | 1 | 1 | 1 | 1 | 12 | |

## 1.2.2 FORMULATION STRATEGY

The overarching strategy is to identify the NED/TSP plan for each planning reach, and recommend an overarching TSP comprised of each reach's NED/TSP plan, showing incrementally justification, to allow for comprehensive storm surge risk reduction within the San Juan Metro Area.

Planning reaches as described in this report were configured in ways such that they would be self- contained units of cost and benefits, or separable elements. This means that benefits accrued in each planning reach would be derived from alternatives only in that reach. Measures that met criteria to be carried forward were combined using the combinability thought process as described earlier, as well as refined geographical elevation information, existing site conditions, and professional engineering judgment as to the most feasible combinations per reach.

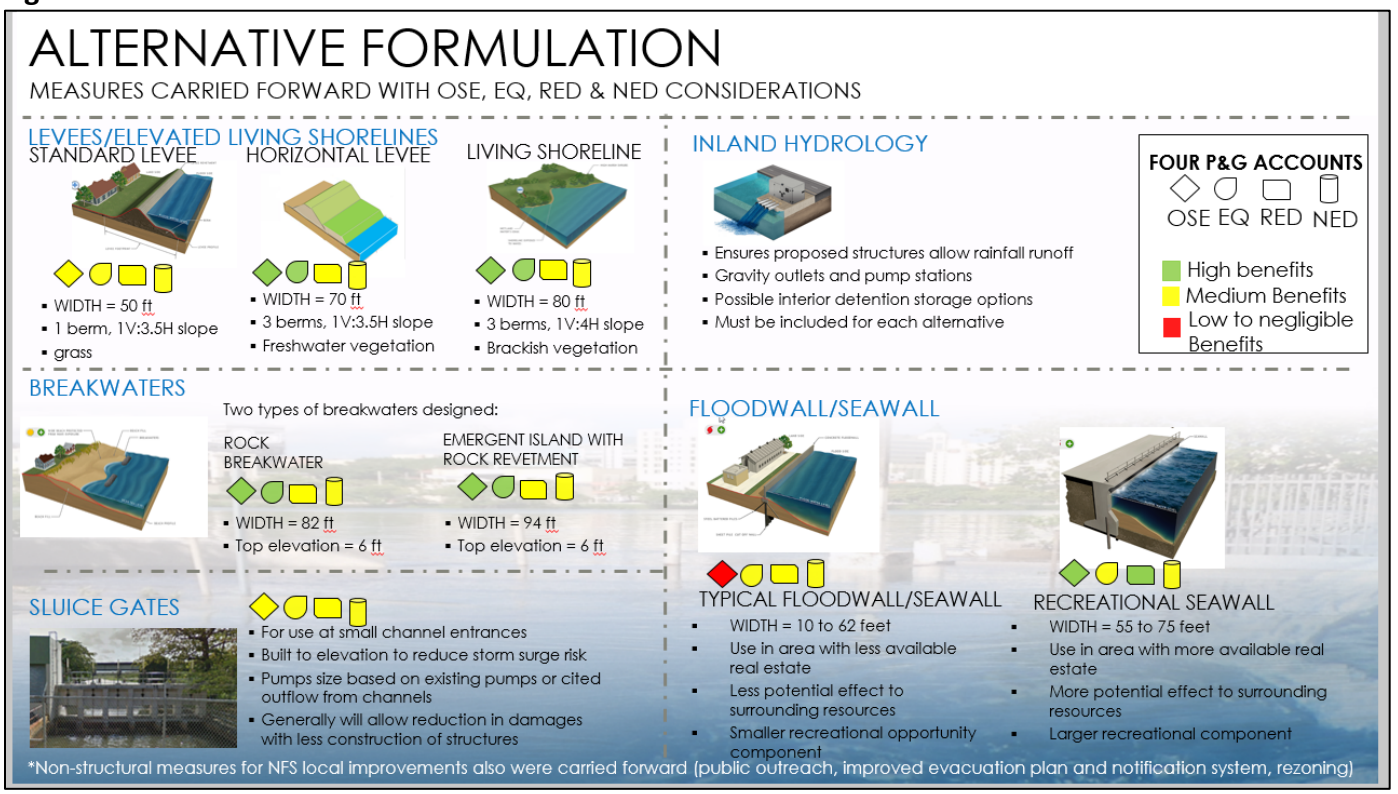
*Design Elevations*

To produce risk-based design elevations for the desired measures the study team followed ECB 2019-15 and ER 1105-2-101. ER 1105-2-101 states the assurance, also known as conditional non-exceedance probability, is based on the uncertainty in the flow and stages associated with a given exceedance probability event. This study utilized the 90% Confidence Intervals (CI) from Federal Emergency Management Administration (FEMA) to incorporate the total water level uncertainty. To represent the design elevation, the study used the 90% CI of the 1% AEP event with mean higher high water (MHHW) and the intermediate sea level Change (SLC) out to the end of the assumed federal participation (2079). The study team analyzed the stage-damage output from the future without-project (FWOP) G2CRM model runs to confirm that the design elevations would provide sufficient damage reduction to each planning reach. The study team assumed the average design elevation between the planning reaches for a representative cost estimate; between the draft and final report, the study team will optimize design elevations. To incorporate sea level change, the intermediate curve (1.17 feet) was chosen for plan formulation, based on trends for 5-year and 19-year MSL moving average (Reference Section 2.3.2). Sensitivities for the high SLC curve were conducted after the TSP was determined (See Chapter 4).

The results of the evaluation that was performed in the screening matrixes for measures under the four P&G accounts (OSE, EQ, RED, and NED) are graphically expressed in **Figure 3**. Measures that scored highest rank of 2 are designated with green; measures that scored a mid-range of 1 are shown in yellow; and measures that scored zero are shown in red. The P&G accounts, combined with design assumptions, existing site conditions of the area, and environmental and real estate considerations, were considered for formulation of alternatives, are shown as well**.** In this figure, certain measures are grouped together which share common design characteristics and functions, for ease of reading and rationale of how and why measures were formulated into

alternatives. In additional to the structural and natural and nature-based feature measures shown, the non-structural measure of acquisition of land and structures (buyout) in strategic areas which are flooded to certain elevations was also carried forward. Additionally, non-structural measures that the non-federal sponsor and local communities would carry out were also carried forward, such as improved public outreach about coastal flooding, improved evacuation plans and notification systems, and evaluations of re-zoning over time as needed. These were carried forward as recommendations to the non-federal sponsor and local communities only and would not be carried out as part of the federal project.

**Figure 3. Consideration of Measures for Formulation of Alternatives.**




## 1.3 COMPARISON & EVALUATION OF THE FOCUSED ARRAY OF ALTERNATIVES

Using the key information as described above in concert with ground elevations and key flooding sources leading to the highest risk of damages, the focused array of alternatives was formulated and is provided in **Table 8** and graphically below in **Figure 4 and Figure 5**. All alternatives in the focused array include inland hydrology measures, to allow to outflow of rainfall runoff and non-structural measures that the non-federal sponsor and local communities would carry out such as improved public outreach about coastal flooding, improved evacuation plans and notification systems, and evaluations of re-zoning over time as needed.

Although the key objectives are generally the same in each planning reach, it is important to note that the planning reaches represent unique communities within the San Juan Metro Area. While each planning reach has been defined as a separate unit, the goal is to provide a comprehensive storm risk reduction plan for the communities at risk of storm surge within the San Juan Metro Area.

The focused array of alternatives is first a quantitative economic evaluation must be made to identify which plan in the final array maximizes NED benefits. Additionally, the focused array of alternatives are also qualitatively compared and evaluated against criteria. An environmental analysis must also be conducted under NEPA to compare and evaluate the final array for a set of environmental factors, prior to determination of the NED Plan or Tentatively Selected Plan. Those three evaluations are found in the discussions below.

**Table 8. Focused Array of Alternatives.**

| Alternative | Description |
|---|---|
| **CONDADO LAGOON REACH (CL-1)** | |
| CL1-Alt 1 | Full Seawall |
| CL1-Alt 2 | Full Recreational Seawall (this is a seawall with a greater width so that it can serve recreational purposes) |
| CL1-Alt 3 | Full Recreational seawall with vegetation |
| CL1-Alt 4 | Full Elevated Living Shoreline |
| CL1-Alt 5 | Seawall north + Elevated Living Shoreline south |
| **WEST SAN JUAN BAY (WSJB-1A)** | |
| WSJB1A-Alt 1 | Seawall + Levee |
| **WEST SAN JUAN BAY (WSJB-1B)** | |
| WSJB1B-Alt 1 | Seawall + Levee + Elevated living shoreline |
| WSJB1B-Alt 2 | Seawall + Levee |
| **WEST SAN JUAN BAY (WSJB-1A + WSJB-1B)** | |
| WSJB1A/B-Alt 1 | Small Storm Gate + Seawall + Levee + Elevated living shoreline |
| **WEST SAN JUAN BAY (WSJB-2)** | |
| WSJB2-Alt 1 | Levee + Seawall |
| WSJB2-Alt 2 | Horizontal levee + Seawall |
| WSJB2-Alt 3 | Small Storm Surge Gate + Levee + Seawall |
| WSJB2-Alt 4 | Small Storm Surge Gate + Horizontal Levee + Seawall |
| WSJB2-Alt 5 | Buyout in low lying elevations |
| **WEST SAN JUAN BAY (WSJB-3)** | |
| WSJB3-Alt 1 | Seawall + Higher T-wall |
| WSJB3-Alt 2 | Seawall + Breakwater |

| | |
|---|---|
| **WSJB3-Alt 3** | **Seawall + Emergent Island** |
| **WSJB3-Alt 4** | **Seawall + Recreational Seawall + Breakwater** |
| **WSJB3-Alt 5** | **Seawall + Living Shoreline + Breakwater** |
| **WEST SAN JUAN BAY (WSJB-4)** | |
| **WSJB4-Alt 1** | **Seawall in low elevations** |
| **WSJB4-Alt 2** | **Seawall + Levee in low elevations** |

**Figure 4. Focused Array of Alternatives for the San Juan Metro Area (CL, WSJB-1A, WSJB-1B).**

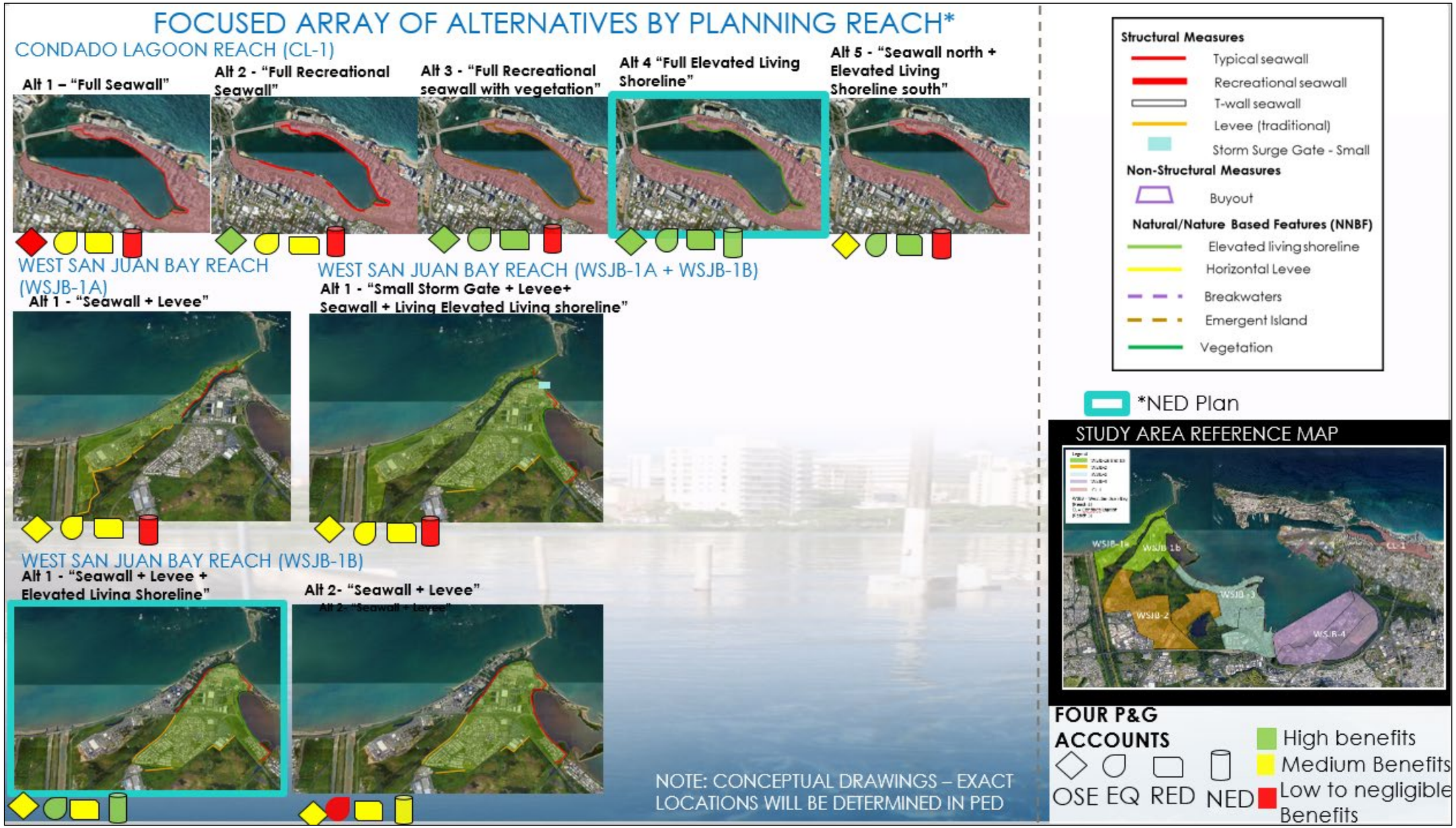
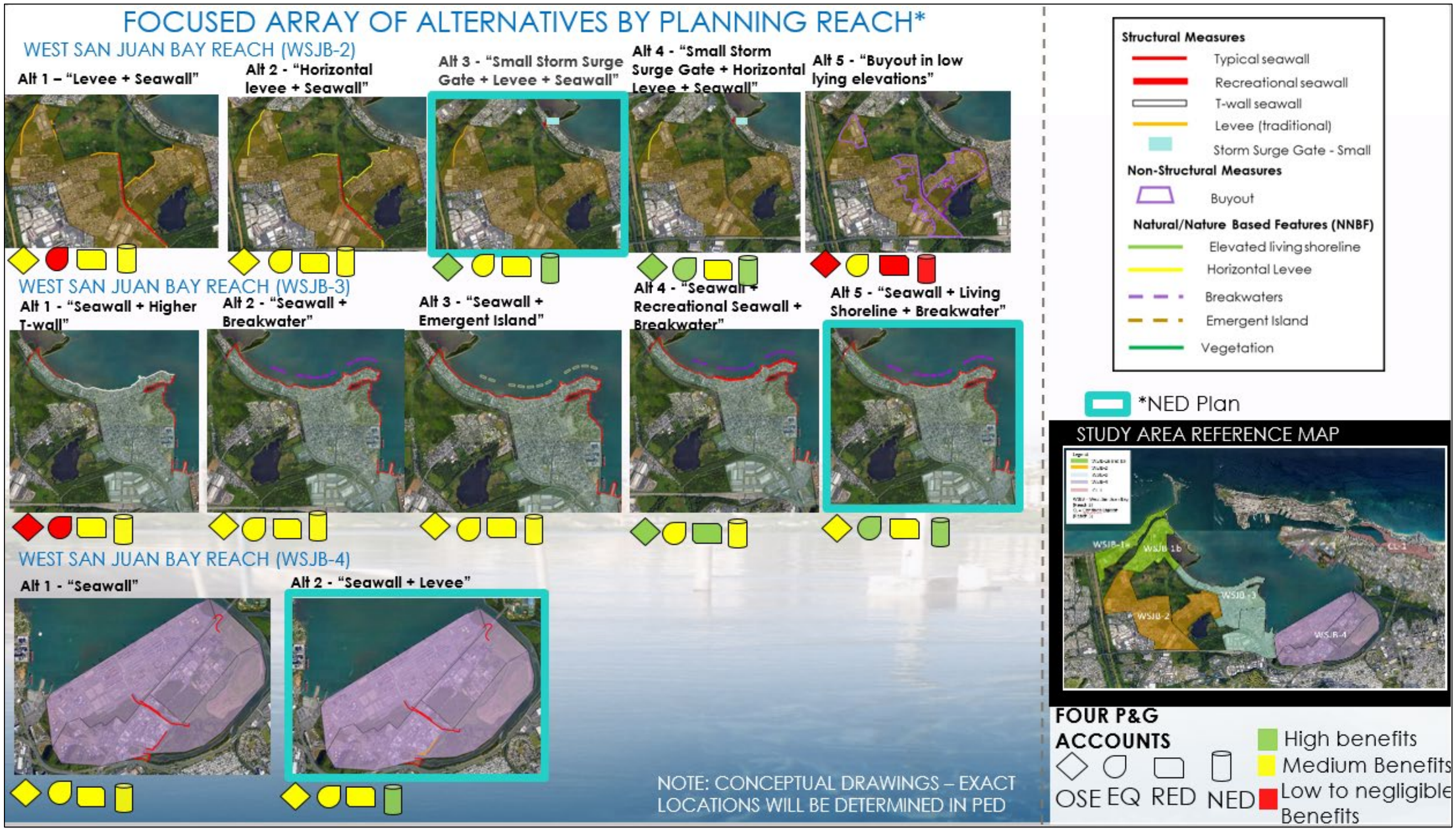


**Figure 5. Focused Array of Alternatives for the San Juan Metro Area (WSJB-2,WSJB-3, WSJB-4).**



### 1.3.1 PLANNING CRITERIA EVALUATION

Criteria to evaluate the study alternatives consisted of meeting specific project objectives, evaluations under the four P&G accounts, long term consideration, as well as avoiding constraints, and required evaluation criteria of completeness, efficiency, effectiveness and acceptability. The alternatives were evaluated and rated in as follows: 0 = does not meet criteria, 1 = partially meets criteria, and 2 = fully meets criteria. If the total rating equals a number greater than 14, the study alternative partially meets, at least, over half of the objectives and constraints and is carried forward for further analysis. If the total rating is less than 14, the study alternative is not considered further. Screening matrixes showing the criteria and evaluations are shown in **Tables 9-13.**

All alternatives scored above 14. However, the NED account noted which alternatives had negative net benefits, as described in the economic evaluation in the next section.

## Table 9. Condado Lagoon- Alternatives Evaluation & Comparison.

| 1. Alternatives | Alt 1 -"Full Seawall" | Alt 2- "Full Recreational Seawall" | Alt 3 - "Full Recreational seawall with vegetation" | Alt 4 - "Full Elevated Living Shoreline" | Alt 5 - "Seawall north + Elevated Living Shoreline south" | Alt 6 - "Recreaional Seawall north + Elevated Living Shoreline south" |
|---|---|---|---|---|---|---|
| **2. Impact Assessment (4 Accounts)** | | | | | | |
| A. National Economic Development (NED) | O - would provide needed elevation to reduce risk and contribute NED benefits but net benefits are negative and BCR<1. | O - would provide needed elevation to reduce risk and contribute NED benefits but net benefits are negative and BCR<1. | O - would provide needed elevation to reduce risk and contribute NED benefits but net benefits are negative and BCR<1. | F - would provide needed elevation to reduce risk and contribute NED benefits. | O - would provide needed elevation to reduce risk and contribute NED benefits but net benefits are negative and BCR<1. | O - would provide needed elevation to reduce risk and contribute NED benefits but net benefits are negative and BCR<1. |
| Score | 0 | 0 | 0 | 2 | 0 | 0 |
| B. Environmental Quality (EQ) | P - Would have some impacts to mangrove and SAV which would likely require mitigation | P - Would have some impacts to mangrove and SAV which would likely require mitigation | P - Would have some impacts to mangrove and SAV which would likely require mitigation but would also add in those species as a part of the plan in the same area. | F- Would have some impacts to mangrove and SAV which would likely require mitigation but would also add in those species as a part of the plan in the same area. | F - Would have some impacts to mangrove and SAV which would likely require mitigation but would also add in those species as a part of the plan in the same area. | P - Would have some impacts to mangrove and SAV which would likely require mitigation but would also add in those species as a part of the plan in the same area. |
| Score | 1 | 1 | 1 | 2 | 1 | 1 |
| C. Regional Economic Development (RED) | P - Reduction in tidal flooding and flooding after major storm events could allow businesses to contribute to the economy more compared to losses in FWOP | F - Reduction in tidal flooding and flooding after major storm events could allow businesses to contribute to the economy more compared to losses in FWOP. Recreational seawall could stimulate local economy. | F - Reduction in tidal flooding and flooding after major storm events could allow businesses to contribute to the economy more compared to losses in FWOP. Recreational seawall could stimulate local economy. | F - Reduction in tidal flooding and flooding after major storm events could allow businesses to contribute to the economy more compared to losses in FWOP. Living shoreline could stimulate local economy. | P - Reduction in tidal flooding and flooding after major storm events could allow businesses to contribute to the economy more compared to losses in FWOP. | F - Reduction in tidal flooding and flooding after major storm events could allow businesses to contribute to the economy more compared to losses in FWOP . Recreational seawall could stimulate local economy. |
| Score | 1 | 2 | 2 | 2 | 1 | 2 |
| D. Other Social Effects (OSE) | 0 - Reduction in tidal flooding and flooding after major storm events could allow communitieis to resume normal life sooner and in a safe manner compared to losses in FWOP. However, this seawall would block viewshed of lagoon, and could impact existing recreation, and could be opposed. | F - Reduction in tidal flooding and flooding after major storm events could allow communitieis to resume normal life sooner and in a safe manner compared to losses in FWOP. Recreational seawall could provide additional recreation for residents and views of the lagoon. | F - Reduction in tidal flooding and flooding after major storm events could allow communitieis to resume normal life sooner and in a safe manner compared to losses in FWOP. Recreational seawall could provide additional recreation for residents as well as aethetics and views of the lagoon. | F - Reduction in tidal flooding and flooding after major storm events could allow communitieis to resume normal life sooner and in a safe manner compared to losses in FWOP. Living shoreline could provide additional recreation for residents as well as aethetics, and views of the lagoon. | P - Reduction in tidal flooding and flooding after major storm events could allow communitieis to resume normal life sooner and in a safe manner compared to losses in FWOP | F - Reduction in tidal flooding and flooding after major storm events could allow communitieis to resume normal life sooner and in a safe manner compared to losses in FWOP. Living shoreline could provide additional recreation for residents as well as aethetics, and views of the lagoon. Recreational seawall could provide additional recreation for residents as well as aethetics |
| Score | 0 | 2 | 2 | 2 | 1 | 2 |
| **3. Plan Evaluation** | | | | | | |
| **A. Contribution to Planning Objectives** | | | | | | |
| (1) Reduce risk of damages to infrastructure from storm surge effects to Condado Lagoon area combined with sea level rise (intermediate scenario) over the next 50 years | F - Modeling shows ~ 90% reduction in damages | F - Modeling shows ~ 90% reduction in damages | F - Modeling shows ~ 90% reduction in damages | F - Modeling shows ~ 90% reduction in damages | F - Modeling shows ~ 90% reduction in damages | F - Modeling shows ~ 90% reduction in damages |
| Score | 2 | 2 | 2 | 2 | 2 | 2 |
| (2) Reduce flood stages/durations along evacuation routes and to critical infrastructure to improve accessibility, as well as maintain public health and safety, to community before, during and after storm surge events in combination with sea level rise. (resilience) | F- Reduction in tidal flooding and flooding after major storm events could allow communities to return to normal life more quickly | F- Reduction in tidal flooding and flooding after major storm events could allow communities to return to normal life more quickly | F- Reduction in tidal flooding and flooding after major storm events could allow communities to return to normal life more quickly | F- Reduction in tidal flooding and flooding after major storm events could allow communities to return to normal life more quickly | F- Reduction in tidal flooding and flooding after major storm events could allow communities to return to normal life more quickly | F- Reduction in tidal flooding and flooding after major storm events could allow communities to return to normal life more quickly |
| Score | 2 | 2 | 2 | 2 | 2 | 2 |
| **B. Longterm Considerations** | | | | | | |
| (1) Longterm ease of use/adaptability to sea level rise. | P - Seawall would be built to sufficient height to reduce risk over 50 years. Seawalls are adaptable, with some cost. | P - Seawall would be built to sufficient height to reduce risk over 50 years. Seawalls are adaptable, with some cost. | P - Seawall would be built to sufficient height to reduce risk over 50 years. Seawalls are adaptable, with some cost. | P - Living shorelone would be built to sufficient height to reduce risk over 50 years. It could be adapted to larger heights as needed, with more earthen material. | P - Seawall would be built to sufficient height to reduce risk over 50 years. Seawalls are adaptable, with some cost. Alogn with living shorelines. | P - Seawall would be built to sufficient height to reduce risk over 50 years. Seawalls are adaptable, with some cost. Alogn with living shorelines. |
| Score | 1 | 1 | 1 | 1 | 1 | 1 |
| (2) Sustainability (ie:Lower operation and Maintenance). | P - Periodic inspections would be necessary to avoid costly repairs. | P - Periodic inspections would be necessary to avoid costly repairs. | P - Periodic inspections would be necessary to avoid costly repairs. | P - Periodic inspections would be necessary. | P - Periodic inspections would be necessary to avoid costly repairs. | P - Periodic inspections would be necessary to avoid costly repairs. |
| Score | 1 | 1 | 1 | 1 | 1 | 1 |
| **B. Response to Planning Constraints** | | | | | | |
| (1) Avoid conflict with state and Federal regulations | F - All regulations are met in the no action alternative. | F - All regulations are met in the no action alternative. | F - All regulations are met in the no action alternative. | F - All regulations are met in the no action alternative. | F - All regulations are met in the no action alternative. | F - All regulations are met in the no action alternative. |
| Score | 2 | 2 | 2 | 2 | 2 | 2 |
| (2) Cannot increase life loss compared to the FWOP conditions | F - Does not put life safety more at risk compared to the FWOP. | F - Does not put life safety more at risk compared to the FWOP. | F - Does not put life safety more at risk compared to the FWOP. | F - Does not put life safety more at risk compared to the FWOP. | F - Does not put life safety more at risk compared to the FWOP. | F - Does not put life safety more at risk compared to the FWOP. |
| Score | 2 | 2 | 2 | 2 | 2 | 2 |
| **C. Response to Evaluation Criteria** | | | | | | |
| (1) Completeness | F - This plan reduces risk for the vulnerable area. | F - This plan reduces risk for the vulnerable area. | F - This plan reduces risk for the vulnerable area. | F - This plan reduces risk for the vulnerable area. | F - This plan reduces risk for the vulnerable area. | F - This plan reduces risk for the vulnerable area. |
| | 2 | 2 | 2 | 2 | 2 | 2 |
| (2) Effectiveness | F- Highly effective in meeting objectives | F- Highly effective in meeting objectives | F- Highly effective in meeting objectives | F- Highly effective in meeting objectives | F- Highly effective in meeting objectives | F- Highly effective in meeting objectives |
| | 2 | 2 | 2 | 2 | 2 | 2 |
| (3) Efficiency | O - not cost effective | O - not cost effective | O - not cost effective | F- cost effective | O - not cost effective | O - not cost effective |
| | 0 | 0 | 0 | 2 | 0 | 0 |
| (4) Acceptability | O - seawall blocking views would likely be unpopular. | F - seawall accessible and likely acceptable | F - Will likely be supported by public | F - Will likely be supported by public | O - seawall blocking views would likely be unpopular. | F - Will likely be supported by public |
| | 0 | 2 | 2 | 2 | 0 | 2 |
| TOTAL | 16 | 21 | 21 | 26 | 17 | 21 |

**Table 10. West San Juan Bay 1A & 1B -Alternatives Evaluation & Comparison.**

| 1. Alternatives | Alt1 (1A)-"Seawall + Levee" | Alt1 (1A+1B) - "Storm gate + Seawall + Levee + Elevated living shoreline" | Alt1 (1B) - "Seawall + Levee + Living Shoreline" | Alt2 (1B) - "Seawall + Levee" |
|---|---|---|---|---|
| **2. Impact Assessment (4 Accounts)** | | | | |
| A. National Economic Development (NED) | O - would provide needed elevation to reduce risk and contribute NED benefits but net benefits are negative and BCR<1. | O - would provide needed elevation to reduce risk and contribute NED benefits but net benefits are negative and BCR<1. | F - would provide needed elevation to reduce risk and contribute NED benefits. | P - would provide needed elevation to reduce risk and contribute NED benefits. |
| Score | 0 | 0 | 2 | 1 |
| B. Environmental Quality (EQ) | O- Would have some impacts to mangrove, wetland and SAV which would likely require mitigation . | P - Would have some impacts to mangrove, wetland and SAV which would likely require mitigation but would also add in those species as a part of the plan in the same area, and would have less than alt 1 which would require more levees. | F - Would have some impacts to mangrove, wetland, and SAV which would likely require mitigation but would also add in those species as a part of the plan in the same area. | O - Would have some impacts to mangrove, wetland and SAV which would likely require mitigation . |
| Score | 0 | 1 | 2 | 0 |
| C. Regional Economic Development (RED) | P - Reduction in flooding after major storm events could | P - Reduction in flooding after major storm events could allow businesses to | P - Reduction in flooding after major storm events could allow | P - Reduction in flooding after major storm events could |
| Score | 1 | 1 | 1 | 1 |
| D. Other Social Effects (OSE) | P - Reduction in flooding after major storm events could allow communities to resume normal life sooner and in a safe manner compared to losses in FWOP. | P - Reduction in flooding after major storm events could allow communities to resume normal life sooner and in a safe manner compared to losses in FWOP. | P - Reduction in flooding after major storm events could allow communities to resume normal life sooner and in a safe manner compared to losses in FWOP. | P - Reduction in flooding after major storm events could allow communities to resume normal life sooner and in a safe manner compared to losses in FWOP. |
| Score | 1 | 1 | 1 | 1 |
| **3. Plan Evaluation** | | | | |
| **A. Contribution to Planning Objectives** | | | | |
| (1) Reduce risk of damages to infrastructure from storm | P - Modeling shows some reduction in damages | F - Modeling shows reduction in damages | F - Modeling shows 90% reduction | F - Modeling shows 90% reduction |
| Score | 1 | 2 | 2 | 2 |
| (2) Reduce flood stages/durations along evacuation routes and to critical infrastructure to improve accessibility, as well as maintain public health and safety, to community before, during and after storm surge events in combination with sea level rise. (resilience) | F- Reduction in tidal flooding and flooding after major storm events could allow communities to return to normal life more quickly | F- Reduction in tidal flooding and flooding after major storm events could allow communities to return to normal life more quickly | F- Reduction in tidal flooding and flooding after major storm events could allow communities to return to normal life more quickly | F- Reduction in tidal flooding and flooding after major storm events could allow communities to return to normal life more quickly |
| Score | 2 | 2 | 2 | 2 |
| **B. Long-term Considerations** | | | | |
| (1) Long-term ease of use/adaptability to sea level rise. | P - Structures would be built to sufficient height to reduce risk over 50 years and are adaptable with some cost. | P - Structures would be built to sufficient height to reduce risk over 50 years and are adaptable with some cost. | P - Structures would be built to sufficient height to reduce risk over 50 years and are adaptable with some cost. | P - Structures would be built to sufficient height to reduce risk over 50 years and are adaptable with some cost. |
| Score | 1 | 1 | 1 | 1 |
| (2) Sustainability (ie:Lower operation and Maintenance). | P - Periodic inspections would be necessary to avoid costly repairs. | P - Periodic inspections would be necessary to avoid costly repairs. Storm gate would need to be staffed and manned to ensure proper function of closure when needed to reduce risk of damages. | P - Periodic inspections would be necessary to avoid costly repairs. | P - Periodic inspections would be necessary to avoid costly repairs. |
| Score | 1 | 1 | 1 | 1 |
| **B. Response to Planning Constraints** | | | | |
| (1) Avoid conflict with state and Federal regulations | F -Meets | F -Meets | F -Meets | F -Meets |
| Score | 2 | 2 | 2 | 2 |
| (2) Cannot increase life loss compared to the FWOP conditions | F - Does not put life safety more at risk compared to the FWOP. | F - Does not put life safety more at risk compared to the FWOP. | F - Does not put life safety more at risk compared to the FWOP. | F - Does not put life safety more at risk compared to the FWOP. |
| Score | 2 | 2 | 2 | 2 |
| **C. Response to Evaluation Criteria** | | | | |
| (1) Completeness | F - This plan reduces risk for the vulnerable area. | F - This plan reduces risk for the vulnerable area. | F - This plan reduces risk for the vulnerable area. | F - This plan reduces risk for the vulnerable area. |
| | 2 | 2 | 2 | 2 |
| (2) Effectiveness | F- Highly effective in meeting objectives | F- Highly effective in meeting objectives | F- Highly effective in meeting objectives | F- Highly effective in meeting objectives |
| | 2 | 2 | 2 | 2 |
| (3) Efficiency | O - not cost effective | O - not cost effective | F- cost effective | F- cost effective |
| | 0 | 0 | 2 | 2 |
| (4) Acceptability | F - Will likely be supported by public and environmental agencies | F - Will likely be supported by public and environmental agencies | F - Will likely be supported by public and environmental agencies | F - Will likely be supported by public and environmental agencies |
| | 2 | 2 | 2 | 2 |
| TOTAL | 17 | 19 | 24 | 21 |

**Table 11. West San Juan Bay 2 -Alternatives Evaluation & Comparison.**

| 1. Alternatives | Alt 1 -"Levee+ Seawall" | Alt 2- "Horizontal Levee + Seawall" | Alt 3 - "Small Storm Surge Gate + Levee + Seawall" | Alt 4 - "Small Storm Surge Gate + Horizontal Levee + Seawall" | Alt 5 - "Buyout in low lying elevations" |
|---|---|---|---|---|---|
| **2. Impact Assessment (4 Accounts)** | | | | | |
| A. National Economic Development (NED) | P- would provide needed elevation to reduce risk and contribute NED benefits. | P - would provide needed elevation to reduce risk and contribute NED benefits. | F - would provide needed elevation to reduce risk and most fully contribute NED benefits. | P - would provide needed elevation to reduce risk and contribute NED benefits. | O -benefits are negative and BCR<1 |
| Score | 1 | 1 | 2 | 1 | 0 |
| B. Environmental Quality (EQ) | O - Would have some impacts to mangrove, wetland and SAV which would likely require mitigation . | P - Would have some impacts to mangrove, wetland and SAV which would likely require mitigation but would also add in those species as a part of the plan in the same area | P - Would have some impacts to mangrove, wetland and SAV which would likely require mitigation , but would have less impacts compared to Alt 1 and 2 | F- Would have some impacts to mangrove, wetland and SAV which would likely require mitigation but would also add in those species as a part of the plan in the same area, and would have less than alts 1 and 2 which would require more levees. | P - No impacts; no benefits |
| Score | 0 | 1 | 1 | 2 | 1 |
| C. Regional Economic Development (RED) | P - Reduction in flooding after major storm events could allow businesses to contribute to the economy more compared to losses in FWOP. | P - Reduction in flooding after major storm events could allow businesses to contribute to the economy more compared to losses in FWOP. | P - Reduction in flooding after major storm events could allow businesses to contribute to the economy more compared to losses in FWOP. | P - Reduction in flooding after major storm events could allow businesses to contribute to the economy more compared to losses in FWOP. | O - Would not reduce flooding but would allow flooding in controlled way; may lose some RED buy relocating community from the area |
| Score | 1 | 2 | 2 | 2 | 0 |
| D. Other Social Effects (OSE) | P - Reduction in flooding after major storm events could allow communities to resume normal life sooner and in a safe manner compared to losses in FWOP. | P - Reduction in flooding after major storm events could allow communities to resume normal life sooner and in a safe manner compared to losses in FWOP. | P - Reduction in flooding after major storm events could allow communities to resume normal life sooner and in a safe manner compared to losses in FWOP. | P - Reduction in flooding after major storm events could allow communities to resume normal life sooner and in a safe manner compared to losses in FWOP. | O- Buyout and relocation of community has a significant effect on people's lives. |
| Score | 1 | 1 | 1 | 1 | 0 |
| **3. Plan Evaluation** | | | | | |
| **A. Contribution to Planning Objectives** | | | | | |
| (1) Reduce risk of damages to infrastructure from | F - Modeling shows reduction in damages | F - Modeling shows reduction in damages | F - Modeling shows reduction in damages | F - Modeling shows ~ 90% reduction in | P - Reduces risk in low lying elevations only |
| Score | 2 | 2 | 2 | 2 | 1 |
| (2) Reduce flood stages/durations along evacuation routes and to critical infrastructure to improve accessibility, as well as maintain public health and safety, to community before, during and after storm surge events in combination with sea level rise. (resilience) | F- Reduction in tidal flooding and flooding after major storm events could allow communities to return to normal life more quickly | F- Reduction in tidal flooding and flooding after major storm events could allow communities to return to normal life more quickly | F- Reduction in tidal flooding and flooding after major storm events could allow communities to return to normal life more quickly | F- Reduction in tidal flooding and flooding after major storm events could allow communities to return to normal life more quickly | P - Reduces risk in low lying elevations only |
| Score | 2 | 2 | 2 | 2 | 1 |
| **B. Long-term Considerations** | | | | | |
| (1) Long-term ease of use/adaptability to sea | P - Structures would be built to sufficient height to | P - Structures would be built to sufficient | P - Structures would be built to sufficient | P - Structures would be built to sufficient height | O - would not reduce risk in surrounding areas due to sea |
| Score | 1 | 1 | 1 | 1 | 0 |
| (2) Sustainability (ie:Lower operation and | P - Periodic inspections would be necessary to avoid | P - Periodic inspections would be | P - Periodic inspections would be necessary | P - Periodic inspections would be necessary to | O- no operation and maintenance but not sustainable for |
| Score | 1 | 1 | 1 | 1 | 0 |
| **B. Response to Planning Constraints** | | | | | |
| (1) Avoid conflict with state and Federal | F - All regulations are met in the no action alternative. | F - All regulations are met in the no action | F - All regulations are met in the no action | F - All regulations are met in the no action | F - All regulations are met in the no action alternative. |
| Score | 2 | 2 | 2 | 2 | 2 |
| FWOP conditions | FWOP. | compared to the FWOP. | compared to the FWOP. | compared to the FWOP. | FWOP. |
| Score | 2 | 2 | 2 | 2 | 2 |
| **C. Response to Evaluation Criteria** | | | | | |
| (1) Completeness | F - This plan reduces risk for the vulnerable area. | F - This plan reduces risk for the vulnerable area. | F - This plan reduces risk for the vulnerable area. | F - This plan reduces risk for the vulnerable area. | F - This plan reduces risk for the vulnerable area. |
| | 2 | 2 | 2 | 2 | 2 |
| (2) Effectiveness | F- Highly effective in meeting objectives | F- Highly effective in meeting objectives | F- Highly effective in meeting objectives | F- Highly effective in meeting objectives | F- Highly effective in meeting objectives |
| | 2 | 2 | 2 | 2 | 2 |
| (3) Efficiency | F- cost effective | F- cost effective | F- cost effective | F- cost effective | P- cost effective, but not as cost effective as other alts |
| | 2 | 2 | 2 | 2 | 1 |
| (4) Acceptability | F - Will likely be supported by public and environmental agencies | F - Will likely be supported by public and environmental agencies | F - Will likely be supported by public and environmental agencies | F - Will likely be supported by public and environmental agencies | O - likely would not be acceptable to communities facing buyout |
| | 2 | 2 | 2 | 2 | 0 |
| TOTAL | 21 | 23 | 24 | 24 | 12 |

**Table 12. West San Juan Bay 3 -Alternatives Evaluation & Comparison.**

| 1. Alternatives | Alt 1 -"Seawall + Higher T-wall" | Alt 2- "Seawall + Breakwater" | Alt 3 - " Seawall + Emergent Island" | Alt 4 - "Seawall + Recreational Seawall + Breakwater" | Alt 5 - "Seawall + Living Shoreline + Breakwater" |
|---|---|---|---|---|---|
| **2. Impact Assessment (4 Accounts)** | | | | | |
| A. National Economic Development (NED) | P- would provide needed elevation to reduce risk and contribute NED benefits. | P- would provide needed elevation to reduce risk and contribute NED benefits. | P- would provide needed elevation to reduce risk and contribute NED benefits. | P- would provide needed elevation to reduce risk and contribute NED benefits. | F- would provide needed elevation to reduce risk and most fully contributes to NED benefits. |
| Score | 1 | 1 | 1 | 1 | 2 |
| B. Environmental Quality (EQ) | O - Would have some impacts to mangrove, wetland and SAV which would likely require mitigation. | P - Would have some impacts to mangrove, wetland and SAV which would likely require mitigation; however, breakwater could potentially support mangroves and provide foraging habitat for fish | P - Would have some impacts to mangrove, wetland and SAV which would likely require mitigation , however, breakwater could potentially support mangroves and provide foraging habitat for fish | P - Would have some impacts to mangrove, wetland and SAV which would likely require mitigation , however, breakwater could potentially support mangroves and provide foraging habitat for fish | F - Would have some impacts to mangrove, wetland and SAV which would likely require mitigation , however, breakwater could potentially support mangroves and provide foraging habitat for fish plus habitat creation with living shoreline |
| Score | 0 | 1 | 1 | 1 | 2 |
| C. Regional Economic Development (RED) | P- Reduction in flooding after major storm events | P- Reduction in flooding after major storm events | P- Reduction in flooding after major storm events could | F- Reduction in flooding after major storm | P- Reduction in flooding after major storm events could allow |
| Score | 1 | 1 | 1 | 2 | 1 |
| D. Other Social Effects (OSE) | O - Reduction in flooding after major storm events could allow communities to resume normal life sooner and in a safe manner compared to losses in FWOP. However, higher seawall at approx. range of elevation from 12 to 17 feet would block view shed. | P - Reduction in flooding after major storm events could allow communities to resume normal life sooner and in a safe manner compared to losses in FWOP. Lower seawall of 6.5 feet would block view shed to a point but not as fully as Alt 1 | P - Reduction in flooding after major storm events could allow communities to resume normal life sooner and in a safe manner compared to losses in FWOP. Lower seawall of 6.5 feet would block view shed to a point but not as fully as Alt 1 | F - Reduction in flooding after major storm events could allow communities to resume normal life sooner and in a safe manner compared to losses in FWOP. Recreational seawall would allow access and recreation. | P - Reduction in flooding after major storm events could allow communities to resume normal life sooner and in a safe manner compared to losses in FWOP. Lower seawall of 6.5 feet would block view shed to a point but not as fully as Alt 1. Living shoreline allows public accessibility. |
| Score | 0 | 1 | 1 | 2 | 1 |
| **3. Plan Evaluation** | | | | | |
| **A. Contribution to Planning Objectives** | | | | | |
| (1) Reduce risk of damages to infrastructure from storm surge effects combined with sea level rise (intermediate scenario) over the next 50 years | F - Modeling shows ~ 90% reduction in damages | F - Modeling shows ~ 90% reduction in damages | F - Modeling shows ~ 90% reduction in damages | F - Modeling shows ~ 90% reduction in damages | F - Modeling shows ~ 90% reduction in damages |
| Score | 2 | 2 | 2 | 2 | 2 |
| (2) Reduce flood stages/durations along evacuation routes and to critical infrastructure to improve accessibility, as well as maintain public health and safety, to community before, during and after storm surge events in combination with sea level rise. (resilience) | F - Reduction in flooding after major storm events could allow communities to resume normal life sooner and in a safe manner compared to losses in FWOP. | F - Reduction in flooding after major storm events could allow communities to resume normal life sooner and in a safe manner compared to losses in FWOP. | F - Reduction in flooding after major storm events could allow communities to resume normal life sooner and in a safe manner compared to losses in FWOP. | F- Reduction in flooding after major storm events could allow communities to resume normal life sooner and in a safe manner compared to losses in FWOP. | F- Reduction in flooding after major storm events could allow communities to resume normal life sooner and in a safe manner compared to losses in FWOP. |
| Score | 2 | 2 | 2 | 2 | 2 |
| (3) Reduce risk of damages from wave attack | F - would provide needed elevation to reduce risk | F - breakwater reduces risk | F -island reduces risk | F - breakwater reduces risk | F - breakwater reduces risk |
| Score | 2 | 2 | 2 | 2 | 2 |
| **B. Long-term Considerations** | | | | | |
| (1) Long-term ease of use/adaptability to sea | P - Structures would be built to sufficient height to | P - Structures would be built to sufficient height to | P - Structures would be built to sufficient height to reduce | P - Structures would be built to sufficient height | P - Structures would be built to sufficient height to reduce risk |
| Score | 1 | 1 | 1 | 1 | 1 |
| (2) Sustainability (ie:Lower operation and Maintenance). | P - Periodic inspections would be necessary to avoid costly repairs. | P - Periodic inspections would be necessary to avoid costly repairs. | P - Periodic inspections would be necessary to avoid costly repairs. | P - Periodic inspections would be necessary to avoid costly repairs. | P - Periodic inspections would be necessary to avoid costly repairs. |
| Score | 1 | 1 | 1 | 1 | 1 |
| **B. Response to Planning Constraints** | | | | | |
| (1) Avoid conflict with state and Federal | F - All regulations are met in the no action | F - All regulations are met in the no action alternative. | F - All regulations are met in the no action alternative. | F - All regulations are met in the no action | F - All regulations are met in the no action alternative. |
| Score | 2 | 2 | 2 | 2 | 2 |
| (2) Cannot increase life loss compared to the FWOP conditions | F - Does not put life safety more at risk compared to the FWOP. | F - Does not put life safety more at risk compared to the FWOP. | F - Does not put life safety more at risk compared to the FWOP. | F - Does not put life safety more at risk compared to the FWOP. | F - Does not put life safety more at risk compared to the FWOP. |
| Score | 2 | 2 | 2 | 2 | 2 |
| **C. Response to Evaluation Criteria** | | | | | |
| (1) Completeness | F - This plan reduces risk for the vulnerable area. | F - This plan reduces risk for the vulnerable area. | F - This plan reduces risk for the vulnerable area. | F - This plan reduces risk for the vulnerable area. | F - This plan reduces risk for the vulnerable area. |
| | 2 | 2 | 2 | 2 | 2 |
| (2) Effectiveness | F- Highly effective in meeting objectives | F- Highly effective in meeting objectives | F- Highly effective in meeting objectives | F- Highly effective in meeting objectives | F- Highly effective in meeting objectives |
| | 2 | 2 | 2 | 2 | 2 |
| (3) Efficiency | F- cost effective | F- cost effective | F- cost effective | F- cost effective | F cost effective, |
| | 2 | 2 | 2 | 2 | 2 |
| (4) Acceptability | O - may not be acceptable due to high seawall | F - Will likely be supported by public and environmental agencies | F - Will likely be supported by public and environmental agencies | F - Will likely be supported by public and environmental agencies | F - Will likely be supported by public and environmental agencies |
| | 0 | 2 | 2 | 2 | 2 |
| TOTAL | 20 | 24 | 24 | 26 | 26 |

**Table 13. West San Juan Bay 4 -Alternatives Evaluation & Comparison.**

| **1. Alternatives** | **Alt 2 -"Seawall"** | **Alt 2- "Levee + Seawall"** |
|---|---|---|
| **2. Impact Assessment (4 Accounts)** | | |
| A. National Economic Development (NED) | P - would provide needed elevation to reduce risk and contribute NED benefits. | F - would provide needed elevation to reduce risk and most fully contribute NED benefits. |
| Score | 1 | 2 |
| B. Environmental Quality (EQ) | P - Would have lesser impacts to mangrove, wetland, and SAV which would | P - Would have lesser impacts to mangrove, wetland, and SAV which would |
| Score | 1 | 1 |
| C. Regional Economic Development (RED) | P - Reduction in flooding after major storm events could allow businesses to | P - Reduction in flooding after major storm events could allow businesses to |
| Score | 1 | 1 |
| D. Other Social Effects (OSE) | P - Reduction in flooding after major storm events could allow communitieis to resume normal life sooner and in a safe manner compared to losses in FWOP. | P- Reduction in flooding after major storm events could allow communitieis to resume normal life sooner and in a safe manner compared to losses in FWOP. |
| Score | 1 | 1 |
| **3. Plan Evaluation** | | |
| **A. Contribution to Planning Objectives** | | |
| (1) Reduce risk of damages to infrastructure from storm surge effects | F - Modeling shows ~ 80% reduction in damages | F - Modeling shows ~ 80% reduction in damages |
| Score | 2 | 2 |
| (2) Reduce flood stages/durations along evacuation routes and to critical infrastructure to improve accessibility, as well as maintain public health and safety, to community before, during and after storm surge events in | F - Reduction in flooding after major storm events could allow communitieis to resume normal life sooner and in a safe manner compared to losses in FWOP. | F - Reduction in flooding after major storm events could allow communitieis to resume normal life sooner and in a safe manner compared to losses in FWOP. |
| Score | 2 | 2 |
| **B. Longterm Considerations** | | |
| (1) Longterm ease of use/adaptability to sea level rise. | P - Structures would be built to sufficient height to reduce risk over 50 yearrs | P - Structures would be built to sufficient height to reduce risk over 50 yearrs |
| Score | 1 | 1 |
| (2) Sustainability (ie:Lower operation and Maintenance). | P - Periodic inspections would be necessary to avoid costly repairs. | P - Periodic inspections would be necessary to avoid costly repairs. Storm |
| Score | 1 | 1 |
| **B. Response to Planning Constraints** | | |
| (1) Avoid conflict with state and Federal regulations | F -Meets | F -Meets |
| Score | 2 | 2 |
| (2) Cannot increase life loss compared to the FWOP conditions | F - Does not put life safety more at risk compared to the FWOP. | F - Does not put life safety more at risk compared to the FWOP. |
| Score | 2 | 2 |
| **C. Response to Evaluation Criteria** | | |
| (1) Completeness | F - This plan reduces risk for the vulnerable area. | F - This plan reduces risk for the vulnerable area. |
| | 2 | 2 |
| (2) Effectiveness | F- Highly effective in meeting objectives | F- Highly effective in meeting objectives |
| | 2 | 2 |
| (3) Efficiency | F- cost effective | F- cost effective |
| | 2 | 2 |
| (4) Acceptability | F - Will likely be supported by public and environmental agencies | F - Will likely be supported by public and environmental agencies |
| | 2 | 2 |
| TOTAL | 22 | 23 |

## 1.3.2 ECONOMIC EVALUATION (COSTS & BENEFITS)

Each NED plan, shown below in **Table 3-3** and marked with blue highlight, is shown to have the highest net benefits within the reach compared to the other alternatives, and is also shown to be economically justified with a BCR greater than 1.0.

Several alternatives are shown to have negative net benefits and a benefit to cost ratio less than 1. These alternatives are: CL Alt 1-3; CL 5-6; WSJB-1A Alt 1a; WSJB-1A + 1B Alt 1(1a +1b).

**Table 14. Highest Net benefits for each reach.**[2]

| Planning Reach | Alt | AAEQ NED Benefits | AAEQ NED Costs | AAEQ Net NED Benefits | BCR |
|---|---|---|---|---|---|
| CL | Alt 1 | $1,615,029 | $2,765,543 | -$1,150,513 | 0.58 |
| | Alt 2 | $1,615,029 | $3,041,053 | -$1,426,024 | 0.53 |
| | Alt 3 | $1,615,029 | $3,177,832 | -$1,562,803 | 0.51 |
| | Alt 4 | $1,615,029 | $1,173,503 | $441,526 | 1.38 |
| | Alt 5 | $1,615,029 | $2,213,702 | -$598,673 | 0.73 |
| | Alt 6 | $1,615,029 | $2,381,342 | -$766,313 | 0.68 |
| WSJB-1A | Alt 1a | $845,901 | $1,366,053 | -$520,152 | 0.62 |
| WSJB-1B | Alt 1b | $2,489,862 | $1,551,049 | $938,813 | 1.61 |
| | Alt 2b | $2,489,862 | $1,776,316 | $713,546 | 1.40 |
| WSJB-1A+1B | Alt 1(a+b) | $3,520,179 | $3,961,721 | -$441,542 | 0.89 |
| WSJB_2 | Alt 1 | $10,560,200 | $1,418,998 | $9,141,202 | 7.44 |
| | Alt 2 | $10,560,200 | $1,501,723 | $9,058,477 | 7.03 |
| | Alt 3 | $12,722,287 | $929,641 | $11,792,646 | 13.69 |
| | Alt 4 | $12,722,287 | $949,714 | $11,772,572 | 13.40 |
| | Alt 5 | $13,532,392 | $9,053,628 | $4,478,764 | 1.49 |
| WSJB_3 | Alt 1 | $63,239,363 | $6,953,358 | $56,286,005 | 9.09 |
| | Alt 2 | $63,826,013 | $6,033,587 | $57,792,426 | 10.58 |
| | Alt 3 | $63,239,363 | $5,864,812 | $57,374,551 | 10.78 |
| | Alt 4 | $63,826,013 | $6,118,909 | $57,707,103 | 10.43 |
| | Alt 5 | $63,826,013 | $5,794,279 | $58,031,734 | 11.02 |
| WSJB_4 | Alt 1 | $2,667,710 | $1,545,697 | $1,122,014 | 1.73 |
| | Alt 2 | $2,667,710 | $1,370,288 | $1,297,423 | 1.95 |

## 1.3.1 ENVIRONMENTAL QUALITY

[2] Results are based on 5-iteration model runs in G2CRM, and are a good representation of damages for plan formulation. 50-iteration model runs in G2CRM are used for refined benefits in Chapter 4.

The environmental quality account considers non-monetary effects on ecological, cultural, and aesthetic resources. Under this account, the preferred plan should avoid or minimize environmental impacts and maximize environmental quality in the project area to the extent practicable considering other criteria and planning objectives. More detailed descriptions of the analysis and impacts can be found in Section 5 of this report and in the Appendices. For the purposes of alternatives analysis, all action plans were compared to the future without-project condition (i.e., NEPA No Action), which factors in 50 years of sea level change (to 2076). Effects for each alternative were evaluated below in **Table 3-3** and were carefully considered during plan formulation and for selection of the tentatively selected plan.

## ENVIRONMENTAL QUALITY & MITIGATION AND AVOIDANCE MEASURES

The environmental quality account considers non-monetary effects on ecological, cultural, and aesthetic resources. Under this account, the preferred plan should avoid or minimize environmental impacts and maximize environmental quality in the project area to the extent practicable considering other criteria and planning objectives. More detailed descriptions of the analysis and impacts can be found in **Chapter 3 of the Main Report** and **Appendix G.** For the purposes of alternatives analysis, all action plans were compared to the future without-project condition (i.e., NEPA No Action), which factors in 50 years of sea level change (to 2076). Effects for each alternative were evaluated in the **Main Report (Table 3-3**) and were carefully considered during plan formulation and for selection of the tentatively selected plan.

The first step in mitigation planning involves employing efforts to avoid adverse impacts. After development of the initial array of alternatives, the PDT coordinated with resource agencies who participated during the PDT meetings. These meetings focused on the primary resources (cultural resources, fish habitat, SAV, hardbottom, wetlands) that could be impacted by the proposed alternatives.

Cultural Resources. The USACE has conducted a review of recorded resources located near the proposed project features. The USACE will conduct surveys to refine the locations of resources as the features are designed to ensure avoidance and minimization of effects to cultural resources from the construction and implementation of the alternatives. If avoidance is not possible, USACE will develop mitigation measures with the Puerto Rico State Historic Preservation Officer (SHPO) and with input from Instituto de Cultura Puertorriqueña and other interested parties. The terms detailing how USACE will ensure additional measures to protect cultural resources are in a programmatic agreement being developed by USACE and SHPO. As project designs are refined and optimized, impacts to cultural resources will continue to be minimized and avoided in some cases. Because the USACE cannot fully determine how the project may affect historic properties prior to finalization of this feasibility study, a Programmatic Agreement (PA) will be used to ensure compliance with Section 106 of the National Historic Preservation Act of

1966 (NHPA). Specifically, the scope and diversity of potential effects of the project and constraints of the USACE planning policy make a PA for compliance with Section 106 essential. The PA will allow the USACE to complete the necessary archaeological surveys during the follow on Preconstruction Engineer and Design (PED) phase of the project, and it will also allow any additional inventories and mitigation to be completed after measures have been clearly defined and sited. Consultation and coordination with all interested parties is ongoing and will be finalized prior to project implementation.

Fish Habitat, SAV, Hardbottom, Wetlands. The USACE will avoid and minimize effects to these resources by limiting CSRM measure construction within these areas to the minimum required to meet the project purpose. Many areas could be avoided and their extents would be determined during the PED Phase of the project when detailed, site-specific surveys would be conducted. Therefore, environmental impacts can be minimized by limiting CSRM measure footprints. In addition, construction adjacent the coral reefs at the entrance to San Juan bay and Condado lagoon would not occur. The reduction of impacts includes a minimized footprint and the potential for decreased indirect effects. Section 3.8.3.1 provides additional environmental evaluations.

## 1.4 SCREENING OF ALTERNATIVES

After the above analyses were completed, the economic analysis shows that several alternatives are shown to have negative net benefits and a benefit to cost ratio less than 1. These alternatives are: CL Alt 1-3; CL 5-6; WSJB-1A Alt 1a; WSJB-1A + 1B Alt 1(1a +1b). With consideration given to the planning criteria evaluation and summarized in **Figure 4 and Figure 5**, inclusive of the environmental evaluation, these alternatives are not carried forward for further analysis. Reach WSJB-1A does not have any alternatives which have a BCR greater equal to or greater than 1. The team consulted with staff at the Palo Seco Power Plants, which are the most significant critical infrastructure in this reach. Verbal communication indicated that the power plants have never had problems from storm surge, given past historical storms. The current analysis using planning criteria and environmental evaluations did not provide sufficient additional benefits or rationale to carry this reach forward in the analysis for inclusion in the TSP.

## 1.5 THE TENTATIVELY SELECTED PLAN

This analysis finds that there is Federal Interest in a comprehensive plan to reduce damages to the San Juan Metro Area. The P&G and ER 1105-2-100 state that the NED plan is the plan that reasonably maximizes net economic benefits consistent with protecting the Nation's environment. The NED Plan consists of the plan with the highest net benefits from each of the most vulnerable areas within the San Juan Metro Area, which is:

- CL Alt 4- Elevated Living Shoreline;
- WSBJ-1B: Alt 1 - Seawall + Levee + Elevated Living Shoreline;
- WSJB-2: Alt 3 – Small Storm Surge Gate + Levee + Seawall;
- WSJB-3: Alt 5 – Seawall + Living Shoreline + Breakwater;
- WSJB-4: Alt 2 – Levee + Seawall;

This NED plan uses key structural and natural and nature-based features in strategic locations designed to appropriate elevations which work together to reduce the risk of damages as a result of coastal flooding from storm surge, tide and waves during coastal storms and hurricanes in the San Juan Metro Area.

The NED plan brings benefits to the nation in all of the four P&G accounts (NED, EQ, RED, OSE), meet the planning criteria of being complete, efficient, effective, and acceptable. Under NEPA, the NED plan has been evaluated for effects, which are described in Chapter 4. Consistent with the NEPA, USACE has formalized its commitment to the environment by creating a set of "Environmental Operating Principles" applicable to all its decision making and programs. These principles foster unity of purpose regarding environmental issues and ensure that environmental conservation and preservation, and restoration are considered in all USACE activities. These are identified and addressed specifically in Section 6.6.27 of the **Main Report**. The NED provides average annual net benefits (AAEQ) of $64M each year over a 50-year period of analysis. The NED plan is economically justified with a benefit to cost ratio of 5.2.

The TSP includes levees (2 miles), a series of breakwaters (0.7 miles) along the Cataño shoreline, seawall/floodwalls (6.7 miles), elevated living shoreline (2.3 miles), a storm surge gate/sluice gate on the Malaria Canal, and associated inland hydrology features (to allow rainfall runoff with constructed features).[3] Although the NED plan was formulated to avoid and minimize impacts to every extent possible, impacts are expected to occur and would be addressed as mitigation, which is evaluated further in Chapter 5 under NEPA and in the mitigation plan in Appendix G, Environmental, Attachment 3, and in Chapter 4.

Typically, the NED plan becomes the Tentatively Selected Plan unless the non-federal sponsor chooses to pursue a Locally Preferred Plan (LPP) which differs from the NED plan. An LPP is subject to the requirements described in ER 1105-2-100. The option of selecting an LPP was coordinated with the non-federal sponsor, who does not wish to pursue an LPP at this time. The

[3] Recreation features were not included in plan formulation, but were added to the TSP after plan selection. Recreation assumptions and discussions can be found in Chapter 4.

NED plan therefore is the tentatively selected plan.