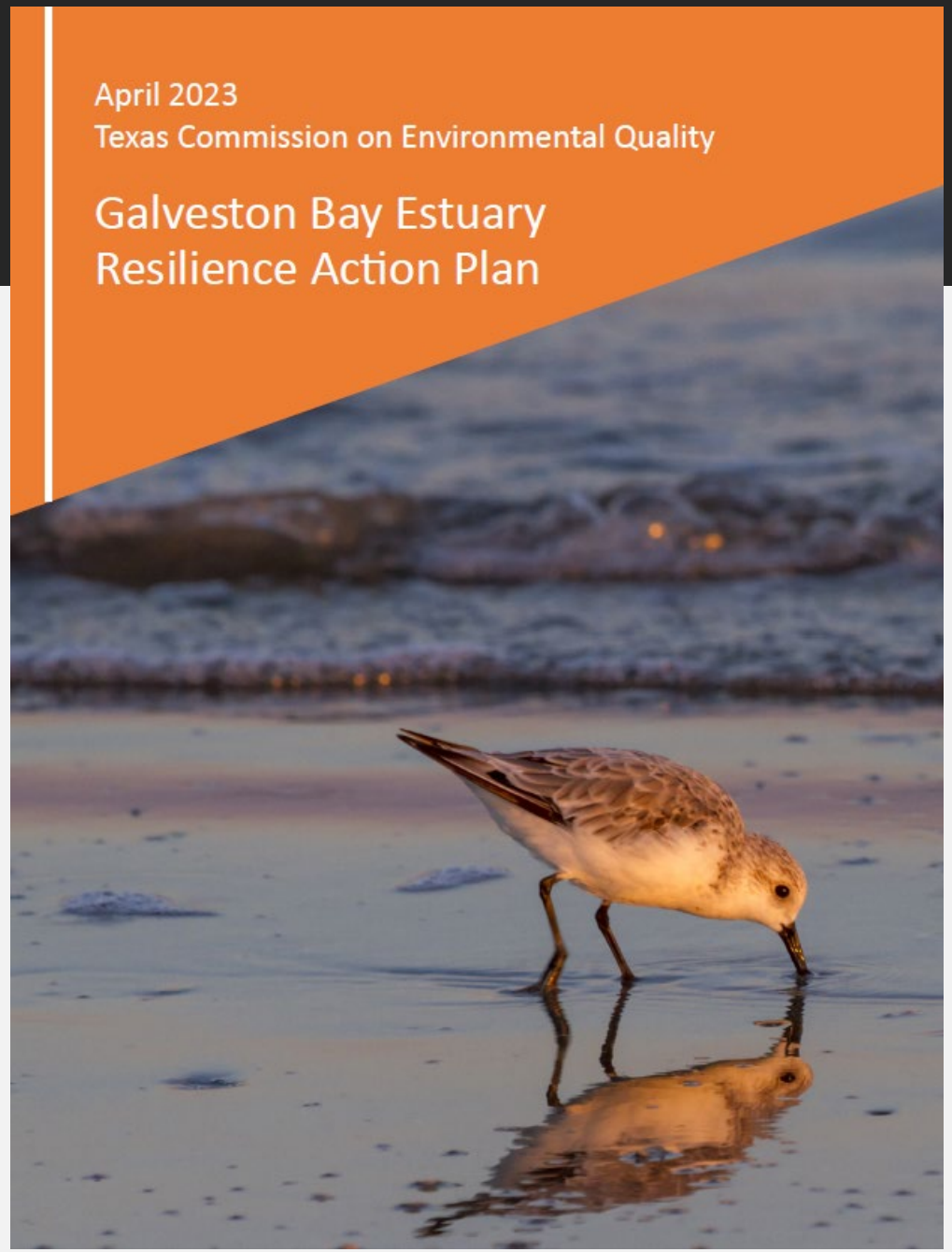
Galveston Bay Council Meeting
April 2023

Galveston Bay Estuary Resilience Action Plan

The Galveston Bay Estuary Resilience Assessment is a stakeholder-driven project; the ideas and thoughts on stressors, risks and management strategies were generated by stakeholders in the expert Workgroup and do not necessarily reflect the official policy or position of TCEQ.

HARC



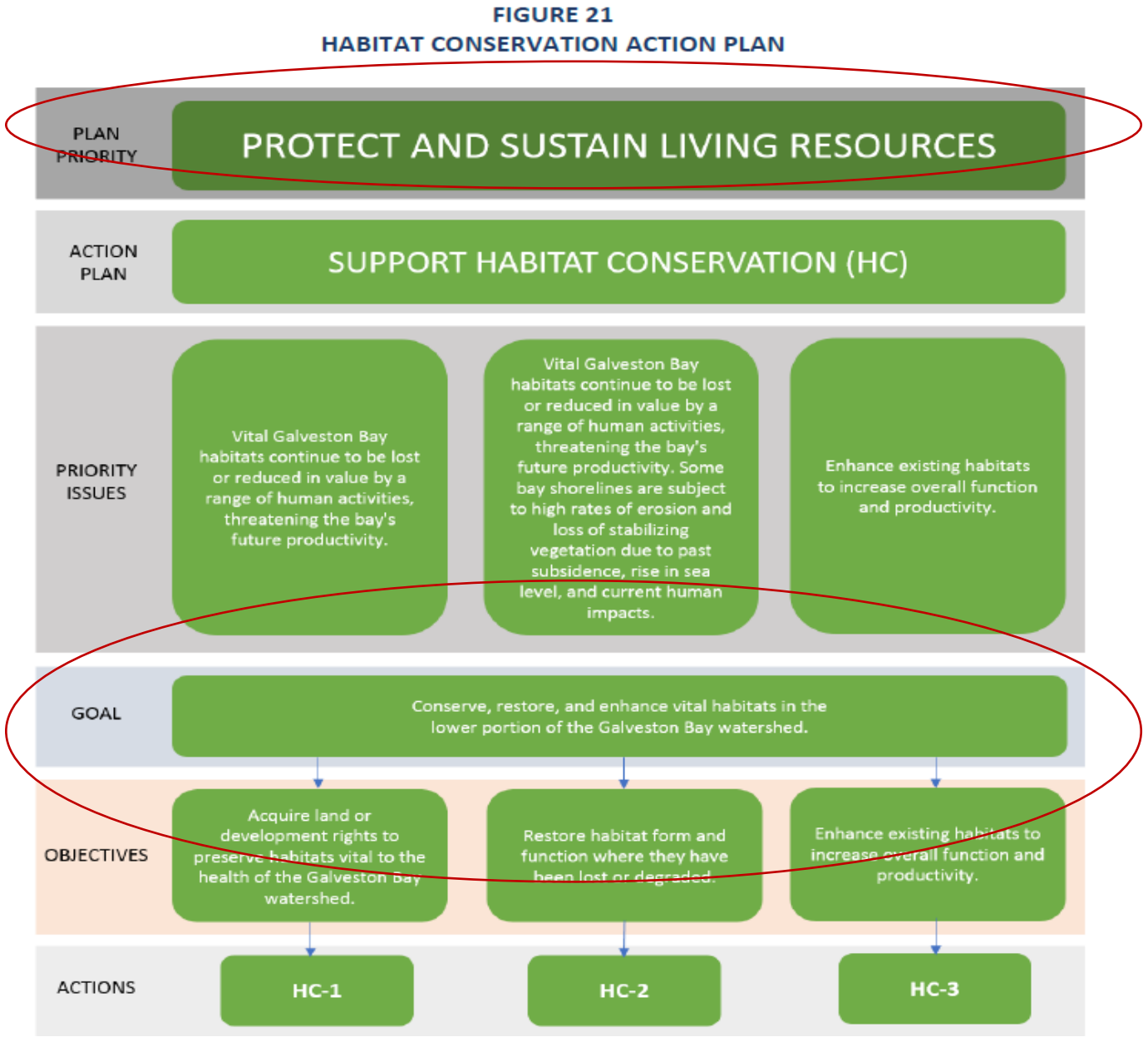
Where We Started February 2019

Goal: Assess a series of coastal resilience criteria against the priority/goals, in *The Galveston Bay Plan, 2nd Edition* (GBP)

Through a series of workgroup meetings, working group of GBEP subcommittee members:

- Developed a set of stressors Galveston Bay will be facing now and in the future
- Developed a series of risks to the Bay and to GBEP's Plan goals based on those stressors
- Developed the likelihood (probability) and consequence of each of those risks

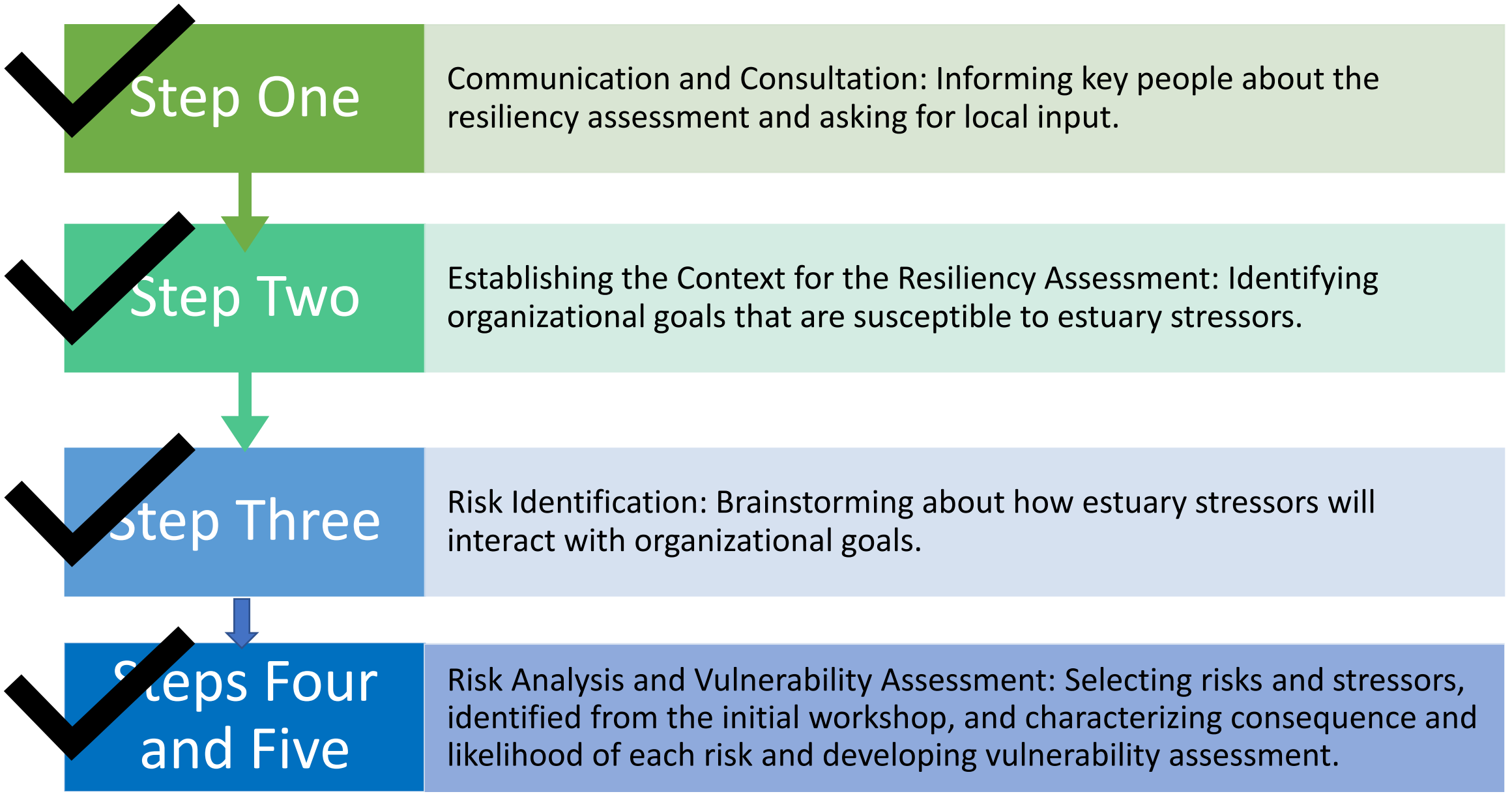
GBEP's Galveston Bay Plan Organizational Goals



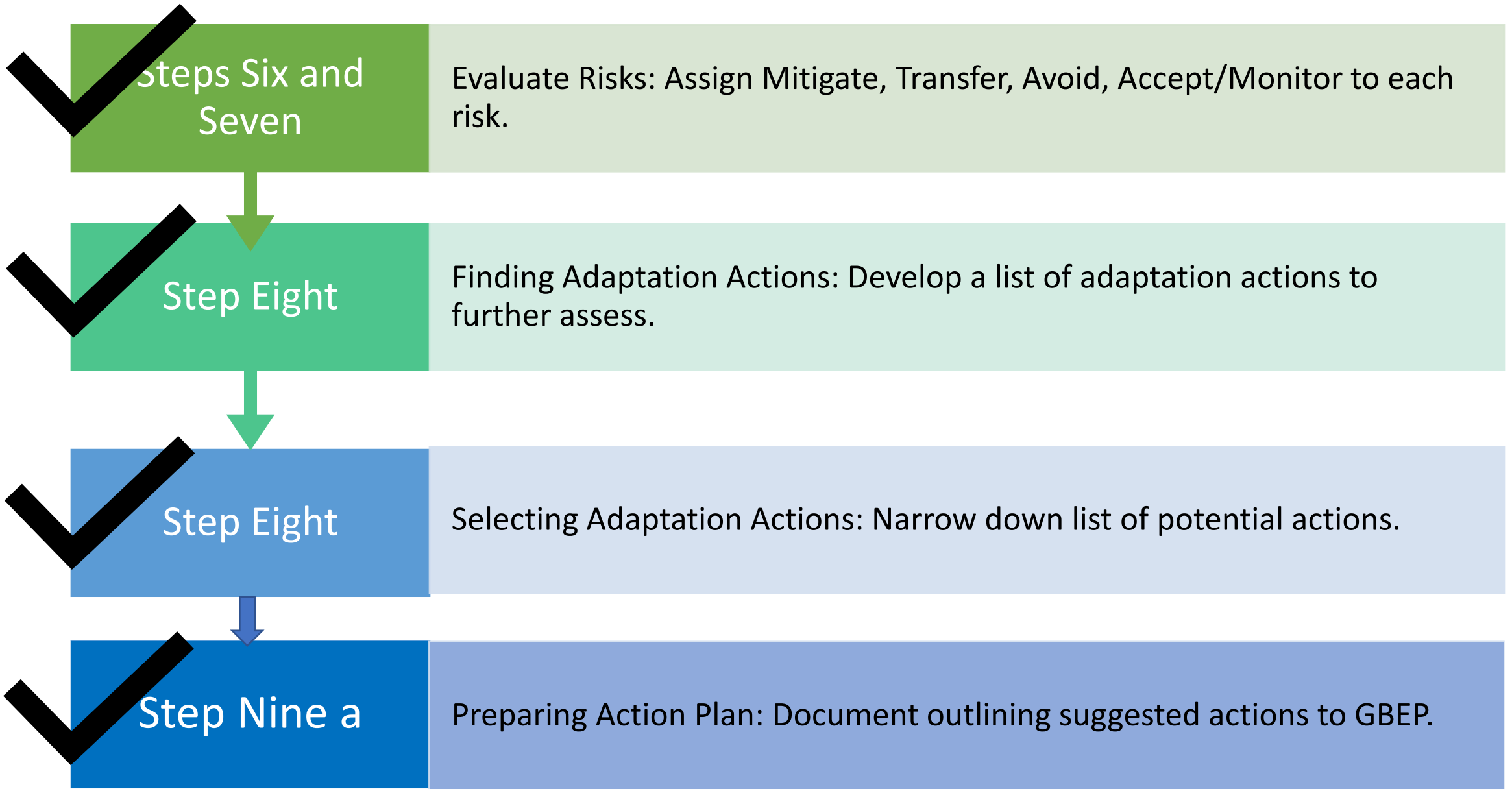
Galveston Bay Estuary Resilience Assessment Stakeholder Expert Work Group

Organization	Expertise
USGS	Water Resources
EIH-UHCL	Water Resources/Ecology
TPWD	Habitat Restoration
GBF	Restoration
TAMU AgriLife Extension Service	Habitat ecology
H-GAC	Water Quality
TPWD	Estuarine ecology
TPWD	Kills and Spills
USFWS	Estuarine ecology/restoration/conservation
Texas A&M University at Galveston (TAMUG)	Relative sea level rise
TAMU	Relative sea level rise & wetlands
TAMUG	Phytoplankton/Freshwater Inflows
TAMUG	Phytoplankton communities
GBF	Social/Community
Upper Coast Field - GLO	Coastal Biologist
TCEQ	Coastal Programs Specialist
Texas GLO	Coastal Resources
TWDB	Inflows
TNC	SLAMM, marine spatial planning

Vulnerability Assessment



Action Plan


Steps Six and Seven
Evaluate Risks: Assign Mitigate, Transfer, Avoid, Accept/Monitor to each risk.
Step Eight
Finding Adaptation Actions: Develop a list of adaptation actions to further assess.
Step Eight
Selecting Adaptation Actions: Narrow down list of potential actions.
Step Nine a
Preparing Action Plan: Document outlining suggested actions to GBEP.

Galveston Bay Plan Goals	Warmer Summers	Warmer Winters	Warmer Water	Increasing Drought	Increasing inland flooding (largely rain-based)	Increase in extreme events (coastal flooding/storm surge)	Sea Level Rise + subsidence	Chronic higher tides/nuisance flooding	Ocean Acidification	Population increase	Changes to land use and the built environment (infrastructure)
Reduce NPS pollution	If also drier, using more water for irrigation leading to increased runoff. Warmer summers will lead to warmer water, increased likelihood of fecal indicator bacteria, and increased frequency of water quality exceedances.	Extended growing season leading to increased irrigation and runoff Eliminates freeze events that would normally prohibit long-term establishment of invasive species. Warmer winters will lead to warmer water, increased likelihood of fecal indicator bacteria, and increased frequency of water quality exceedances. Criteria for discharging may not be met	Increased bacterial growth, increasing bacteria load exceedances. Warmer temperatures may increase toxicity of pollutants due to increased metabolism rates	Increased human use of water for irrigation leading to increased runoff Increasing bacteria Pollutant concentrations increase (less dilution)	Increased runoff from event will lead to short-term pollutant load increase May cause more septic systems to fail - lead to long-term pollutant load increase Could increase erosion of streambeds, increasing sedimentation and decreasing width of riparian corridors, which reduces vegetated land available for filtration, increasing short-term and long-term pollutant loads Contaminated sites may flood	Increase in extent in tidal flooding could lead to new sources of pollution from floating tanks, runoff etc; increased inundation of septic systems	Higher water tables will drown septic systems causing them to fail - lead to short-term and long-term pollutant load increases Increase in extent in tidal flooding could cause more septic systems to fail - lead to long-term pollutant load increase Contaminated sites may flood or have shoreline erosion Greater coastal wetland losses could occur (less filtration)	Increase in extent in tidal flooding could lead to new sources of pollution Increase in extent in tidal flooding could cause more septic systems to fail - lead to long-term pollutant load increase	Ocean Acidification will lead to decreased pH which could impact mobilization of pollutants (e.g. metals)	Increased population leads to increase in sources of NPS pollutants	Increase in impervious surfaces leads to increased runoff and alters pollutant pathways and residence time Loss of agriculture lands could change types and seasonality of NPS pollution

Stakeholders identified 11 **stressors** Galveston Bay will be facing now and in the future

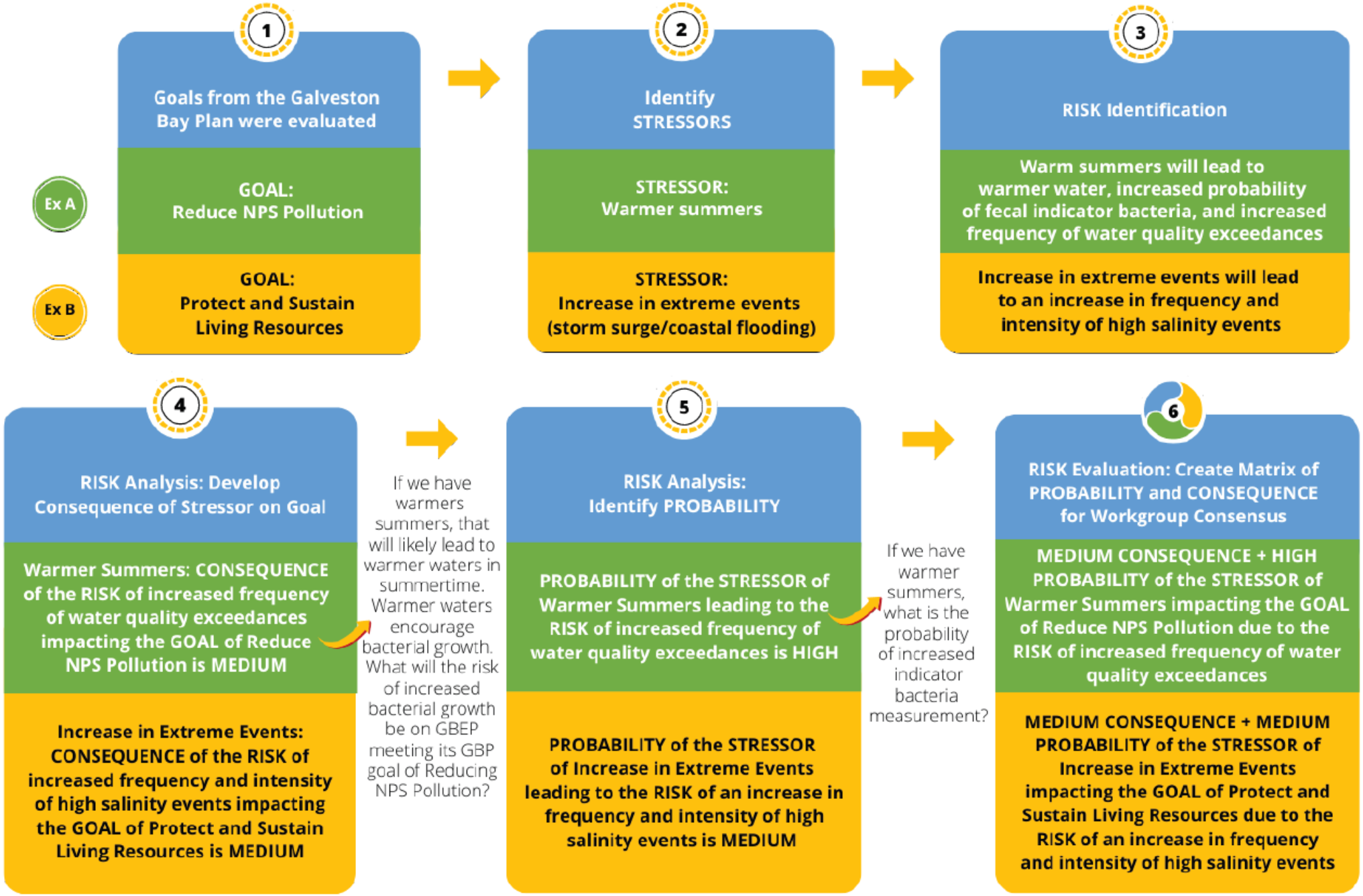
Stakeholders identified a series of Risks (toward the GBEP Plan Goal) associated with each Stressor, and then a Consequence and Probability (likelihood) of each risk

Galveston Bay Plan Priorities/Goals	Warmer Summers	Consequence (Low, Medium, High)	Probability (Low, Medium, High)	Spatial Extent (Site Specific, Local, Regional (estuary))	Time Scale (first impact) (Now-10 years, 10-30 years, > 30 years)
Ensure Safe and Aquatic Human Use: Reduce NPS and PS (including WWTF and sanitary sewer system) pollution	Using more water for irrigation leading to increased runoff	**Medium** *(effect of increased runoff from irrigation on Reduce NPS Pollution)*	**Medium** *(If we have warmer summers, what is the probability of increased runoff from irrigation occurring?)*	**Regional**	**Now-10 years**
	Warmer summers will lead to warmer water, increased likelihood of fecal indicator bacteria, and increased frequency of water quality exceedances	**High**	**High**	**Regional**	**Now-10 years**
	Increased evapotranspiration – compromised integrity of water bodies	**Medium**	**High**	**Regional**	**Now-10 years**

Consequence: For the Stressor (i.e. warmer summers), what is impact of the Risk (i.e. increased runoff) on the GB Plan goal/priority (i.e. Reduce PS/NPS Pollution)?

Low – plan goals not impacted, not as important as other things
Medium – status quo will change, goal more difficult to reach
High – makes goal out of reach – major disruption

Probability: For the Stressor (i.e. warmer summers) what is the likelihood of the Risk (i.e. increased runoff) occurring?


1
Goals from the Galveston Bay Plan were evaluated
Ex A
GOAL: Reduce NPS Pollution
Ex B
GOAL: Protect and Sustain Living Resources
2
Identify STRESSORS
STRESSOR: Warmer summers
STRESSOR: Increase in extreme events (storm surge/coastal flooding)
3
RISK Identification
Warm summers will lead to warmer water, increased probability of fecal indicator bacteria, and increased frequency of water quality exceedances
Increase in extreme events will lead to an increase in frequency and intensity of high salinity events
4
RISK Analysis: Develop Consequence of Stressor on Goal
Warmer Summers: CONSEQUENCE of the RISK of increased frequency of water quality exceedances impacting the GOAL of Reduce NPS Pollution is MEDIUM
Increase in Extreme Events: CONSEQUENCE of the RISK of increased frequency and intensity of high salinity events impacting the GOAL of Protect and Sustain Living Resources is MEDIUM
If we have warmers summers, that will likely lead to warmer waters in summertime. Warmer waters encourage bacterial growth. What will the risk of increased bacterial growth be on GBEP meeting its GBP goal of Reducing NPS Pollution?
5
RISK Analysis: Identify PROBABILITY
PROBABILITY of the STRESSOR of Warmer Summers leading to the RISK of increased frequency of water quality exceedances is HIGH
PROBABILITY of the STRESSOR of Increase in Extreme Events leading to the RISK of an increase in frequency and intensity of high salinity events is MEDIUM
If we have warmer summers, what is the probability of increased indicator bacteria measurement?
6
RISK Evaluation: Create Matrix of PROBABILITY and CONSEQUENCE for Workgroup Consensus
MEDIUM CONSEQUENCE + HIGH PROBABILITY of the STRESSOR of Warmer Summers impacting the GOAL of Reduce NPS Pollution due to the RISK of increased frequency of water quality exceedances
MEDIUM CONSEQUENCE + MEDIUM PROBABILITY of the STRESSOR of Increase in Extreme Events impacting the GOAL of Protect and Sustain Living Resources due to the RISK of an increase in frequency and intensity of high salinity events

Consequence/Probability Matrix by GB Plan Goal

GBP Goal: Engage Communities

Likelihood (Probability of Occurrence)	Low	Medium	High
High		1. Land Use Change| **Increased impervious surfaces** 2. Population Increase| **Increased resource demands** 3. Relative Sea Level Rise| **Wetland loss** 4. Warmer Summers| **Heat stress** 5. Warmer Summers| Warmer Waters| **Increase in vibrio illness**	1. Nuisance Flooding|Increasing Extreme Event Flooding|Relative Sea Level Rise| **Increased flooding of property and habitat** 2. Warmer Summers|Warmer Waters| **Warmer waters lead to increased bacteria** 3. Warmer Water| **Heat Stress** **4. Ocean Acidification| Loss of oyster reef habitat**
Medium		1. Increasing Drought| **Increase in tree loss** 2. Warmer Winters| **Increase in invasive species**	1. Increasing Extreme Event Flooding| **Stakeholders may not be able to deal with more events/damages** 2. Increasing Drought| **Decrease in water quality** 3. Relative Sea Level Rise| **Increased storm surge**
Low			1. Increasing Inland Flooding| **Wider spread of waterborne pathogens**
	Low	**Medium**	**High**
	Consequence		

GBP Goal: Ensure Safe Human and Aquatic Use: Reduce NPS and PS (including WWTF and sanitary sewer system) pollution

Likelihood (Probability of Occurrence)	Low	Medium	High
High	1. Increasing Extreme Event Flooding| **WWTF will go offline more often** 2. Increasing Extreme Event Flooding| **Frequency of sanitary sewers infiltration events will increase** 3. Increasing Inland Flooding| **Increased runoff from event will lead to pollutant load increase** 4. Increasing Inland Flooding| **Potential for increased overtopping and "leaking systems" releasing greater pollutants**	1. Warmer Summers| Warmer Winters| **More water for irrigation leading to increased runoff** 2. Warmer Summers| **Lead to warmer water, increased likelihood of fecal indicator bacteria and water quality exceedances**	1. Nuisance Flooding| **Septic systems and WWTF and lift stations to fail** 2. Increasing Extreme Event Flooding| **New sources of pollution** 3. Increasing Drought| **Increased water usage** 4. Increasing Inland Flooding| **Could increase erosion of streambeds** 5. Population Increase| **Increased population leads to increase in sources of NPS pollutants** 6. Relative Sea Level Rise| **High water tables will drown coastal septic systems causing them to fail** 7. Relative Sea Level Rise| **Contaminated sites may flood** 8. Relative Sea Level Rise| **Greater coastal wetland losses**
Medium	1. Ocean Acidification| **Lead to decreased pH**	1. Land Use Change| **Increase in impervious surfaces leads to increased runoff** 2. Increasing Drought| **Increasing bacteria load** 3. Population Increase| **Increased quantity and decreased quality of stormwater**	1. Relative Sea Level Rise| **Potential increase of saltwater intrusion**
Low	1. Increasing Drought| **Older "leaking systems" have less pollution due to decreased rainfall** 2. Warmer Summers| **Increased evapotranspiration**	1. Warmer Waters| **Increased bacterial growth, Increasing bacteria load exceedances** 2. Warmer Winters| **Eliminates freeze events** 3. Warmer Winters| **Lead to warmer water, increased likelihood of fecal indicator bacteria and water quality exceedances**	
	Low	**Medium**	**High**
	Consequence		

GB Plan Goal: Protect and Sustain Living Resources: Sustain and restore native species populations

Likelihood (probability of Occurrence)	Low	Medium	High
High		1. Warmer Winters| **Proliferation of mangroves in Galveston Bay is likely if deep freezes occur less often**	1. Increasing Drought| **Sessile organism stress**	1. Increasing Inland Flooding| **Changes in shallow water habitat and secondary impacts of juvenile stages of estuarine and marine organisms** 2. Relative Sea Level Rise| **Increased marsh flooding** 3. Relative Sea Level Rise| **Changing spatial extent of available habitat** 4. Relative Sea Level Rise| **Loss of restored and enhanced habitat due to drowning** 5. Warmer Winters| **Could alter habitat distribution and lower dissolved oxygen in some area**
Medium		1. Warmer Winters| **Potentially more suitable for manatees and less cold stunning events for sea turtles**	1. Increasing Extreme Event Flooding| Increasing Inland Flooding| **Habitat loss, conversion, and migration hold implications for native species** 2. Relative Sea Level Rise| **Increased extent of saline waters** 3. Warmer Summers| **Heat stress to native populations** 4. Warmer Summers| Warmer Winters| **Increased salinity can impact distribution, abundance, and productivity of native species** 5. Warmer Summers| **Life cycle stages is influenced by environmental cues** 6. Warmer Summers| **Shifts in fisheries populations** 7. Warmer Waters| Warmer Winters| **Oyster reef loss to dermo and oyster drilling predators** 8. Warmer Waters| **Correlation with drop in salinity and increase in lesions on bottlenose dolphins** 9. Warmer Winters| **Could expand range of invasive species**	1. Increasing Extreme Event Flooding| **Changes in shallow water habitat and secondary impacts on juvenile estuarine and marine organisms** 2. Increasing Drought| **Species may not tolerate new drought regimes** 3. Increasing Drought| **Increasing marine and invasive species including predators, parasites, and diseases** 4. Increasing Drought| **Increased conditions for harmful algal blooms** 5. Relative Sea Level Rise| **Changing light attenuation** 6. Warmer Summers| **Increased water temperatures would increase oyster predation and parasites** 7. Warmer Summers| **Warmer water temperatures have been linked to long-term decline in blue crab abundance** 8. Warmer Winters| **Potential increase in pests**
Low			1. Increasing Extreme Event Flooding| Increasing Drought| Increasing Inland Flooding| **Potential adverse effect for secretive marsh birds like rails if drier transition habitats are not available** 2. Increasing Drought| **Increase in stranding events and inundation of freshwater habitats** 3. Increasing Drought| **Shifting vegetation community composition** 4. Warmer Winters| **Potential to increase return intervals for wildfires affect vegetation structure and use by threatened or endangered species**	

High Consequence – High Probability Risks

- **Changes to land use and the built environment (infrastructure)**
  - Alter the quantity, timing, and duration of inflows
- **Chronic higher tides/ nuisance flooding**
  - Increased flooding of property and habitat
  - More septic systems and WWTF and lift stations failures
- **Increase in extreme events (coastal flooding/ storm surge)**
  - Increased flooding of property and habitat
  - Greater exposure to bacteria in flood waters
  - Exposure to pollutants during flood events
  - Exposure to new sources of pollution from floating tanks, runoff etc;
  - Potential for increased spills/ contaminants entering the bay system
  - Increased stream erosion and sediment loads
  - Loss of habitat
- **Increasing Drought**
  - Increase need for water conservation and water restrictions
  - Increased irrigation leading to increased runoff
  - Increased evapotranspiration and/or decrease in freshwater inflows which will cause increased salinity impacts and decreases in oyster reef habitat
  - Loss of habitat for riparian spawning fish species
  - Decrease in discharge to Galveston Bay
  - Base flow in streams may decrease
  - Increase demand on groundwater = reduction of base flow
- **Increasing Inland Flooding (largely rain-based)**
  - Exposure to pollutants during flood events
  - Increased erosion of streambed: increasing sedimentation loads and decreasing width of riparian corridors
  - Changes in shallow water habitat and secondary impacts on juvenile stages of estuarine and marine organisms
  - Increased exposure to bacteria in flood waters
- **Ocean Acidification**
  - Unknowns: Oysters amd other shellfish in the Bay impacted by acidification
- **Population Increase**
  - Increase in sources of NPS pollutants
  - Loss of native habitat to development
- **Sea Level Rise + Subsidence**
  - Increased flooding of property and habitat
  - Greater coastal wetland losses (less filtration)
  - Drown coastal septic systems causing them to fail
  - Contaminated sites may flood or have shoreline erosion
  - Increased extent of saline waters
  - Changing light attenuation
  - Increased marsh flooding
  - Changing spatial extent of available habitat
  - Loss of restored and enhanced habitat due to drowning
- **Warmer Summers**
  - Increased exceedances of bacteriological standards
  - Increased evapotranspiration - less freshwater inflow
  - Potential for more & stronger tropical storms/ hurricanes
  - Warmer summers could expand range of invasive species
  - Increased evapotranspiration will decrease freshwater inflows
  - Heat Stress
- **Warmer Waters**
  - Increase in fecal bacteria
  - Increase in vibrio illnesses
  - Increased evapotranspiration - less freshwater inflow
  - Decrease in dissolved oxygen
  - Increased stratification
  - Warmer water could alter habitat distribution and lower dissolved oxygen in some areas
- **Warmer Winters**
  - Enhanced survival of insect pests

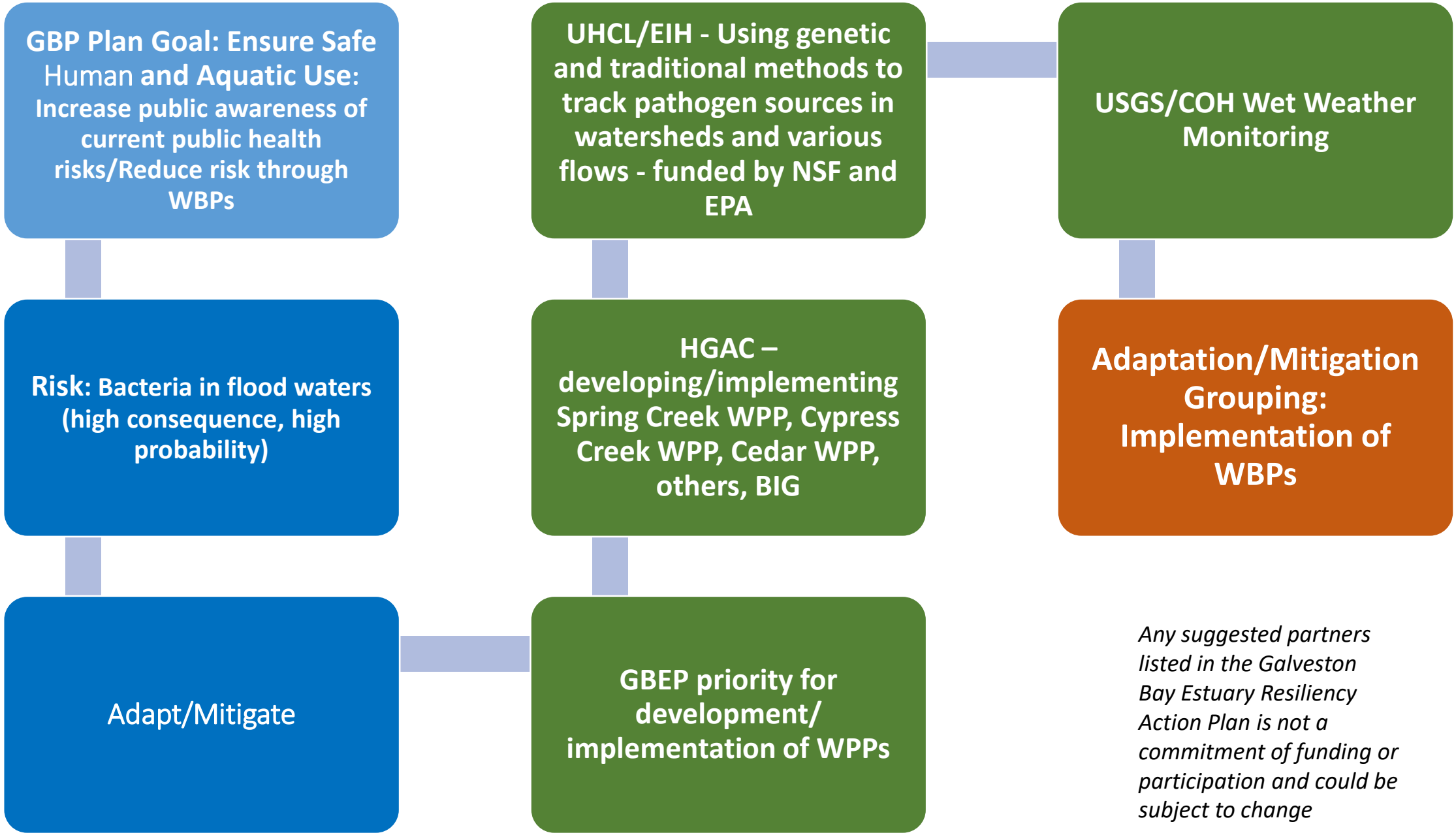
Assign Risk Management Approach

Risk management approach	Description	How your organization would use this approach
Mitigate	Take action to lower the consequence or likelihood of the risk (or both).	Address the risk or lead the effort to address the risk.
Transfer	Another party has responsibility for mitigating the risk.	Allow or ask others to take the lead; assist as you can.
Accept/Further Evaluation	Run the risk. Accept that the consequences may occur.	Business as usual in spite of the risk. Monitor, and reassess options in the future.
Avoid	Take organizational or administrative action so that you will not be exposed to the risk.	Stop putting resources toward the goal that would be affected. Or delete/revise your goal and thus be out of the risk altogether.

Adaptation Mitigation Actions

- Stakeholder expert work group met to determine *Adaptation/Mitigation Actions* for risks categorized as mitigate.
- In addition to risk reduction potential, the work group was encouraged to assess other criteria such as feasibility, effectiveness, equity, and cost-effectiveness.
- The goal of the adaptation and mitigation actions is that they could mitigate the risk by bringing either the **consequence** or **probability down** to a medium or low.
- Ranged from specific programs to educational opportunities to land conservation to broader monitoring and research goals.
- From the detailed actions, nine adaptation/mitigation action categories decided on by the work group, along with examples of organizations who are currently or will be soon carrying out adaptation/ mitigation actions.

Any suggested partners listed in the Galveston Bay Estuary Resiliency Action Plan is not a commitment of funding or participation and could be subject to change



Any suggested partners listed in the Galveston Bay Estuary Resiliency Action Plan is not a commitment of funding or participation and could be subject to change

Groupings for potential Adaptation/Mitigation Actions

- **Stakeholder Outreach: Education** –Formal education, community workshops, webinars, etc. [Texas A&M Agrilife Extension, GBF, H-GAC, USGS, TWDB]
- **Stakeholder Outreach: Alerts/Risk** - Means and methods to alert stakeholders to risks. Posted signs, websites, text alerts, fliers. [Texas Department of State Health Services, cities, and municipalities]
- **Monitoring** –Characterize how risks impact systems in order to identify and execute appropriate mitigation actions if/when needed. [USGS, GLO, U.S. Army Corps of Engineers, TAMUG, UH, GBF]
- **Implementation of WBPs** – stakeholder-led documents to identify potential sources of waterbody impairments throughout a watershed and provide a framework for implementation strategies [GBEP and H-GAC fund WBPs]
- **Preservation/Conservation/Restoration** – Preservation of lands, waters and habitats seeks to protect natural areas from use. Conservation seeks to use natural areas properly. Restoration's goal is to return natural areas to what they were or at least to functional parts of their ecosystem. [GBF, TPWD, Artist Boat, GLO, TNC]
- **Research** – Research is required when not enough information is known about the environment, ecosystems, or community at risk to better understand what the impacts are and if/how they should be mitigated. [USGS, HARC, TAMUG, UH, Rice University, HARC, TWDB]
- **Promote Water Conservation and Reuse** - Cities, council of governments, non-profits, water agencies, and local municipal utility districts can and should promote water conservation and may provide programming.. [H-GAC, GBF, TWDB promote water conservation]
- **Promote Native Habitat** – Preserving, conserving, restoring (including removing/preventing invasive species), monitoring, and educating the public about native habitats. [TPWD, Coastal Prairie Conservancy, Texas A&M Agrilife Extension, TNC]

Reference Table with all Goals, Stressors, Adaptation/ Mitigation Strategies, Likelihood, Consequences, and Examples of Adaptation/ Mitigation Actions

Table 5: Evaluation of Potential Adaptation/Mitigation Actions and Strategies for Galveston Bay

Stressors appear in bold type, Risks appear in italics. Stressors and Associated Risks Selected for Adaptation/Mitigation are color coded by the CCMP goals they address: purple for Engage Communities, blue for Ensure Safe Human and Aquatic Life Use, orange for Inform Science-Based Decision Making, green for Protect and Sustain Living Resources. WBPs = Watershed-based Plans.

Stressors and Associated *Risks* Selected for Adaptation/ Mitigation	Potential Adaptation/Mitigation Action Strategies	Could the action reduce likelihood of the *risk*?	Could the action reduce consequence of the *risk*?	Selected Examples of Adaptation/Mitigation Actions
Nuisance flooding, sea level rise and subsidence, and/ or extreme event flooding leading to *increased flooding of property and habitat*	Stakeholder Outreach: Education	NO	YES	Development of resilience plans; networks to share data with stakeholders
	Monitoring	NO	YES	
Warmer summers and **warmer waters** leading to *increased bacteria*	Stakeholder Outreach: Education	YES	YES	Bacteria monitoring on beaches, streams, and lakes; informing stakeholders
	Monitoring	NO	YES	
	Implementation of WBPs	YES	YES	
Warmer waters leading to *heat stress*	Stakeholder Outreach: Education	NO	NO	Monitoring on beaches; informing stakeholders
	Monitoring	NO	YES	
Extreme events and **inland flooding** leading to *bacteria in flood waters*	Stakeholder Outreach: Alerts/Risk	YES	YES	WBPs; water quality criteria; using genetic and traditional methods to track sources of bacteria and pathogens
	Monitoring	NO	YES	
	Implementation of WBPs	YES	YES	
Extreme events				

Table 6: Adaptation/Mitigation Strategy Groupings vs. GBP Priorities/Goals

	GBP Priorities/Goals						
	Engage Communities	Ensure Safe Human and Aquatic Life Use: Increase public awareness of current public health risks/Reduce risk through WBPs	Ensure Safe Human and Aquatic Life Use: Reduce NPS and PS (including WWTFs and sanitary sewer system) pollution	Inform Science -Based Decision Making	Protect and Sustain Living Resources: Conserve, restore, and enhance vital habitats in the lower portion of the Galveston Bay watershed.	Protect and Sustain Living Resources: Ensure adequate quantities of freshwater reach Galveston Bay	Protect and Sustain Living Resources: Sustain and restore native species populations
Adaptation/Mitigation Grouping							
Stakeholder Outreach: Education	X	X	X		X		X
Stakeholder Outreach: Alerts/Risk		X			X		
Monitoring	X	X	X	X	X		X
Implementation of WBPs	X	X	X	X	X	X	
Preservation/Conservation/Restoration		X	X	X	X	X	X
Research			X	X	X		
Promote Water Conservation and Reuse				X	X	X	
Promote Native Habitat							X

Table 7: Adaptation/Mitigation Strategy Groupings vs. Stressors

Stressors	Chronic higher tides/nuisance flooding	Increase in extreme events (coastal flooding/storm surge)	Sea Level Rise + subsidence	Warmer Summers	Warmer Waters	Increasing Drought	Increasing Inland Flooding (largely rain-based)	Population Increase	Ocean Acidification	Changes in land use and the built environment (infrastructure)
Adaptation/Mitigation Grouping										
Stakeholder Outreach: Education	X	X	X	X	X			X		
Stakeholder Outreach: Alerts/Risk		X		X	X	X	X			
Monitoring	X	X	X	X	X		X			
Implementation of Watershed Based Plans	X	X	X	X		X	X	X		X
Preservation/Conservation/Restoration		X	X	X			X	X		
Research		X		X	X	X	X		X	
Promote Water Conservation and Reuse				X	X	X	X			X
Promote Native Habitat				X			X			X

Example Tracking Tables for Future GBEP Projects

Table 8: Tracking Selected Adaptation/Mitigation Actions

Adaptation/ Mitigation	Risk(s) addressed	Responsible party(ies)	Next steps	Reporting frequency
1.				
2.				
3.				
n.				

Table 9: Example: Tracking Risk Reductions

Risk selected for adaptation/mitigation	Action(s) employed/completed
1.	
2.	
3.	
n.	

Thank you, please contact

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Extra Slides

GBP Goal: Ensure Safe and Aquatic Human Use: Increase public awareness of current public health risks/Reduce risk through WBPs

Likelihood (Probability of Occurrence)	Low	Medium	High
High		1. Increasing Drought| **Pollutant concentrations increase** 2. Warmer Waters| **Increased bacterial growth and bacterial load exceedances** 3. Warmer Winters| **Mosquito populations will not fall dormant with extended summers** 4. Warmer Winters| **Increased exceedances of bacteriological standards** 5. Warmer Winters| **Criteria for discharging may not be met**	1. Increasing Extreme Event Flooding|Increasing Inland Flooding| **Bacteria in flood waters** 2. Increasing Extreme Event Flooding|Increasing Inland Flooding| **Exposure to pollutants during flood events** 3. Increasing Drought| **Increase need for water conservation and restrictions** 4. Relative Sea Level Rise| **Greater coastal wetland losses could occur** 5. Warmer Summers| **Increased exceedances of bacteriological standards** 6. Warmer Waters| **Increase in vibrio illness**
Medium			1. Warmer Summers| **Increased heat stress (education)**
Low		1. Land Use Change| **Increased runoff** 2. Warmer Waters| **Water temperatures may increase toxicity of pollutants**	
	Low	**Medium**	**High**
	Consequence		

GBP Goal: Inform Science – Based Decision Making

Likelihood (Probability of Occurrence)	Low	Medium	High
High	1. Warmer Winters| **Potential for prolonged time period of bacterial/pathogen presence**	1. Nuisance Flooding| **Unknowns: do chronic higher tides impact restored wetlands** 2. Increasing Extreme Event Flooding| **Reduction of positive impacts of freshwater inflow** 3. Increasing Drought| **Less freshwater inflow** 4. Increasing Drought| **Prolonged reduced freshwater has long term effects** 5. Increasing Drought| **Increased salinity in brackish habitats** 6. Increasing Drought| **Increased chances of red and brown tides** 7. Increasing Inland Flooding| **Changes in inflow regime** 8. Population Increase| **Increased demand places more pressure on available freshwater supply** 9. Relative Sea Level Rise| **Reduction of positive impacts of freshwater inflow** 10. Relative Sea Level Rise| **Increase in bacteria levels from failing septic systems** 11. Warmer Summers| Warmer Winters| **Increased bacteria levels** 12. Warmer Winters| **More & stronger tropical storms/Hurricane** 13. Warmer Winters| **Increase in invasive species in Galveston Bay** 14. Warmer Winters| **Potential for prolonged Hurricane season**	1. Land Use Change| **Increase in impervious surfaces leads to increase of freshwater** 2. Increasing Extreme Event Flooding| **Potential for increased spills/contaminants entering the bay system** 3. Warmer Summers| Warmer Winters| **Increased evapotranspiration – less freshwater inflow** 4. Warmer Summers| **Potential for more & stronger tropical storms/Hurricanes**
Medium	1. Land Use Change| **Unknowns: how conversion of agricultural land impacts the Bay?** 2. Increasing Drought| **Unknowns: does drought change habitat functionality?** 3. Relative Sea Level Rise| **Salinizes brackish area** 4. Warmer Waters| **Impact dynamics of salinity stratification** 5. Warmer Waters| **Reduction in nutrient loading/productivity of estuary** 6. Population Increase| **More people to educate and promote water conservation**	1. Relative Sea Level Rise| **Increased extent of marine water may impact the freshwater balance of the bay** 2. Warmer Summers| **Essential food sources may die off** 3. Warmer Summers| **Unknowns: do warmer summers impact oyster reefs** 4. Warmer Waters| **Changes in communities to more tropical composition** 5. Warmer Winters| **Increased evapotran**spiration	1. Warmer Summers| **Heat stress to native populations** 2. Warmer Summers| **Changes in communities to more tropical composition** 3. Increasing Extreme Event Flooding| **Unknowns: how do storms impact freshwater wetlands?** 4. Warmer Waters| **Unknowns: How does warmer water impact phytoplankton community composition?**

GBP Goal: Protect and Sustain Living Resources: Conserve, restore and enhance vital habitats in the lower portion of the Galveston Bay watershed

Likelihood (Probability of Occurrence)	Low	Medium	High
High	1. Increasing Drought| **Changes to sediment loads** 2. Increasing Drought| **Loss of seasonal wetlands** 3. Increasing Inland Flooding| **Low light due to increased sediment load** 4. Warmer Summers| **Increased evapotranspiration which could lead to aquatic/subtidal species composition change** 5. Warmer Summers| Warmer Winters| **Increase plant productivity, vertical accretion and carbon sequestration** 6. Warmer Waters| **Increased water temperatures could cause changes in phytoplankton community composition**	1. Nuisance Flooding| **Loss of outer marsh habitat** 2. Nuisance Flooding| **Habitat loss, conservation, and migration impact native species** 3. Nuisance Flooding| **May create unfavorable habitat conditions more frequently** 4. Increasing Extreme Event Flooding| Increasing Inland Flooding| **Movement of invasive species** 5. Increasing Drought| **Loss of tree and vegetative cover** 6. Increasing Extreme Event Flooding | **Recreational fishing pressure** 7. Relative Sea Level Rise| **Changing spatial extent of available habitat** 8. Warmer Waters| **Increase in oyster predation and parasites**	1. Increasing Extreme Event Flooding| Increasing Inland Flooding| **Increased stream erosion and sediment loads** 2. Increasing Extreme Event Flooding| Increasing Drought| **Loss of habitat** 3. Increasing Drought| **Increased evapotranspiration** 4. Population Increase| **Loss of native habitat to development** 5. Relative Sea Level Rise| **Increased extent of saline waters** 6. Relative Sea Level Rise| **Changing light attenuation** 7. Warmer Summers| **Could expand range of invasive species** 8. Warmer Waters| **Decrease in dissolved oxygen** 9. Warmer Waters| **Increased stratification** 10. Warmer Winters| **Will enhance survival of insect pests** 11. Ocean Acidification| **Unknowns: Bay oysters impacted by acidification**
Medium		1. Increasing Extreme Event Flooding| **Increase in frequency and intensity of high salinity events** 2. Increasing Drought| **Area of suitable habitat decreases** 3. Increasing Inland Flooding| **Loss of habitat** 4. Increasing Inland Flooding| **Increase in frequency, intensity of decreased salinity events** 5. Increasing Inland Flooding| **Impacts for riparian fish spawning** 6. Population Increase| **Impacts from increased human pollution** 7. Relative Sea Level Rise| **Habitat conversion to open water** 8. Increasing Inland Flooding| **Correlation with drop**	1. Land Use Change| **Increase in impervious surfaces leads to increased runoff** 2. Land Use Change| **Coastal barriers reduce tidal exchange** 3. Land Use Change| **Loss of native habitat due to development** 4. Relative Sea Level Rise| **Increased marsh flooding**

GB Plan Goal: Protect and Sustain Living Resources: Ensure adequate quantities of freshwater reach Galveston Bay

Likelihood (probability of Occurrence)	Low	Medium	High
High		1. Increasing Extreme Event Flooding| **Changes periodicity of freshwater inflows**	1. Increasing Drought| **Increasing demand on water resources; decrease in discharge to Galveston Bay** 2. Increasing Drought| **Base flow in streams may decrease** 3. Increasing Drought| **Increase in demand on groundwater = further reduction of base flow** 4. Warmer Summers| **Increased evapotranspiration will decrease freshwater inflows**
Medium		1. Increasing Extreme Event Flooding| **Changes periodicity of freshwater inflows** 2. Relative Sea Level Rise| **Loss of wetlands could impact quality of freshwater inflows** 3. Warmer Summers| Warmer Waters|Warmer Winters| **Increased evapotranspiration will increase salinity in upstream reaches**	1. Land Use Change| **Reservoir operations can shift the timing and amount of peak inflows** 2. Increasing Extreme Event Flooding| **Accumulated impacts from other stressors** 3. Relative Sea Level Rise| **Less availability of groundwater = more demand on surface water, decreased base flow** 4. Warmer Summers| **Harmful algal blooms are more likely to develop in warm, salty water** 5. Warmer Waters| Warmer Winters| **Increased evapotranspiration will decrease freshwater inflows**
Low		1. Increasing Extreme Event Flooding| Increasing Inland Flooding| **Changes seasonality of freshwater inflows**	
	Low	**Medium**	**High**
	Consequence		

Example process to assign Risk Mitigation Approach

FIGURE 7-3. Your organization can opt for any risk management approach that serves its needs. The flow chart depicts a logical sequence that could help with decision-making when resources are limited and not every risk can be mitigated.