June 2023

Delta Adapts

Scenario Evaluation Metrics - Results

Delta Stewardship Council

A CALIFORNIA STATE AGENCY

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Introduction and Purpose

The Delta Stewardship Council (Council) is currently preparing an Adaptation Plan, Phase 2 of a regional climate change study called Delta Adapts: Creating a Climate Resilient Future. To inform the Adaptation Plan, a set of landscape-wide adaptation scenarios focused on land use were developed to visualize different options for adapting the Sacramento-San Joaquin Delta (Delta) and Suisun Marsh to the climate impacts identified in the Vulnerability Assessment. Our scenarios describe a range of futures in which ecosystem restoration, agriculture, and flood protection goals are maximized. For example, goals include continuing agriculture at a similar level as today, undertaking more ecosystem restoration to meet established targets, and incorporating varying levels of flood protection for levees located in different areas of the Delta. This allows us to consider alternative futures, to estimate the future adaptation benefits of potential land use changes, and to determine the relative effectiveness and cost of potential adaptations under different conditions. The impacts and tradeoffs of the various scenarios are assessed using evaluation metrics. Scenario results will inform development of individual adaptation strategies included in the Adaptation Plan. It is important to note other strategies will be informed by community input, best practices, best available science, and other sources.

Adaptation Scenarios Overview

Definition of Regions

For this analysis, the Delta and Suisun Marsh are divided into four regions, which are groupings of the smaller conservation units developed for the Delta Vision Strategic Plan[1] (Blue Ribbon Task Force 2008). These four regions were also used in the Delta Adapts Vulnerability Assessment. These four regions include:

- Suisun Marsh
- North Delta
- Central Delta
- South Delta.

Metrics results are presented by region and for the study area (Delta and Suisun Marsh) as a whole.

Scenario Baseline Assumptions

The Scenario Baseline Assumptions describe the starting point for the scenarios. Individual scenarios adjust these in different ways to meet scenario goals, but remain above the minimum level of protection or start with the baseline restoration assumptions. All scenarios share a set of baseline assumptions with the exception of Scenario 4: Levee Underinvestment. For the remaining scenarios, the baseline flood level of protection (LOP) assumptions are largely based on the tolerable risk standards adopted by the Council in the Delta Levees Investment Strategy (DLIS) Final Report, or State law (e.g. 200-year urban level of flood protection in the Central Valley). It is assumed that all Delta levees achieve Bulletin 192-82 standards with 1992 Special Studies hydrology – consistent with Delta Plan Performance Measure 7.3 and Recommendation RR R12. In Suisun Marsh, levees would achieve Suisun Resource Conservation District levee standards, except in areas with small communities, highways, or completed/planned restoration projects. The baseline assumptions include that restoration occurs on public lands where it is suitable and on existing and planned restoration project areas. The baseline assumptions are that water supply management and operations continue to react to real-time hydrologic and hydrodynamic conditions in the Delta (e.g., attempt to meet regulations through reservoir releases for water quality with existing tools such as deploying salinity barriers and issuing temporary urgency change petitions).

Scenarios

There are four primary scenarios and one associated sub-scenario as described below:

[1] Source: Blue Ribbon Task Force. 2008. Delta Vision Strategic Plan. Sacramento, California. USA. One revision to these regions was made by including the City of Stockton in the South Delta region instead of the Central Delta region.

- Scenario 1: Climate Smart Agriculture Focused
- Scenario 2: Restoration Focused
- Scenario 3: Less Delta Restoration
- Scenario 4: Levee Underinvestment
- Sub-scenario A: Water Infrastructure Protection

Scenario 1: Climate Smart Agriculture Focused

This scenario focuses on the continuation of existing land uses—primarily agriculture in the Delta—with the exceptions noted above in the baseline.

In this scenario, all existing land zoned for agriculture would continue on existing privately-owned land. Agriculture on select areas of public lands may be converted to restoration or multi-benefit crop type mosaics (e.g., rice), where suitable and with a view toward restoration targets identified in the Delta Plan. Restoration primarily consists of non-tidal wetlands, with some tidal wetlands, depending on location and elevation. In this scenario, approximately 5% of agriculture on subsided lands and 30,000 acres of restoration on subsided lands (9% together) would include subsidence reversal land cover types, meaning rice production or managed wetlands (on private lands) or non-tidal wetlands (on public lands). Including existing land cover types that can halt or reverse subsidence, this figure increases to nearly 24% of subsided areas.

Implementation of Scenario 1 assumes a set of climate smart adaptation strategies will be implemented to enable agricultural use to continue on existing private lands with changing climate conditions in the Delta (such as changing irrigation practices (e.g. dry farming, microirrigation), actions to improve soil health (e.g. composting, salt leaching), or planting changes (e.g. cover cropping, crop rotation, using native plants), among other strategies).

Restoration in Suisun Marsh would be limited to less than 5,000 additional acres on public lands. Non-tidal wetland targets can be achieved under this scenario, but most habitat targets identified in the Delta Plan would not be achieved, primarily due to the elevation of existing public lands and other constraints. The Suisun Marsh Habitat Management, Preservation, and Restoration Plan, adopted in 2014, includes a target of 5,000 to 7,000 acres of restoration, and this target would not be met in this scenario.

Figure 1 shows the land cover assumptions in Scenario 1, including the base land cover and changes to land cover as a result of the scenario (“Scenario Land Cover”).

This scenario assumes that flows are managed to meet water quality standards in the Delta without waivers.

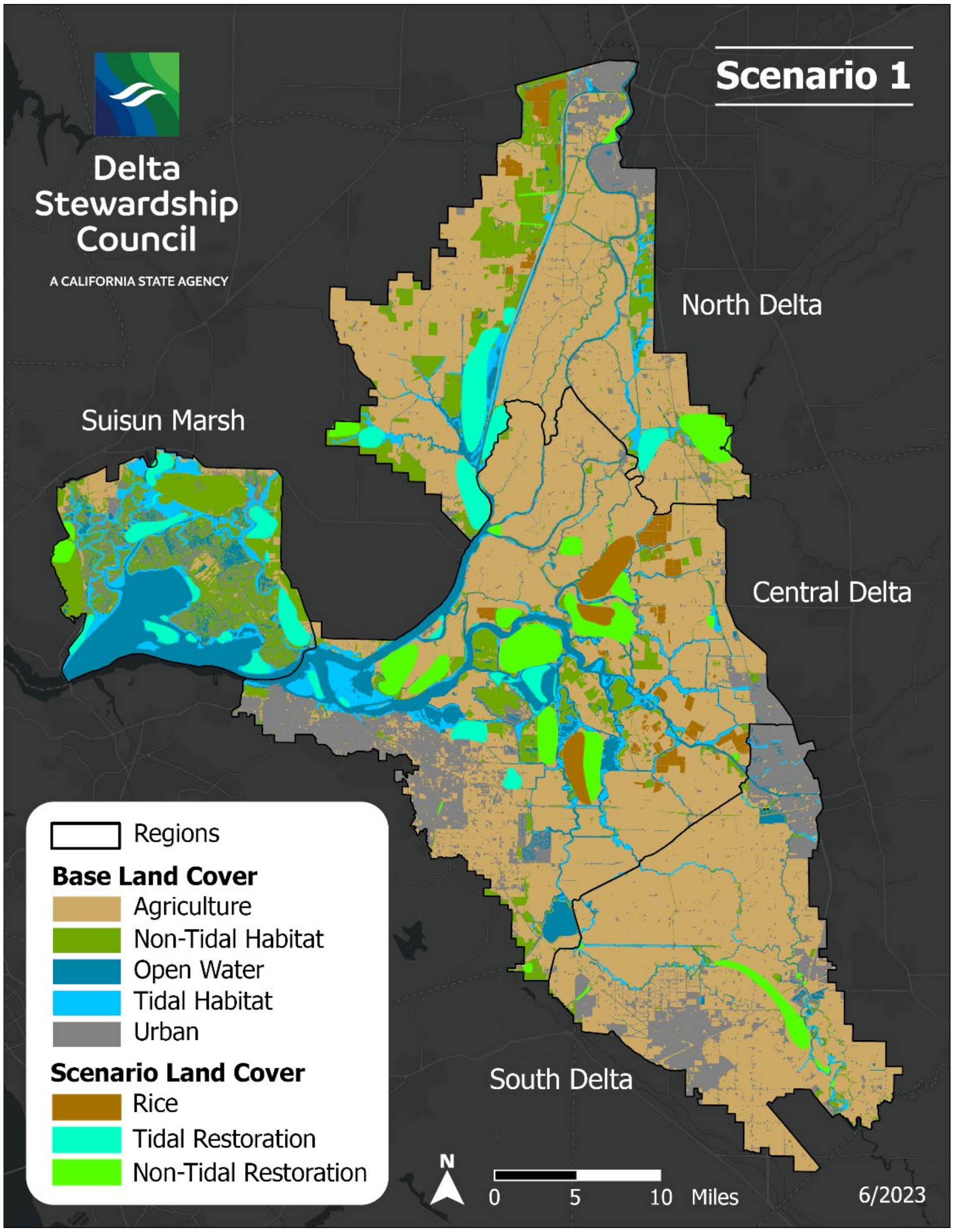

Figure 1: Scenario 1 land cover assumptions

Scenario 2: Restoration Focused

This scenario focuses on meeting restoration targets and habitat types that are identified in the Delta Plan, assuming restoration occurs on suitable public lands first. The remaining restoration needed to meet the Delta Plan targets is then assumed to occur on currently privately-owned lands suitable for the needed habitat types. A key principle for successful adaptive pathways will be to first maximize the use of publicly owned land and resources, before engaging willing sellers.

In this scenario, restoration is focused on public areas in the Delta and Suisun Marsh to meet Delta Plan restoration targets of 60,000 to 80,000 acres, and Performance Measure 4-

16 habitat type-specific acreage targets for 2050. Elevation is the primary driver for determining which types of restoration can exist in different areas. When it is not possible to reach a target solely on public lands, limited private land has been identified for restoration based on suitability as part of the modeling exercise. In Suisun Marsh, restoration would occur on all public lands at appropriate elevations and would exceed the required 5,000-7,000 acres identified in the Suisun Marsh Habitat Management, Preservation, and Restoration Plan.

In this scenario, a target of 42% of subsided areas was identified for subsidence reversal land cover types, meaning rice production or managed wetlands (on private lands), and wetland restoration (on public lands), including existing land cover types that contribute to subsidence halting or reversal.

The suitability of areas for potential restoration considers several factors, including appropriate elevation; potential impact to water supply or water quality, infrastructure, or communities; adjacency to upland transition or other appropriate elevation areas; connectivity; and too-wet-to-farm areas[2].

Figure 2 shows the land cover assumptions in Scenario 2, including the base land cover and changes to land cover as a result of the scenario ("Scenario Land Cover").

This scenario assumes that adequate water is available and is prioritized to enhance ecosystem function.

[2] Areas where farming is not possible or economical due to saturated conditions. This is described in further detail in *Evolution of Arability and Land Use, Sacramento–San Joaquin Delta, California* (Deverel et al. 2015).

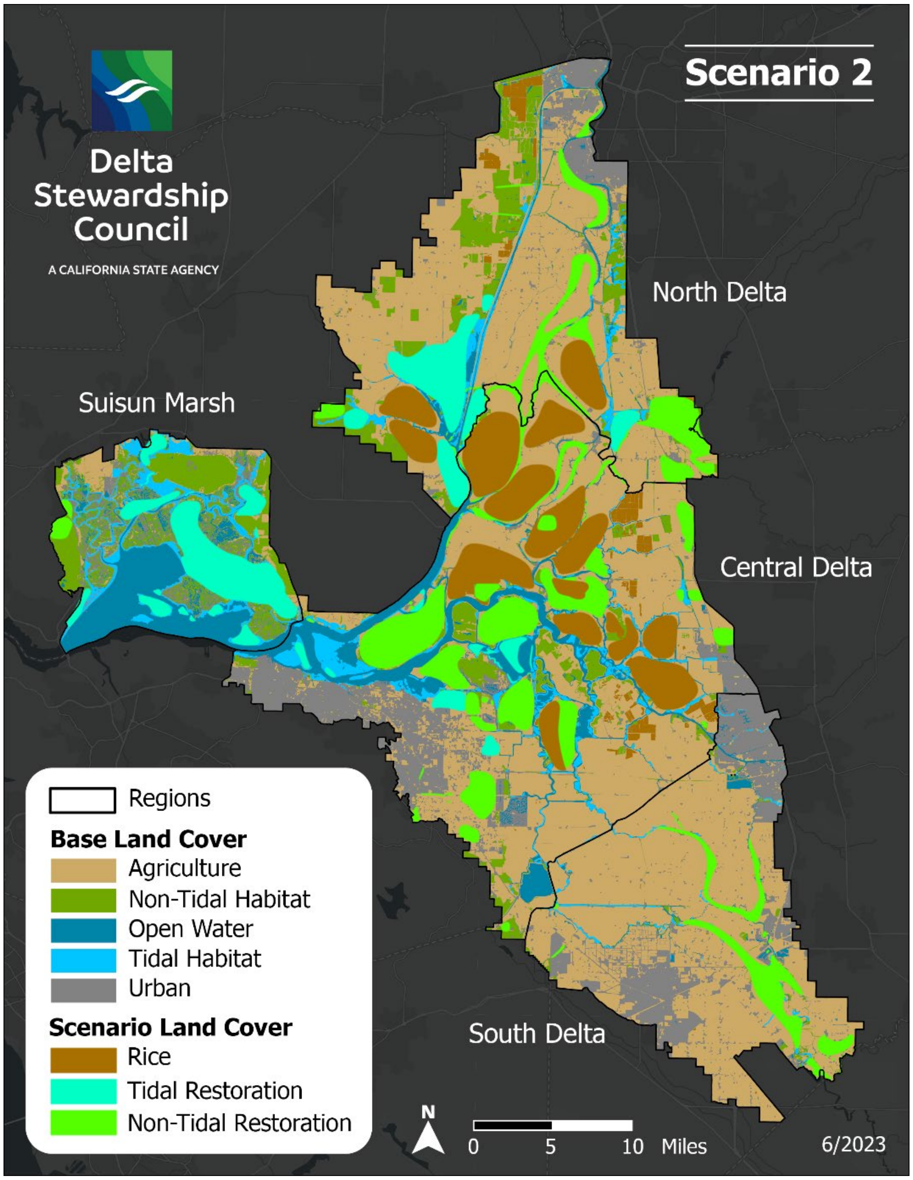

Figure 2: Scenario 2 land cover assumptions

Scenario 3: Less Delta Restoration

This scenario focuses on meeting overall restoration targets established in the Delta Plan while minimizing conversion of prime farmland.

This scenario is similar to Scenario 2, although it would reduce the amount of restoration that would occur on currently privately-owned land in the Delta, while increasing restoration in Suisun Marsh. Restoration would be maximized on public lands in Suisun Marsh, and a lower level of restoration is assumed on currently privately-owned land in the Delta relative to Scenario 2 (privately-owned lands are an artifact of existing restoration projects; no new, private areas were identified under Delta Adapts). Restoration would occur on currently privately-owned lands in Suisun Marsh that have existing or planned restoration.

Scenario 3 would meet the overall minimum Delta Plan target of 60,000 acres for restoration in the Delta as a whole, but would not meet the targets by habitat type as outlined in Performance Measure 4-16. Implementation of this scenario would also exceed the restoration targets identified in the Suisun Marsh Habitat Management, Preservation, and Restoration Plan. This approach helps reduce conversion of prime farmland while still meeting overall restoration acreage targets. However, it would have a larger effect on current land use types in Suisun Marsh. This scenario identifies 42% of subsided land in the Delta and Suisun Marsh to be prioritized in land cover types that could halt or reverse subsidence. This includes approximately 14% of subsided lands that currently have land cover types that halt or reverse subsidence, for a net gain of 28%.

Figure 3 shows the land cover assumptions in Scenario 3, including base land cover and changes to land cover as a result of the scenario ("Scenario Land Cover").

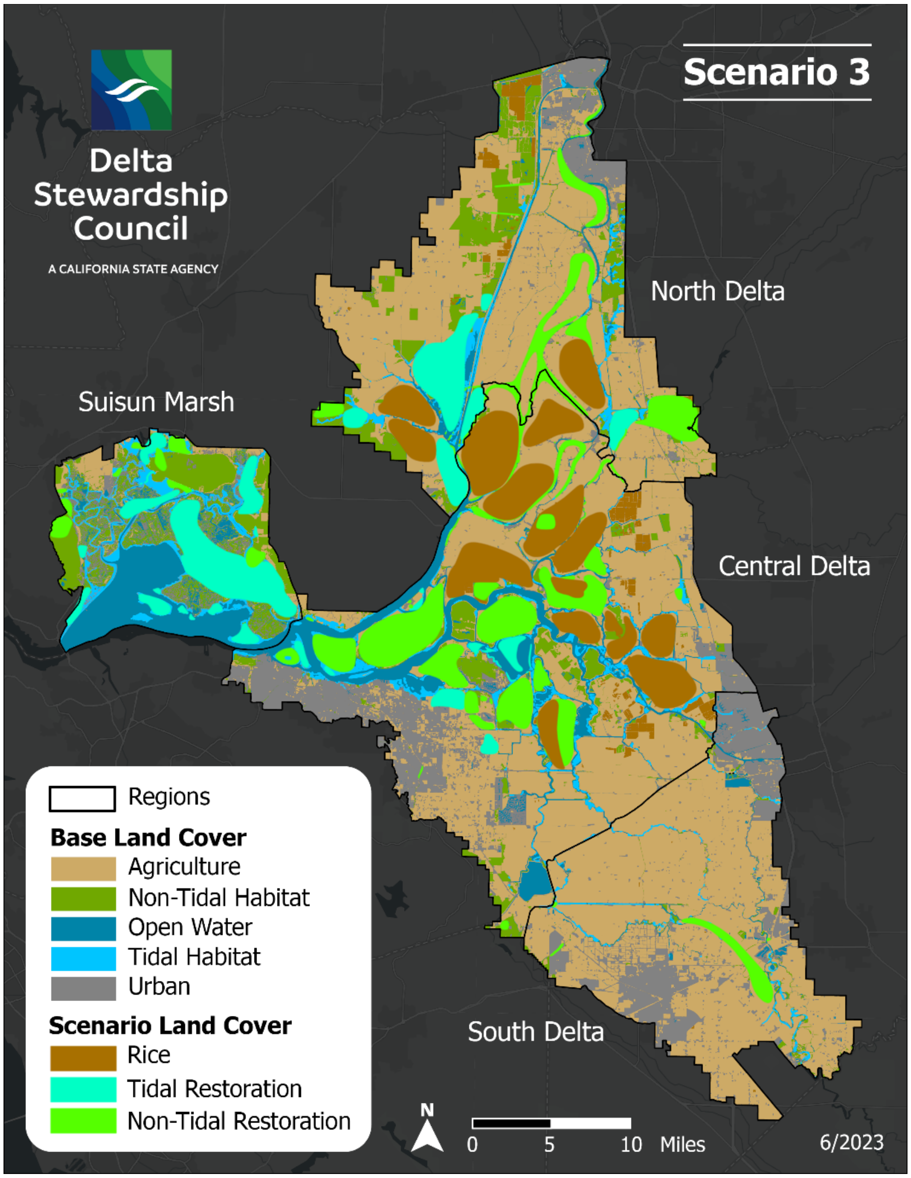

Figure 3: Scenario 3 land cover assumptions

Scenario 4: Levee Underinvestment

Assuming less funding for flood risk reduction is available, this scenario highlights the Delta impacts that would occur with fewer levee improvements.

This scenario would consider lower levels of flood protection in some areas and no levee improvements for others, where the total cost to improve the levees would be lower. It is estimated that in order to improve all levees in the Delta to accommodate for changing climate conditions in 2050, it would cost about $3.3 billion. This scenario assumes less than $3.3 billion is available for levee improvements and assumes the areas with the highest benefit-cost ratios have levees improved while all other areas do not have levees improved. Total levee costs under this scenario are estimated at $1.8 billion. Additionally, this scenario assumes approximately 2.5% of additional subsided lands would be converted to rice. **Figure 4** shows the land cover assumptions in Scenario 4, including the base land cover and changes to land cover as a result of the scenario ("Scenario Land Cover").

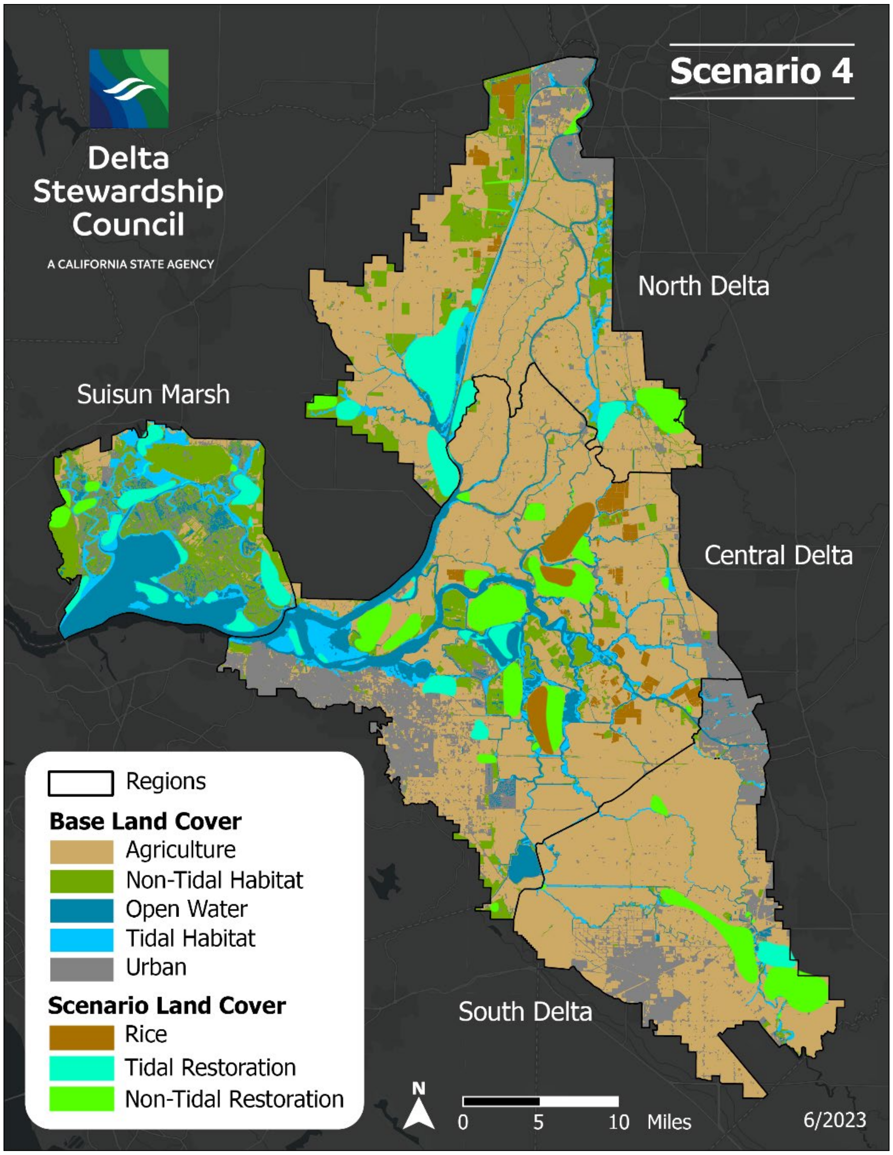

Figure 4: Scenario 4 land cover assumptions

Sub-scenario A: Water Infrastructure Protection

This sub-scenario, which can be paired with Scenarios 1, 2 or 3, is designed to protect water supply reliability by increasing the level of protection of Delta levees that contribute to the protection of water supply. These levees protect islands that contain critical water infrastructure such as municipal water intakes, make up the freshwater pathway, or protect water quality. Several islands help keep water exports fresh by acting as a barrier to salinity intrusion from the brackish Suisun Marsh. Other leveed islands serve as a freshwater pathway which directs fresh water from the Sacramento River in the north to the middle and south Delta for export at Clifton Court. Protecting water infrastructure would result in higher costs for levee improvements of these islands. Islands and tracts included in this scenario can be seen in **Figure 5**.

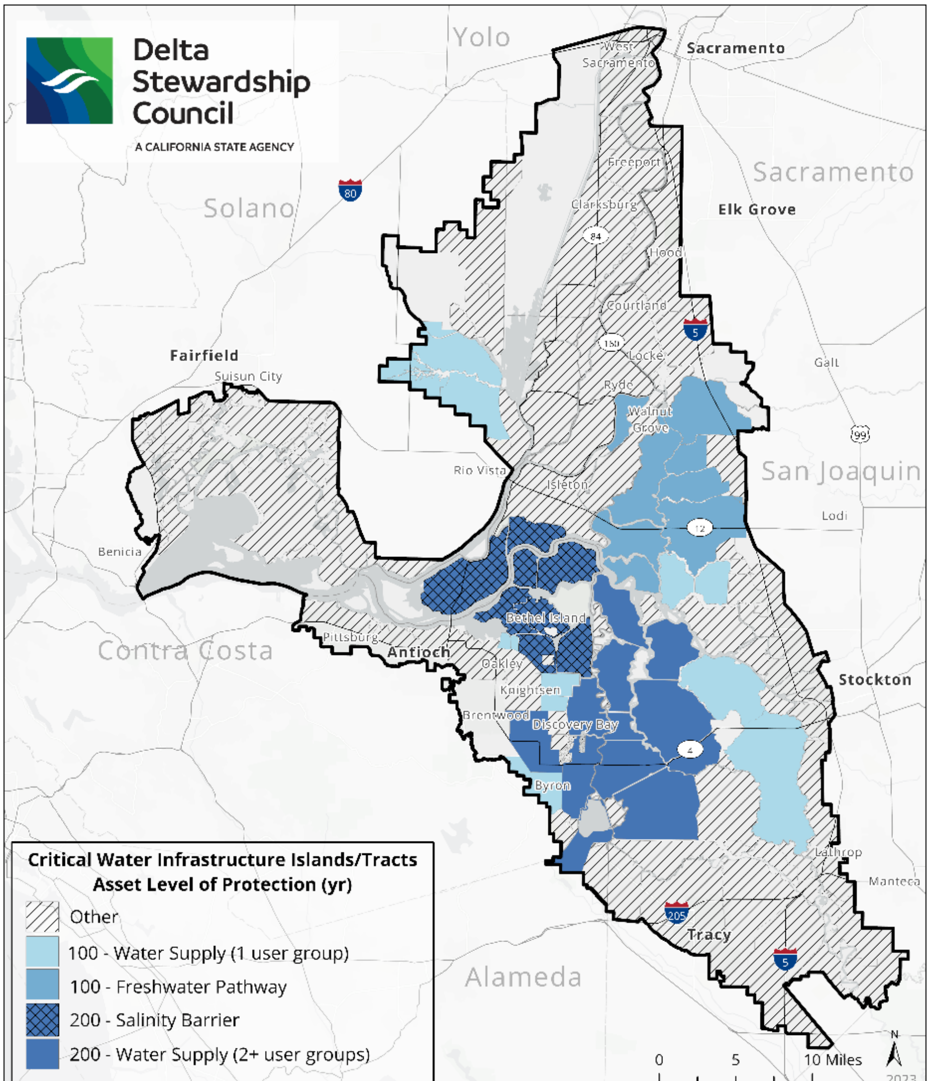

Figure 5: Critical water infrastructure islands/tracts in the Delta

Metrics Methodology

Metrics were calculated to quantitatively compare tradeoffs among the four scenarios. The metrics measure tradeoffs related to the four technical focus areas: ecosystems, agriculture, flood risk reduction, and water supply (water quality); there are also metrics related to economics, and a subset of the metrics focus on equity. The primary objective of these metrics is to examine the relative differences among the scenarios. Metrics were calculated in the same manner for all scenarios. It should be noted that water quality metrics were only calculated for Scenarios 1 through 3, while flood exposure metrics were only calculated for Scenario 4 as explained below.

Ecosystem Metrics

Ecosystem metrics were evaluated using the Delta Landscape Scenario Planning Tool (DLSPT) Version 2.2.0, developed by the San Francisco Estuary Institute[3]. The DLSPT is an ArcPy Toolbox designed for use in ArcGIS Pro. The tool takes GIS input layers depicting potential future land use changes to evaluate metrics related to ecosystem function, landscape processes, infrastructure, and agriculture. The tool outputs summary tables of quantitative metrics and a narrative report that allows users to evaluate trade-offs among scenarios. A wide range of metrics are available including habitat types, marshes, marsh connectivity, fish support, subsidence, agriculture, economics, and carbon and greenhouse gas emissions, among others. Our analysis uses a number of key metrics tabulated for the Delta and Suisun Marsh as a whole as well as at the subregional level (Suisun Marsh, North Delta, Central Delta, and South Delta). The key DLSPT metrics evaluated are described below:

- **Total extent and net change in habitat types:** This metric computes the extent of and net change in habitat types for each scenario as compared to the modern and historical Delta. The area in acres of each habitat type per scenario is compared to both the modern and historical Delta habitat types to evaluate net change in area.
- **Subsidence:** This metric computes the area of wetted habitat types (emergent wetlands and open water) on currently subsided land. The metric provides the area in acres for each scenario and presents the results in proportion (%) of currently subsided land covered by wetted habitat types (by comparing to the total subsided land defined in the tool as: areas below the local elevation of Mean Lower Low Water level (MLLW) in the Delta and Mean Tide Level (MTL) in Suisun Marsh).
- **Carbon storage and net greenhouse gas emissions:** This metric computes the avoided carbon losses in million metric tons of carbon dioxide ($MMTCO_2$) for each scenario. The avoided carbon losses are computed by comparing the accumulated carbon storage of peat to a baseline scenario[4]. The scenarios add tidal wetlands and managed non-tidal wetlands to the landscape, which can build peat and therefore accumulate carbon. The DLSPT computes the area of those habitat types in each of the scenarios and then computes how much carbon would be stored in those areas.
- For greenhouse gas emissions, the metric reports the change in greenhouse gas emissions in metric tons of carbon dioxide equivalent ($MTCO_{2e}$) per year relative to the baseline (net benefit or loss). The estimation of greenhouse gas emissions or

[3] https://www.sfei.org/projects/landscape-scenario-planning-tool

[4] The baseline scenario is built from the assumption of continued subsidence rates and therefore loss of land that stores CO_2 when compared to the Modern Delta. Metric is evaluated 40 years into the future and assumes mean sea level rise of 1.1 ft by 2060.

uptake comes from the habitat types. For example, methane (CH_4) is emitted from freshwater wetlands and high nitrous oxide (N_2O) emissions are associated with peat oxidation and nitrogen fertilized area that can be found in grazed pasture lands. Based on a change in land use area between the baseline and each scenario, the greenhouse gas emissions and a net benefit or loss can be computed and compared to the baseline.

- **Fish Support – Connectivity of large wetlands:** This metric computes the average distance (in miles) along the channel network to the nearest large connected tidal wetland. This distance represents the migratory distance that a fish needs to swim to find suitable conditions necessary for growth and survival.
- **Fish Support – Marsh area:** These metrics compute the area of connected wetland for the modern Delta and the user scenarios.

In addition to the metrics derived from the DLSPT, the Council identified two additional ecosystem-related metrics, described below:

- **Total extent and net change in habitat types in socially vulnerable communities:** This metric is similar to the DLSPT metric capturing total extent and net change of habitat types; however, it focuses on the area of land use changes within communities with high and highest social vulnerability, as identified by the Delta Adapts social vulnerability index, and within communities identified as disadvantaged by the Climate and Economic Justice Screening Tool (together referred herein as socially vulnerable communities). The intent of the metric is to capture how much restoration would occur in socially vulnerable communities, since restoration can have benefits for nearby communities.
- **Capital cost of ecosystem restoration:** This metric tabulates the approximate cost of proposed restoration activities for each scenario, including tidal wetland, riparian, non-tidal wetland, and oak woodland habitat restoration types. Restoration costs are illustrative and based on average per acre costs derived from analysis of select past restoration projects. Past projects include several components, such as acquisition price, levee maintenance (when applicable), and construction costs (such as mobilization/demobilization, excavation, fill placement, planting, and irrigation). However, included costs differ between projects. This is an area where active updates to data sources are being explored.

Agriculture Metrics

Six agricultural metrics were used to evaluate the scenarios: *gross revenue, jobs, land cropped, water used, net revenue, and Gross Domestic Product (GDP).* These metrics were acquired through a hydroeconomic model called the Delta Agricultural Production (DAP) model developed by the Water Systems Management Lab, Vice Lab, and the Center for Information Technology Research in the Interest of Society (CITRIS) at UC Merced, 2023. We also implemented the Economic Impact Analysis for Planning Model (IMPLAN) to calculate these metrics. In each scenario, we used the proposed percentage of agricultural land that would be converted to either restoration or rice for each Delta island to estimate these metrics using baseline data of 2014-2017 from the California County Agricultural Commissioner' Reports, California Department of Food and Agriculture, and U.S. Bureau of Labor, U.S. Department of Agriculture. These metrics were calculated for the Delta portion of Scenarios 1 through 4 (DAP does not extend to Suisun Marsh). The metrics for all the islands in a region are aggregated to provide a region-wide value before dividing by the region-wide baseline to find a percent change for each region.

- **Gross revenue ($):** Acres of cropped land that were not restored or converted to rice were multiplied by the average gross revenue/acre specific for each island during the baseline years of 2014-2017. For any islands that had conversion to rice, we multiplied the rice acres to the rice revenue/acre specific to the island. If there were no data on rice revenue/acre, the island closest in geographical proximity with a value for rice revenue/acre was used.
- **Jobs:** Each island has an average number of jobs depending on how much gross revenue is made from agriculture for that island. This was multiplied by the gross revenue for all non-rice crops. This was done with rice acres multiplied by the number of jobs/rice acres. The total jobs for each island consists of all non-rice jobs added to rice jobs.
- **Land cropped (acres):** The number of acres cropped (rice and non-rice) for each island was summed by regions and compared to the baseline.
- **Water used (acre-feet):** This metric was calculated using the number of non-rice cropped acres multiplied by the average amount of water/acre used on each island. This was also done for acres of rice cropped but multiplied by the average amount of water used for rice/acre for each island that grows rice. If this water for rice/acre value is not found, the adjacent island that has this value was used.
- **Net revenue ($):** A similar process was applied as gross revenue with the exception that land cropped was multiplied by average net revenue/acre for all non-rice croplands and rice acres multiplied by rice net revenue/acre. Net revenue accounts for land, water, labor, and supply costs whereas gross revenue does not.
- **Gross Domestic Product ($):** This estimates the value of the cropped lands by multiplying the number of non-rice acres with the average GDP/acre specific for each island. If rice is on those islands, the rice GDP/acre was multiplied to rice acres for each island. This value was added to the non-crop GDP to calculate a total GDP for each island. Then the region-wide GDP summed all the island GDPs.

In addition to the metrics derived from DAP, two additional metrics were assessed:

- **Acres converted to rice**

- **Cost of conversion to rice:** This metric includes equipment, land, water, and labor costs associated with crop switching from row crops to rice. Conversion rate of $843/acre were adopted from Leinfelder-Miles et al. (2023)[5].

Flood Risk Reduction Metrics

Flood risk reduction metrics were developed to assess tradeoffs associated with potential investments in levee improvements to mitigate future flood impacts within the Delta and Suisun Marsh. Flood risk cannot be eliminated; there will always be residual risk. The assigned LOP was based on the asset class and the tolerable risk associated with that asset. For example, population centers have a higher LOP than agricultural islands or tracts. This doesn't mean that that an urban area will never flood, but the tolerable risk is lower for people and property compared to farmland. **An asset class that is exposed to flooding means that the infrastructure required to protect the asset from flooding was not improved to the LOP assigned to that asset class. In other words, exposure to flooding means that the chances of being flooded exceed what is tolerable according to State law, or policy.**

Flood risk reduction metrics evaluated the cost of future levee improvements to address changes in Delta water levels, tabulated the LOP provided by Delta levees, and evaluated the residual flood risk to Delta assets and communities. The key flood risk reduction metrics evaluated are described below:

- **Capital cost of levee improvements –** Levee improvement costs were estimated for each scenario on a segment-by-segment basis and then rolled up to the island/tract, subregion, and Delta-wide scale. Costs were estimated based on information collected from Local Levee Maintaining Agencies' Five Year Plans prepared for the State Department of Water Resources (DWR) (to estimate costs to meet current Bulletin 192-82 standards) and DWR's Parametric Cost Estimating Tool (PCET) (to estimate costs to maintain freeboard standards for future hydrology). The PCET tool accounts for construction activities such as mobilization/demobilization, clearing and grubbing, stripping, excavation, fill, material disposal, aggregate road base, and hydroseeding. Allowances for change orders, design and engineering, permitting and legal, engineering during construction, construction management, and contingency are accounted for. For each scenario, levels of protection and freeboard were specified for each Delta levee segment and the required raising

[5] Michelle Leinfelder-Miles, Bruce Linquist, Paul Buttner, Jeremy Murdock, and Brittney Goodrich. 2022. Sample Costs to Produce Rice, Delta Region of San Joaquin & Sacramento Counties, San Joaquin Valley North, Continuous Rice Production. 2023.

height to provide protection for events with 2050 hydrology was calculated. Unit costs on a per mile basis as a function of raise height were estimated using the PCET tool and applied to each levee segment to meet its specified level of protection (for each scenario). This metric does not account for the costs to bring existing levees in compliance with freeboard requirements for current hydrology. Costs were tabulated at the island/tract, subregion, and Delta-wide levels, with the assumption that they had an appropriate baseline level of protection for each land use type. Levee improvement costs to meet future hydrology account for improvements to address freeboard deficiencies, but do not consider other types of improvements to address seepage, stability, or erosion.

- **Economic value of assets and economic activity exposed to flooding by island/tract** – The economic value of assets and activity for each island/tract was tabulated to inform a benefit-cost assessment to prioritize levee improvement investments for a levee underinvestment scenario (Scenario 4), where funding for all identified levee improvements is assumed to not be available. Under this scenario, not all Delta islands are brought up to a consistent level of flood protection which results in residual risk to some Delta assets and economic activities.
- **Population exposed to flooding** – For the levee underinvestment scenario (Scenario 4), total population, population in socially vulnerable communities, and population in Legacy Communities exposed to flooding (i.e., the population that does not receive the appropriate LOP) was also tabulated.
- **Critical facilities and highways exposed to flooding** – For the levee underinvestment scenario (Scenario 4), critical facilities and highways exposed to flooding were also tabulated.

Water Quality Metrics

Salinity implications for Scenarios 1, 2 and 3 were estimated using a simple one-dimensional DSM2 model. The modeling focused on understanding general trends, not the exact levels of change, anticipated in the Delta with changing climate conditions. With the existing tools, it is not possible to consider all the management actions and natural changes (e.g. sea level rise) simultaneously. Model simulations were performed using hydrology from fifteen consecutive water years (Oct 1, 2001, to Oct 1, 2015) and with a projected sea level rise of 1.8 feet in 2060. 66 locations were considered for this analysis, including locations adjacent to Legacy Communities and SAFER (Safe and Affordable Funding for Equity and Resilience Program) drinking water wells identified as failing or at risk of failing human right to water criteria.

- **Electrical Conductivity (EC)** – EC is the most common measure of salinity and is indicative of the ability of water to carry an electrical current. Because dissolved salts and other inorganic chemicals conduct electrical current, conductivity increases as salinity increases. EC is also affected by temperature. The higher the temperature of the water, the greater the ability of the water to conduct electrical charge. EC is measured in microsiemens per centimeter (mS/cm).

EC is commonly used to evaluate the changes resulting from a future scenario on water quality compared to existing conditions (or another scenario). The relative change in EC between a future scenario and existing conditions is commonly expressed as a percent change.

In the 1995 Bay-Delta Water Quality Control Plan (WQCP), the State Water Resources Control Board (State Water Board) set water quality objectives to protect beneficial uses of water in the Delta and Suisun Bay. The objectives must be met by the State Water Project (SWP) and federal Central Valley Project (CVP) as specified in the water right permits issued to the Department of Water Resources (DWR) and the U.S. Bureau of Reclamation (Reclamation). These objectives— minimum Delta outflows, limits on SWP and CVP Delta exports, and maximum allowable salinity levels—are enforced through the provisions of the State Water Board's Water Right D-1641, issued in December 1999 and updated in March 2000, which officially instated the 1995 WQCP.

Both DWR and Reclamation must monitor the effects of their respective diversions and project operations to ensure compliance with existing water quality objectives.

- **X2 -** Among the objectives established in the 1995 WQCP and D-1641 are the “X2” objectives. X2 is defined as the distance in kilometers from the Golden Gate, where salinity concentration in the Delta is 2 parts per thousand. The location of X2 is used as a surrogate measure of Delta ecosystem health.

  For the X2 objective to be achieved, the X2 position must remain downstream of Collinsville in the Delta (approximately 80 km), February through June, and downstream of other specific locations in the Delta on a certain number of days each month from February through June. This means that Delta outflow, which among other factors controls the location of X2, must be at certain specified levels at certain times. This can limit the amount of water the SWP may pump at those times at its Harvey O. Banks Pumping Plant in the Delta.

  X2 position is calculated daily using the results from the DSM2 model.

Economics Metrics

To assess the economic impacts of levee improvements and ecosystem restoration actions, total jobs that would be created as a result of levee improvements and ecosystem restoration were estimated for each of the four scenarios. Job impacts include direct, indirect, and induced jobs, and were calculated based on the amount of spending (costs) of levee improvements and restoration actions. Job impacts represent impacts nationally (i.e., not just within the region) and are based on multipliers from a September 2020 University of Massachusetts Amherst Political Economy Research Institute (PERI) report on levees and ecosystem restoration.

Equity Metrics

By Executive Order, State agencies must consider the most vulnerable populations when incorporating climate change into planning and investment decisions (EO B-30-15). The Delta Adapts process is incorporating equity by identifying the communities and populations that are most vulnerable to climate hazards in the Delta (identified in the Vulnerability Assessment), prioritizing those communities in outreach and engagement, and developing adaptation strategies that recognize and remedy these inequities. To inform the development of equitable adaptation strategies, a set of metrics related to equity were included in the scenario metrics evaluation. This allows for comparisons of equity-related tradeoffs among the scenarios. The equity metrics were selected with input from the Council's Environmental Justice Expert Group.

Table 1 lists the equity metrics, which include metrics drawn from the categories described above (ecosystem, agriculture, flood risk reduction, water quality, and economics).

Table 1: Equity Metrics

Category	Evaluation Metric
Water Quality	Change in salinity (compared to the baseline) at locations adjacent to Legacy Communities and SAFER (Safe and Affordable Funding for Equity and Resilience Program) drinking water wells identified as failing or at risk of failing human right to water criteria.
Flooding (Scenario 4 only)	Population exposed to flooding in socially vulnerable communities
Flooding (Scenario 4 only)	Critical facilities exposed to flooding in socially vulnerable communities
Ecosystems	Total extent and net change in habitat acreage by type in socially vulnerable communities
Agriculture	Percent change in number of jobs (compared to baseline) due to reduction in agriculture.

Metrics Results

Table 2 shows all metrics included in the analysis and results for each scenario (for the study area as a whole). The results discussion sections for each technical topic also include the metrics results by region and an explanation of metrics results.

Metrics are reported relative to the baseline for each of the four topic areas. The metric baseline uses either “existing conditions” (for ecosystem and agriculture) or the “scenario baseline” (flood risk reduction and water quality). The agricultural metric baseline land use is for the years 2014-2017. The ecosystem metric baseline is for the year 2017, but rice land cover is updated using USDA 2021 data. Flood risk reduction uses the flood scenario baseline, which is described in detail in the flood methodology document. Water quality uses the scenario baseline for metric calculations.

Metrics in **Table 2** (below) denoted with an asterisk report values that are “new” as part of the Delta Adapts initiative (for example, additional rice acres converted).

All other metrics report values that include the “new” values plus planned/existing projects (for example, the percentage of subsided lands covered by wetted habitat types includes both planned/existing areas covered by wetted habitat types as well as “new” areas designated under Delta Adapts).

Table 2: All Metrics and Metrics Results

	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Agriculture				
Change in gross revenue (%)	-5	-14	-12	-14
Change in agricultural jobs (%)	-5	-26	-25	-19
Change in cropped lands (%)	-8	-15	-13	-17
Change in water used (%)	-7	-13	-12	-16
Change in net revenue (%)	-4	-20	-18	-17
Change in Gross Domestic Product (GDP) (%)	-5	-14	-12	-15
Rice acres converted*	8,100	62,400	62,300	8,100
Rice conversion costs ($)*	$7M	$52M	$52M	$7M
Ecosystems				
Percentage of subsided lands covered by wetted habitat types (%)	23.5	42.2	42.4	22
GHG Emissions (MT CO2e/yr)	918,700	654,100	654,800	917,000
Avoided GHG emissions (MT CO2e/yr)	259,000	524,000	523,000	282,000
Connectivity of tidal wetlands (average distance along channel network to nearest large connected tidal wetland) (miles)	3	2	3	2
Total connected wetland area (acres)	54,500	58,600	60,200	49,000
Non-tidal restoration (acres)*	16,000	35,000	27,000	17,000
Tidal restoration (acres)*	24,000	39,000	36,000	28,000
Habitat restoration costs ($)*	$247M	$425M	$388M	$306M
Habitat area (landcover types excluding open water, urban/barren, and agriculture areas) in socially vulnerable communities (acres)	47,432	59,404	54,925	48,624
Flood Risk Reduction				
Levee improvement costs ($)*	$3.34B	$3.29B	$3.24B	$1.8B
Population exposed to flooding	n/a	n/a	n/a	4,140
Population exposed to flooding in socially vulnerable communities	n/a	n/a	n/a	502
Economic value of assets exposed to flooding ($)	n/a	n/a	n/a	$98M

Annual economic activity exposed to flooding ($)	n/a	n/a	n/a	$34M
Critical facilities exposed to flooding	n/a	n/a	n/a	1
Miles of highway exposed to flooding	n/a	n/a	n/a	7
Water Quality				
Salinity: Change in electrical conductivity (EC) (% change compared to baseline)	1.0	1.0	1.3	n/a
Change in X2 compared to baseline (kilometers)	-0.12 km	-0.13 km	-0.14 km	n/a
Economics				
Direct levee improvement jobs created*	27,020	26,630	26,230	14,600
Direct habitat restoration jobs created*	3,270	5,620	5,110	4,030

Ecosystem Metrics Results

Tables 3 through 8, on the next page, present the ecosystem metrics results. Note: two metrics (Total Extent and Net Change in Habitat Types, and Total Extent and Net Change in Habitat Types in Socially Vulnerable Communities) are presented in separate tables from the other metrics to show results for all habitat types.

Table 3: Ecosystem Metrics Results – Scenario 1

Scenario 1	Subsidence: Extent (acres) and Percentage of subsided land covered by wetted habitat types	GHG Emissions (MT CO2e per year)	Avoided GHG emissions (MT CO2e per year)	Connectivity of Tidal Wetlands (Avg distance along channel network to nearest large connected tidal wetland (miles)	Total connected wetland area (acres)	Capital Cost of ecosystem restoration actions (dollars)
North Delta	5,088 (10.3%)	61,000	-27,200	1	24,388	$ 68,590,000
Central Delta	42,989 (21.8%)	800,000	-232,000	3	10,904	$ 102,001,000
South Delta	551 (1.6%)	57,700	2	6	3,312	$ 20,159,000
Suisun Marsh	25,341 (75.6%)	4	0	1	15,894	$ 55,813,000
Total	**73,969 (23.5%)**	**918,704**	**-259,198**	**3**	**54,498**	**$ 246,564,000**

Table 4: Ecosystem Metrics Results – Scenario 2

Scenario 2	Subsidence: Extent (acres) and Percentage of subsided land covered by wetted habitat types	GHG Emissions (MT CO2e per year)	Avoided GHG emissions (MT CO2e per year)	Connectivity of Tidal Wetlands (Avg distance along channel network to nearest large connected tidal wetland (miles)	Total connected wetland area (acres)	Capital Cost of ecosystem restoration actions (dollars)
North Delta	12,054 (24.5%)	37,400	-50,800	0	20,531	$ 132,475,000
Central Delta	92,566 (46.9%)	559,000	-473,000	3	10,333	$ 165,147,000
South Delta	551 (1.6%)	57,700	2	3	4,340	$ 45,861,000
Suisun Marsh	27,599 (82.3%)	4	0	1	23,404	$ 81,628,000
Total	**132,770 (42.2%)**	**654,104**	**-523,798**	**2**	**58,608**	**$ 425,111,000**

Table 5: Ecosystem Metrics Results – Scenario 3

Scenario 3	Subsidence: Extent (acres) and Percentage of subsided land covered by wetted habitat types	GHG Emissions (MT CO2e per year)	Avoided GHG emissions (MT CO2e per year)	Connectivity of Tidal Wetlands (Avg distance along channel network to nearest large connected tidal wetland (miles)	Total connected wetland area (acres)	Capital Cost of ecosystem restoration actions (dollars)
North Delta	12,054 (24%)	39,100	-49,200	1	19,952	$ 116,242,000
Central Delta	93,035 (47%)	558,000	-474,000	3	11,830	$ 151,773,000
South Delta	551 (2%)	57,700	2	6	3,217	$ 18,452,000
Suisun Marsh	27,812 (83%)	4	0	1	25,181	$ 101,661,000
Total	**133,452 (42.4%)**	**654,804**	**-523,198**	**3**	**60,180**	**$ 388,128,000**

Table 6: Ecosystem Metrics Results – Scenario 4

Scenario 4	Subsidence: Extent (acres) and Percentage of subsided land covered by wetted habitat types	GHG Emissions (MT CO2e per year)	Avoided GHG emissions (MT CO2e per year)	Connectivity of Tidal Wetlands (Avg distance along channel network to nearest large connected tidal wetland (miles)	Total connected wetland area (acres)	Capital Cost of ecosystem restoration actions (dollars)
North Delta	4,999 (10%)	52,000	-36,100	1	19,913	$80,358,000
Central Delta	39,139 (20%)	812,000	-240,000	3	10,406	$107,046,000
South Delta	796 (2%)	52,500	-5,250	6	3,912	$49,353,000
Suisun Marsh	25,543 (76%)	4	0	1	14,755	$68,938,000
Total	**70,474 (22%)**	**917,000**	**-282,000**	**2**	**49,002**	**$305,695,000**

Table 7: Total extent and net change (from baseline) in habitat types (acres)

Habitat Type by Delta Region	Scenario 1, total extent (acres)	Scenario 1, net change (acres)	Scenario 2, total extent (acres)	Scenario 2, net change (acres)	Scenario 3, total extent (acres)	Scenario 3, net change (acres)	Scenario 4, total extent (acres)	Scenario 4, net change (acres)
Agriculture/ruderal	**476,781**	**-28,343**	**446,567**	**-58,557**	**459,820**	**-45,304**	**469,947**	**-35,177**
Central	199,812	-18,105	185,738	-32,179	191,537	-26,380	199,390	-18,527
North Delta	140,926	-6,158	130,338	-16,746	134,045	-13,039	139,089	-7,995
South Delta	127,099	-2,809	123,153	-6,755	127,267	-2,641	122,634	-7,274
Suisun	8,944	-1,271	7,338	-2,877	6,971	-3,244	8,823	-1,392
Alkali seasonal wetland complex	**864**	**-10**	**796**	**-78**	**796**	**-78**	**8,264**	**7,390**
Central	704	-10	660	-54	660	-54	704	-10
North Delta	105	0	105	0	105	0	105	0
South Delta	23	0	23	0	23	0	7,423	7,400
Suisun	32	0	8	-24	8	-24	32	0
Grassland	**16,460**	**-1,152**	**16,113**	**-1,499**	**15,728**	**-1,884**	**16,167**	**-1,445**
Central	3,008	-130	2,766	-372	2,766	-372	3,005	-133
North Delta	407	-33	405	-35	407	-33	407	-33
South Delta	374	0	373	-1	374	0	87	-287
Suisun	12,671	-989	12,569	-1,091	12,181	-1,479	12,671	-989
Non-tidal emergent wetland	**60,314**	**19,165**	**62,742**	**21,593**	**68,049**	**26,900**	**61,453**	**20,304**
Central	23,025	18,912	31,644	27,531	36,114	32,001	23,470	19,357
North Delta	7,373	852	7,024	503	7,096	575	7,133	612
South Delta	3,501	3,089	3,398	2,986	3,419	3,007	4,577	4,165
Suisun	26,415	-3,688	20,676	-9,427	21,420	-8,683	26,271	-3,832
Oak woodland/savanna	**2,309**	**1,876**	**11,221**	**10,788**	**2323**	**1,890**	**2,310**	**1,877**

Central	176	133	6,174	6,131	190	147	176	133
North Delta	876	875	2,701	2,700	876	875	876	875
South Delta	10	10	1,099	1,099	10	10	10	10
Suisun	1,247	858	1,247	858	1,247	858	1,247	858
Open water	**91,640**	**-7,378**	**90,598**	**-8,420**	**88,745**	**-10,273**	**90,529**	**-8,489**
Central	44,652	-2,015	44,619	-2,048	43,134	-3,533	44,650	-2,017
North Delta	10,889	-3,983	10,793	-4,079	10,800	-4,072	10,823	-4,049
South Delta	5,162	-168	5,162	-168	5,162	-168	4,221	-1,109
Suisun	30,937	-1,212	30,024	-2,125	29,649	-2,500	30,830	-1,319
Stabilized interior dune vegetation	**12**	**0**	**12**	**0**	**12**	**0**	**11**	**-1**
Central	11	0	11	0	11	0	11	0
North Delta	0	0	0	0	0	0	0	0
South Delta	0	0	0	0	0	0	0	0
Suisun	1	0	1	0	1	0	1	0
Tidal emergent wetland	**39,712**	**23,622**	**54,655**	**38,565**	**51,706**	**35,616**	**43,877**	**27,787**
Central	9,162	3,527	9,138	3,503	6,909	1,274	9,162	3,527
North Delta	14,768	12,375	19,576	17,183	18,124	15,731	18,178	15,785
South Delta	173	-7	165	-15	173	-7	173	-7
Suisun	15,609	7,727	25,776	17,894	26,500	18,618	16,358	8,476
Urban/barren	**94,250**	**-1,256**	**91,825**	**-3,681**	**91,773**	**-3,733**	**90,671**	**-4,835**
Central	37,245	-116	36,910	-451	36,964	-397	37,183	-178
North Delta	15,876	-58	15,325	-609	15,353	-581	15,827	-107
South Delta	33,176	-14	33,010	-180	33,179	-11	30,057	-3,133
Suisun	7,953	-1,068	6,580	-2,441	6,277	-2,744	7,602	-1,419
Valley foothill riparian	**11,012**	**711**	**21,517**	**11,216**	**18,515**	**8,214**	**10,497**	**196**
Central	2,770	209	4,487	1,926	4,468	1,907	2,774	213

North Delta	6,133	486	12,448	6,801	12,048	6,401	6,134	487
South Delta	2,023	16	4,496	2,489	1,913	-94	1,499	-508
Suisun	86	0	86	0	86	0	86	0
Vernal pool complex	**12,521**	**-1,728**	**12,485**	**-1,764**	**12,485**	**-1,764**	**12,489**	**-1,760**
Central	1,238	-47	1,236	-49	1,236	-49	1,235	-50
North Delta	10,291	-1,570	10,257	-1,604	10,257	-1,604	10,263	-1,598
South Delta	103	0	103	0	103	0	103	0
Suisun	889	-111	889	-111	889	-111	889	-111
Wet meadow/seasonal wetland	**23,633**	**-5,278**	**20,623**	**-8,288**	**20,205**	**-8,706**	**23,596**	**-5,315**
Central	10,041	-2,997	8,642	-4,396	8,205	-4,833	10,096	-2,942
North Delta	12,388	-2,080	11,038	-3,430	11,071	-3,397	11,273	-3,195
South Delta	370	-28	353	-45	370	-28	1,412	1,014
Suisun	834	-173	590	-417	559	-448	815	-192
Willow riparian scrub/shrub	**9,339**	**-779**	**9,712**	**-406**	**8,697**	**-1,421**	**9,070**	**-1,048**
Central	5,103	73	4,935	-95	4,752	-278	5,091	61
North Delta	2,344	-691	2,373	-662	2,201	-834	2,271	-764
South Delta	1,321	-89	1,999	589	1,343	-67	1,139	-271
Suisun	571	-72	405	-238	401	-242	564	-79
Willow thicket	**966**	**551**	**961**	**546**	**961**	**546**	**961**	**546**
Central	890	567	890	567	890	567	890	567
North Delta	75	-16	70	-21	70	-21	71	-20
South Delta	1	0	1	0	1	0	1	0
Suisun	0	0	0	0	0	0	0	0
Grand Total	**839,813**	**1**	**839,827**	**15**	**839,815**	**3**	**839,842**	**30**

Table 8: Total extent and net change (from baseline) in habitat types (acres) in socially vulnerable communities

Habitat Type by Delta Region	Scenario 1, total extent (acres)	Scenario 1, net change (acres)	Scenario 2, total extent (acres)	Scenario 2, net change (acres)	Scenario 3, total extent (acres)	Scenario 3, net change (acres)	Scenario 4, total extent (acres)	Scenario 4, net change (acres)
Agriculture/ruderal	**246,254**	**-13,506**	**235,000**	**-24,760**	**240,541**	**-19,219**	**246,290**	**-13,470**
Central Delta	141,844	-10,111	135,491	-16,464	137,730	-14,225	141,825	-10,130
North Delta	33,891	-1,772	30,547	-5,116	32,216	-3,447	33,891	-1,772
South Delta	69,763	-1,624	68,206	-3,181	69,840	-1,547	69,820	-1,567
Suisun Marsh	755	0	755	0	755	0	755	0
Alkali seasonal wetland complex	**129**	**0**	**129**	**0**	**129**	**0**	**129**	**0**
Central Delta	114	0	114	0	114	0	114	0
North Delta	0	0	0	0	0	0	0	0
South Delta	14	0	14	0	14	0	14	0
Suisun Marsh	1	0	1	0	1	0	1	0
Grassland	**1,764**	**0**	**1,764**	**0**	**1,764**	**0**	**1,764**	**0**
Central Delta	1,556	0	1,556	0	1,556	0	1,556	0
North Delta	165	0	165	0	165	0	165	0
South Delta	14	0	14	0	14	0	14	0
Suisun Marsh	29	0	29	0	29	0	29	0
Non-tidal emergent wetland	**18,149**	**14,559**	**21,866**	**18,276**	**25,105**	**21,515**	**19,356**	**15,766**
Central Delta	15,065	12,353	18,871	16,159	22,021	19,309	15,122	12,410
North Delta	760	518	755	513	757	515	760	518
South Delta	1,942	1,689	1,856	1,603	1,860	1,607	3,092	2,839

Suisun Marsh	383	0	383	0	468	84	383	0
Oak woodland/savanna	**43**	**0**	**4,085**	**4,041**	**43**	**0**	**43**	**0**
Central Delta	43	0	2,488	2,445	43	0	43	0
North Delta	1	0	1,597	1,596	1	0	1	0
South Delta	0	0	0	0	0	0	0	0
Suisun Marsh	0	0	0	0	0	0	0	0
Open water	**33,057**	**-559**	**33,049**	**-567**	**31,695**	**-1,921**	**32,430**	**-1,185**
Central Delta	15,413	-460	15,405	-468	15,001	-872	15,410	-463
North Delta	3,299	-87	3,299	-87	3,299	-87	3,299	-87
South Delta	4,736	-9	4,736	-9	4,736	-9	4,113	-632
Suisun Marsh	9,608	-2	9,608	-2	8,658	-953	9,608	-3
Stabilized Interior Dune Vegetation	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Central Delta	0	0	0	0	0	0	0	0
North Delta	0	0	0	0	0	0	0	0
South Delta	0	0	0	0	0	0	0	0
Suisun Marsh	0	0	0	0	0	0	0	0
Tidal emergent wetland	**6,093**	**1,741**	**6,063**	**1712**	**4,259**	**-92**	**6,093**	**1,742**
Central Delta	3,699	0	3,677	-22	1,950	-1,749	3,699	0
North Delta	2,022	1,742	2019	1739	2,019	1,739	2,022	1,742
South Delta	84	0	80	-5	84	0	84	-1
Suisun Marsh	288	0	288	0	206	-82	288	0
Urban/barren	**37,915**	**-69**	**37,381**	**-602**	**37,497**	**-486**	**37,313**	**-670**
Central Delta	23,329	-48	23,091	-286	23,091	-286	23,326	-51

North Delta	7,023	-8	6,834	-197	6,842	-189	7,023	-8
South Delta	7,244	-14	7,139	-119	7,246	-11	6,645	-613
Suisun Marsh	318	0	318	0	318	0	318	0
Valley foothill riparian	**5,149**	**292**	**9,402**	**4,545**	**8,413**	**3,556**	**5,019**	**162**
Central Delta	1,795	176	2,662	1,043	2,648	1,029	1,790	171
North Delta	2,495	105	4,890	2,501	4,909	2,519	2,495	105
South Delta	859	11	1,849	1,001	856	8	734	-114
Suisun Marsh	0	0	0	0	0	0	0	**0**
Vernal pool complex	**2,042**	**-19**	**2,040**	**-21**	**2,040**	**-21**	**2,042**	**-18**
Central Delta	46	-19	44	-21	44	-21	46	-18
North Delta	1,893	0	1,893	0	1,893	0	1,893	0
South Delta	103	0	103	0	103	0	103	0
Suisun Marsh	0	0	0	0	0	0	0	0
Wet meadow/seasonal wetland	**8,502**	**-2,657**	**7,692**	**-3,467**	**7,703**	**-3,455**	**8,687**	**-2,472**
Central Delta	7,176	-2,316	6,420	-3,072	6,418	-3,074	7,167	-2,325
North Delta	1,056	-315	1,011	-360	1,016	-355	1,056	-315
South Delta	238	-26	229	-35	238	-26	433	169
Suisun Marsh	31	0	31	0	31	0	31	0
Willow riparian scrub/shrub	**5,230**	**62**	**6,032**	**864**	**5,137**	**-31**	**5,160**	**-8**
Central Delta	3,425	266	3,377	218	3,356	197	3,408	249
North Delta	991	-176	1,067	-100	961	-206	991	-176
South Delta	804	-28	1,578	746	810	-22	751	-81
Suisun Marsh	11	0	11	0	11	0	11	0

Willow thicket	**332**	**-6**	**332**	**-6**	**332**	**-6**	**332**	**-6**
Central Delta	273	0	273	0	273	0	273	0
North Delta	57	-6	57	-6	57	-6	57	-7
South Delta	1	0	1	0	1	0	1	0
Suisun Marsh	0	0	0	0	0	0	0	0
Grand Total	**364,658**	**-162**	**364,834**	**15**	**364,658**	**-162**	**364,658**	**-162**

Results Discussion

Total extent and net change in habitat types: Scenario 2 includes the largest area of habitat areas (landcover types excluding open water, urban/barren, and agricultural areas) (210,837 acres), when compared to baseline conditions, followed by Scenario 3 (199,477 acres), Scenario 4 (188,695 acres), and Scenario 1 (177,142 acres). Scenario 2 includes the largest area of tidal emergent wetlands (54,655 acres), followed by Scenario 3 (51,706 acres), Scenario 4 (43,877 acres) and Scenario 1 (39,712 acres).

Total extent and net change in habitat types in socially vulnerable communities: Scenario 2 includes the largest area of habitat (landcover types excluding open water, urban/barren, and agriculture areas) in socially vulnerable communities (59,404 acres acres), followed by Scenario 3 (54,925 acres), Scenario 4 (48,624 acres) and Scenario 1 (47,432 acres).

Subsidence: Scenario 3 has the highest percentage of subsided lands covered by wetted habitat types (42.4%), followed closely by Scenario 2 (42.2%), then Scenario 1 (23.5%), and Scenario 4 (22%). (Note: This includes a variety of existing "wetted" habitats and land uses, not just restoration, or restoration modeled under this project).

GHG emissions and avoided emissions: Scenario 2 results in the largest emissions reductions compared to the baseline (523,798 MT CO2e per year less than the baseline), followed by Scenario 3 (523,198 MT CO2e per year reduction), Scenario 4 (282,000 MT CO2e per year reduction), and Scenario 1 (259,198 MT CO2e per year reduction).

Connectivity of tidal marsh: For the study area as a whole, the average distance along the channel network to the nearest large connected tidal wetland is lowest for Scenarios 2 and 4 (both 2 miles), followed by Scenarios 1 and 3 (both 3 miles). In other words, tidal marsh connectivity is greatest in Scenarios 2 and 4 and lowest in Scenarios 1 and 3.

Connected wetland area: Scenario 3 results in the largest area of connected wetlands (60,180 acres), followed by Scenario 2 (58,608 acres), Scenario 1 (54,498 acres), and Scenario 4 (49,002 acres).

Capital cost of ecosystem restoration: The cost of ecosystem restoration actions is highest in Scenario 2 ($425,111,000), followed by Scenario 3 ($388,128,000) and Scenario 4 ($305,695,000), with the lowest cost in Scenario 1 ($246,564,000). As described in more detail above, costs are illustrative and should not be considered as the amount required to achieve the habitat areas under each scenario. Actual costs are highly project specific and will vary in the future.

Agriculture Metrics Results

Scenarios 1 - 4

Tables 9 through 12 present the agriculture metrics results. All results are percent decreases compared to the 2014-2017 baseline values. Suisun Marsh was not modelled for these agricultural metrics because DAP does not cover that area. For Scenario 1, the largest losses across all the metrics are from the Central Delta, likely due to the relatively larger number of acres being converted to wetlands in the region. Subsequently, the loss of cropped land and conversion to rice, which is more mechanized and requires less labor, leads to a large drop in jobs in the Central Delta, representing the largest percent reduction compared to the baseline in Scenario 1. For Scenario 2, the largest changes occur in the Central Delta, where agricultural jobs would decrease by 38% due to high conversion to rice. The North Delta also has a lot of rice conversion, which causes high losses across all metrics relative to the South Delta.

For Scenario 3, which proposes more restoration in Suisun Marsh and less in the Delta, the largest changes also occur in the Central Delta, with jobs decreasing by 39% due to high conversion to rice which is more mechanized than other crops so will result in greater loss in jobs. The North Delta also has a lot of rice conversion along which cause high losses in all metrics relative to the South Delta. However, the impacts on the South Delta are much lower than the impacts in Scenario 2. For Scenario 4, which proposes an underinvestment of levees, the greatest reductions are expected to happen in the South Delta.

Table 9: Agriculture Metrics Results – Scenario 1

Scenario 1	Gross Revenue % Change	Jobs % Change	Land Cropped % Change	Water Used % Change	Net Revenue % Change	GDP % Change	Rice Acres Converted	Rice Conversion Costs ($)
North Delta	-4	-3	-6	-1	-2	-4	0	0
Central Delta	-8	-16	-13	-13	-8	-8	8,113	6,839,000
South Delta	-2	-2	-2	-2	-1	-2	0	0
Total Delta	-5	-9	-8	-7	-4	-5	8,113	6,839,000

Table 10: Agriculture Metrics Results – Scenario 2

Scenario 2	Gross Revenue % Change	Jobs % Change	Land Cropped % Change	Water Used % Change	Net Revenue % Change	GDP % Change	Rice Acres Converted	Rice Conversion Costs ($)
North Delta	-17	-23	-17	-17	-24	-17	11,661	9,831,000
Central Delta	-17	-38	-18	-15	-30	-17	50,776	42,804,000
South Delta	-6	-7	-6	-6	-6	-6	0	0
Total Delta	-14	-26	-15	-13	-20	-14	62,437	52,634,000

Table 11: Agriculture Metrics Results – Scenario 3

Scenario 3	Gross Revenue % Change	Jobs % Change	Land Cropped % Change	Water Used % Change	Net Revenue % Change	GDP % Change	Rice Acres Converted	Rice Conversion Costs ($)
North Delta	-15	-21	-14	-14	-22	-15	11,661	9,831,000
Central Delta	-39	-39	-18	-15	-30	-17	50,607	42,662,000
South Delta	-2	-2	-2	-2	-1	-2	0	0
Total Delta	-12	-25	-13	-12	-18	-12	62,268	52,492,000

Table 12: Agriculture Metrics Results – Scenario 4

Scenario 4	Gross Revenue % Change	Jobs % Change	Land Cropped % Change	Water Used % Change	Net Revenue % Change	GDP % Change	Rice Acres Converted	Rice Conversion Costs ($)
North Delta	-4	-4	-8	-8	-3	-4	0	0
Central Delta	-11	-22	-13	-13	-8	-11	8,113	6,839,000
South Delta	-30	-30	-35	-33	-37	-30	0	0
Total Delta	-14	-19	-17	-16	-17	-15	8,113	6,839,000

Flood Risk Reduction Metrics Results

Table 13: Capital Costs of Levee Improvements (Climate Change Costs)

Region	Scenario 1 – Climate Smart Agriculture Focused	Scenario 2 – Restoration Focused	Sub-Scenario A - Water Infrastructure Protection	Scenario 3 – Less Delta Restoration	Scenario 4 –Levee Underinvestment
North Delta	$33,929,000	$33,929,000	$56,032,000	$33,929,000	$20,003,000
Central Delta	$594,385,000	$594,385,000	$742,910,000	$552,103,000	$534,042,000
South Delta	$2,563,873,000	$2,563,873,000	$1,640,740,000	$2,563,873,000	$1,115,900,000
Suisun Marsh	$143,860,000	$96,552,000	$73,075,000	$89,116,000	$132,468,000
Total	$3,336,047,000	$3,288,739,000	$2,512,757,000	$3,239,021,000	$1,802,413,000

Note: Costs do not include an estimated $1.39B investment Delta-wide to bring existing levees to current standards. Levee improvement costs for Sub-Scenario A are lower because it only includes a subset of islands that contain water infrastructure.

Table 14: Flood Exposure Metrics (for Scenario 4: Underinvestment of Levees)

Flood Exposure at 2050 (M6 Flood Scenario):

Metric (Rounded Values)	All	North Delta	Central Delta	South Delta	Suisun
Agricultural Land Value	$ 11,186,000	$ -	$ -	$ 11,186,000	$ -
Residential Asset Value	$ 67,614,000	$ -	$ 211,000	$ 68,174,000	$ -
Commercial Asset Value	$ 1,215,000	$ -	$ -	$ 3,429,000	$ -
Communication Asset Value	$ -	$ -	$ -	$ -	$ -
Energy Asset Value	$ 17,741,000	$ -	$ -	$ 19,390,000	$ -
Agricultural Annual Economic Activity	$ 28,430,000	$ -	$ 2,000	$ 28,535,000	$ -
Commercial Annual Economic Activity	$ 5,713,000	$ -	$ -	$ 8,478,000	$ -
Critical Facilities (Fire, Police, Hospitals, Schools, Wastewater facilities)	1	0	0	1	0
Highways (miles)	7	0	0	7	0
Total Population	4140	0	2	4,139	0
Total Population (in socially vulnerable communities)	502	0	2	501	0
Total Population (Legacy Communities)	0	0	0	0	0

The one exposed facility is the Stockton Wastewater Treatment Plant Ponds on Middle and Upper Roberts Island, which is in an area identified as a socially vulnerable community. Exposed highways include 3.8 miles of CA-4 on Middle and Upper Roberts Island and 3.1 mi of I-5 on Mossdale.

Climate-change driven flood exposure is expected to increase the most along the San Joaquin River and its tributaries. Decades of investment in the North Delta (especially in the urban Sacramento area) has reduced the risk of flooding; this is reflected in the projected impacts of flooding in the underinvestment scenario.

Water Quality Metrics Results

Table 15: Percent change in electrical conductivity (EC) over baseline in a hotter/drier climate scenario

Region	Scenario 1 – Existing Land Use	Scenario 2 – Restoration Focus	Scenario 3
North Delta	0.0%	-0.1%	-0.1%
Central Delta	-2.1%	-2.2%	-2.5%
South Delta	-0.5%	-0.6%	-0.6%
Suisun Marsh	1.6%	1.6%	2.0%
Total	1.0%	1.0%	1.3%

X2 change compared to the baseline in a hotter/drier climate scenario:

- Scenario 1: X2 decreased by 0.12 km relative to the baseline (81.02 km) in 2060
- Scenario 2: X2 decreased by 0.13km relative to the baseline (81.02 km) in 2060
- Scenario 3: X2 decreased by 0.14 km relative to the baseline (81.02 km) in 2060

Comparisons of percent salinity change between the scenarios and baseline showed that salinity, in general, would decrease across the Delta, but would increase in Suisun Marsh. This trend holds true under future 2050 hydrology with a hotter/drier climate condition, a median climate condition, and a cooler than average and wetter climate condition. Salinity would decrease most in the central Delta and least in the north Delta. All three scenarios assume that Delta levees would be improved to keep pace with climate change. This means that, in the future, if any of these scenarios are in place, it would become easier to manage salinity in the Delta, but that is dependent on continued levee investments. Water quality in the Delta is managed through upstream reservoir releases. Lower salinity provides more flexibility for system operations.

Economics Metrics Results

Table 16: Jobs created as a result of levee improvements

		Levee Jobs				
		Spending	Direct Jobs	Indirect Jobs	Induced Jobs	Total Jobs
Scenario 1	North	$ 33,929,000	270	130	230	**640**
	Central	$ 594,384,000	4,820	2,260	4,100	**11,170**
	South	$ 2,563,872,000	20,770	9,740	17,690	**48,200**
	Suisun	$ 143,860,000	1,170	550	990	**2,700**
	Total	**$ 3,336,045,000**	**27,020**	**12,680**	**23,010**	**62,710**
Scenario 2	North	$ 33,929,000	270	130	230	**640**
	Central	$ 594,384,000	4,820	2,260	4,100	**11,170**
	South	$ 2,563,872,000	20,770	9,740	17,690	**48,200**
	Suisun	$ 96,552,000	780	370	670	**1,820**
	Total	**$ 3,288,737,000**	**26,630**	**12,500**	**22,690**	**61,830**
Scenario 3	North	$ 33,929,000	270	130	230	**640**
	Central	$ 552,102,000	4,470	2,100	3,810	**10,380**
	South	$ 2,563,872,000	20,770	9,740	17,690	**48,200**
	Suisun	$ 89,116,000	720	340	620	**1,680**
	Total	**$ 3,239,019,000**	**26,230**	**12,310**	**22,340**	**60,900**
Scenario 4	North	$ 20,003,000	160	80	140	**380**
	Central	$ 534,041,000	4,330	2,030	3,680	**10,040**
	South	$ 1,115,900,000	9,040	4,240	7,700	**20,980**
	Suisun	$ 132,468,000	1,070	500	910	**2,490**

	Total	**$ 1,802,412,000**	**14,600**	**6,850**	**12,430**	**33,890**

Table 17: Jobs created as a result of habitat restoration actions

		Habitat Restoration Jobs				
		Spending	**Direct Jobs**	**Indirect Jobs**	**Induced Jobs**	**Total Jobs**
Scenario 1	North	$ 68,590,000	910	230	440	**1,580**
	Central	$ 102,001,000	1,350	350	650	**2,350**
	South	$ 20,159,000	270	70	130	**460**
	Suisun	$ 55,813,000	740	190	360	**1,280**
	Total	**$ 246,563,000**	**3,270**	**840**	**1,580**	**5,670**
Scenario 2	North	$ 132,475,000	1,750	450	850	**3,050**
	Central	$ 165,147,00	2,180	560	1,060	**3,800**
	South	$ 45,861,000	610	160	290	**1,050**
	Suisun	$ 81,628,000	1,080	280	520	**1,880**
	Total	**$ 425,111,000**	**5,620**	**1,450**	**2,720**	**9,780**
Scenario 3	North	$ 116,242,000	1,530	400	740	**2,670**
	Central	$ 151,773,000	2,000	520	970	**3,490**
	South	$ 18,452,000	240	60	120	**420**
	Suisun	$ 101,661,000	1,340	350	650	**2,340**
	Total	**$ 388,128,000**	**5,120**	**1,330**	**2,480**	**8,920**
Scenario 4	North	$ 80,358,000	1,060	270	510	**1,850**
	Central	$ 107,151,000	1,410	360	690	**2,460**
	South	$ 49,353,000	650	170	320	**1,140**
	Suisun	$ 68,938,000	910	230	440	**1,590**
	Total	**$ 305,800,000**	**4,040**	**1,040**	**1,960**	**7,040**

Results Discussion

Scenario 1 results in the most direct jobs created due to levee improvements (27,020) jobs), followed by Scenario 2 (26,630), Scenario 3 (26,230), and Scenario 4 (14,600) (**Table 16**). Scenario 2 results in the most direct jobs created due to habitat restoration (5,620 jobs), followed by Scenario 3 (5,120), Scenario 4 (4,040), and Scenario 1 (3,270) (**Table 17**). This means that, for total jobs resulting from levee improvement and habitat restoration actions, Scenario 2 results in the most direct jobs (32,250 jobs), followed by Scenario 3 (31,340 jobs), followed by Scenario 1 (30,290 jobs), and Scenario 4 (18,630 jobs).

Equity Metrics Results

Water Quality:

Change in salinity (compared to the baseline) at locations adjacent to Legacy Communities and drinking water wells on the SAFER list (systems that are failing or at risk of failing human right to water standards): As with salinity change for all locations modeled, Scenarios 1, 2 and 3 show decreased salinity across the Delta and increased salinity in Suisun Marsh at locations adjacent to Legacy Communities and SAFER drinking water wells, under all climate conditions modeled. Salinity decreases the most in the central Delta and least in the north Delta.

Flood exposure (for Scenario 4: Levee Underinvestment):

Population and critical facilities in socially vulnerable communities exposed to flooding: One exposed facility in the South Delta, the Stockton Wastewater Treatment Ponds on Middle and Upper Roberts Island, is located in a socially vulnerable community. Of the total population exposed to flooding in Scenario 4 (4,140 people), almost all of the exposed population resides in the South Delta region. Similarly, of the total population in socially vulnerable communities exposed to flooding, almost all are located in the South Delta region. Of the total population exposed to flooding, about 12% live in areas identified as socially vulnerable communities.

Ecosystem:

Total extent and net change in habitat types in socially vulnerable communities: Scenario 2 includes the largest area of habitat (landcover types excluding open water, urban/barren, and agriculture areas) in socially vulnerable communities (59,404 acres acres), followed by Scenario 3 (54,925 acres), Scenario 4 (48,624 acres) and Scenario 1 (47,432 acres). Larger areas of green space, such as from restoration, has been shown to provide benefits to nearby communities.

Agriculture:

Percent change in number of jobs (compared to baseline) due to reduction in agriculture: Scenario 2 results in the largest reduction of agricultural jobs in the Delta due to reduced agriculture (26% reduction), followed closely by Scenario 3 (25%), then Scenario 4 (19%), and Scenario 1 (9%).

Overall Results Discussion

A set of resilience goals were endorsed by the Council in 2019 to guide the Delta Adapts initiative. The Adaptation Plan will identify strategies that respond to the climate vulnerabilities identified in the Vulnerability Assessment, consistent with the following resilience goals:

Water

- Promote statewide water conservation, water use efficiency, and sustainable water use (Water Code 85020(d)).
- Improve water quality to protect human health and the environment consistent with achieving water quality objectives in the Delta (Water Code 85020(e)).
- Improve the water conveyance system and expand statewide water storage (Water Code 85020(f)).

Environment

- Restore the Delta ecosystem, including its fisheries and wildlife, as the heart of a healthy estuary and wetland ecosystem (Water Code 85020(c)).
- Restore critical physical and biological processes; connectivity; complexity and diversity; redundancy; at large scales with a long-time horizon in mind.

Society and Equity

- Protect and enhance the unique cultural, recreational, and agricultural values of the California Delta as an evolving place (Water Code 85020(b)).
- Reduce risks to people, property, and state interests in the Delta by effective emergency preparedness, appropriate land uses, and investments in flood protection (Water Code 85020(g)).
- Increase the resilience of Delta communities, especially those with characteristics that make them more vulnerable to climate risk due to physical (built and environmental), social, political, and/or economic factors. These factors include, but are not limited to, race, class, sexual orientation and identification, national origin, and income inequality (OPR 2018).
- Prioritize actions that protect the most vulnerable populations (EO B-30-15).

Economy

- Maintain and improve local economic vitality and access to diverse employment opportunities by preserving and growing, where appropriate, key economic and employment drivers and associated infrastructure that support the Delta economy and communities.
- Promote the development of urban growth strategies that reduce climate risks by focusing new development in more resilient areas, enhancing the Delta ecosystem, and supporting resilient farming and recreation activities.
- Improve and enhance the resilience of the Delta transportation network while supporting the achievement of regional and statewide greenhouse gas reduction targets.

Governance

- Foster collaboration and build capacity among federal, state, and local agencies, non-governmental and private organizations, and communities in the Delta.
- Commit to working cooperatively to identify and mitigate climate change impacts and risks.
- Improve coordination among regulatory agencies to reduce program or legal barriers to addressing current and future flood, drought, wildfire, and other risks that will be exacerbated by climate change.
- Incorporate climate change into state and local Delta planning and investment decisions (EO B-30-15).
- Prioritize actions that incorporate natural and green infrastructure solutions (EO B-30-15).
- Define the Council's role in coordinating adaptation responses in the Delta.

Benefits and tradeoffs of Scenarios 1 through 4 are discussed in the context of how the metric results are consistent with the resilience goals.

Scenario 1: Climate smart agriculture-focused

This scenario focuses on continuing existing private land uses in the Delta, which are primarily agriculture-related, with land use changes that support restoration/multi-benefit projects occurring on public lands where suitable. This scenario primarily supports the resilience goals for society and equity (particularly the goal to protect agricultural values and communities benefitting from agriculture), improving the water conveyance system of the Delta channels through levee improvements, and the economy as it pertains to agriculture, while enhancing the Delta transportation network. This scenario has the smallest decrease in revenue, GDP, and jobs within the agricultural sector. This scenario also protects water supply by preventing salinity intrusion.

However, this scenario features the least amount of habitat throughout the study area, the least amount of habitat areas in socially vulnerable communities, and does not particularly support the goal to increase resilience of Delta communities. The levee investment costs to maintain existing land uses on private lands is the highest among the four scenarios, while the restoration cost (because restoration occurs only on public lands) is the lowest.

The DSM2 model has been utilized to simulate salinity levels in the Delta and Suisun Marsh for this scenario. The model results indicate that salinity potentially increases in Suisun Marsh and only slightly in certain areas of the Delta when compared to the baseline. However, overall, salinity decreases in the Delta. It is important to note that salinity in the Delta is actively managed through water releases from upstream reservoirs. ThisA management approach ensures that as long as there is a sufficient water supply, the small increases in salinity can be effectively controlled.

This scenario supports water and economic goals, but limiting subsidence reversal strategies and restoration actions to private lands limits the amount of restoration that can happen across the region, particularly related to tidal wetland targets. This scenario has the second-lowest amount of subsidence reversal activities of the four scenarios, which would have flood risk, GHG emissions, and other consequences for the region, and continued subsidence on farmed lands could threaten levee integrity. This scenario also results in the highest GHG emissions of all four scenarios (however, GHG emissions in this scenario are still lower than the current baseline). Implementing climate-smart agricultural practices related to irrigation, planting changes, and crop switching can support the water and environment resilience goals, and may support the economic goals of changing actions to be more profitable in a changing climate.

Scenario 2: Restoration-focused

This scenario focuses on meeting restoration targets and corresponding habitat types identified in the Delta Plan, prioritizing restoration on suitable public land first, while protecting people, property, habitat, critical transportation corridors, small communities, and water supply reliability. This scenario primarily supports resilience goals for water supply reliability, the economy, and the environment as restoration efforts aim to meet targets by habitat type, and siting would depend on factors that would improve water supply or water quality, provide community benefits, and improve habitat connectivity. This scenario has the largest amount of habitat area overall and the largest amount of habitat areas in socially vulnerable communities, which supports the equity-related resilience goal as restoration projects provide indirect benefits to neighboring communities including improved air and water quality, visual reprieve from the urban landscape, access to recreational and cultural resources, and other ecosystem services. As part of this scenario and Scenario 3, significantly more acres of rice would be planted than in Scenarios 1 and 4, which supports halting subsidence and provides GHG emission reduction benefits.

This scenario has the lowest GHG emissions per year given the changes in land use. Depending on the restoration location, the scenario can also support society and equity and economy resilience goals; however, the estimated cost of restoration is the highest in this scenario, and the large conversion to rice associated with this scenario would significantly impact agricultural jobs in the Central Delta, decreasing by 38% (the highest impact to agricultural jobs of all four scenarios) as rice is more mechanized than other crops. However, this scenario results in the second-highest number of jobs created due to levee improvement and habitat restoration actions (almost the same number of jobs as Scenario 3).

A reduced agricultural economy is likely to lead to broader shifts in local economies and communities currently employed in the agricultural sector. In addition, a reduction in economic activity on lands converted from agriculture leads to reduced assessments that aren't sufficient to comprise the local cost share required to operate and maintain Delta levees.

Similar to Scenario 2, the DSM2 model has been employed to assess salinity levels in the Delta and Suisun Marsh. The model results indicate that salinity potentially increases in Suisun Marsh and only slightly in certain areas of the Delta when compared to the baseline. However, overall, salinity levels tend to decrease in the Delta. Additionally, when comparing this scenario to an agriculture-focused scenario, the results suggest slightly decreased salinity levels in the Delta. Salinity management in the Delta relies on the controlled release of water from upstream reservoirs. This approach ensures that as long as there is an adequate water supply, the small increases in salinity observed can be effectively managed.

Scenario 3: Less Delta Restoration

This scenario focuses on meeting the total restoration targets set in the Delta Plan while minimizing impacts to prime farmland by directing more restoration to the Suisun Marsh. Like Scenario 2, this scenario primarily supports resilience goals for the environment and water supply, and secondarily supports goals for society, equity and economy depending on how and where restoration happens.

This scenario has the largest area of connected wetlands and the highest percentage of subsided lands covered by wetted habitat types (meaning the largest amount of subsidence halting or reversal actions). Addressing subsidence at this scale will have a larger impact across the region. Again, the additional acres of rice planted come with an associated cost (decreasing agricultural jobs by 39% in the Central Delta) but provide significantly more GHG reduction benefits than Scenarios 1 and 4. This scenario results in the largest number of direct jobs created from levee improvements and habitat restoration actions.

Similar to Scenario 2, a reduced agricultural economy is likely to lead to broader shifts in local economies and communities currently employed in the agricultural sector. In addition, a reduction in economic activity on lands converted from agriculture leads to reduced assessments that aren't sufficient to comprise the local cost share required to operate and maintain Delta levees. The DSM2 model results, when compared to the baseline scenario, indicate that salinity levels generally increase in Suisun Marsh and slightly in certain areas of the Delta. However, overall, salinity tends to decrease in the Delta. When comparing this scenario to an agriculture-focused scenario (Scenario 1) and an ecosystem-focused scenario (Scenario 2), the results demonstrate that this scenario yields the greatest decreases in salinity levels in the Delta. However, it should be noted that these decreases in salinity come at the expense of increased salinity in Suisun Marsh. Salinity management in the Delta relies on the controlled release of water from upstream reservoirs. With sufficient water availability, the small increases in salinity observed can be effectively managed.

Scenario 4: Levee Underinvestment

This scenario considers lower levels of flood protection in some areas assuming less funding for flood risk reduction is available. Investments would prioritize critical water infrastructure which supports components of the water and society and equity resilience goals.

However, the underinvestment in levees in this scenario, which has a much lower levee improvement cost than Scenarios 1 through 3, mean that some levees wouldn't be improved. This in turn would result in exposure to flooding for approximately 14 islands and over 4,000 people, a portion of a State highway, and a water treatment plant. Of the total population exposed to flooding, almost all are in the South Delta region and 12% live in areas identified as socially vulnerable communities. These islands represent the areas in the region that have the lowest benefit-cost ratio of improvement costs to resulting flood protection benefits of assets with lower values. Due to the lower amount of levee investments in this scenario, total jobs resulting from levee improvements and habitat restoration actions are the lowest across all four scenarios.

Because climate impacts are expected to be the greatest in the South Delta, the cost to protect the same assets here as compared to other parts of the Delta are higher. In terms of agricultural economic impact, the largest impact would be felt in the South Delta.

This scenario has the least amount of subsidence reversal activities across all four scenarios, which would have flood risk, GHG emissions, and other consequences for the region. This scenario includes the least area of connected wetlands.

These results do not support the resilience goals for society and equity that aim to prioritize actions that protect vulnerable populations, reduce flood risk to people, or increase resilience of Delta communities. The impacts to a major highway are not in support of the economy goals to improve and enhance the region's transportation network.

The results of this scenario illustrate an example of some of the challenges with adaptation. These challenges would force some really hard decisions about which levees are improved to provide acceptable protection under climate change conditions, and which levees are not. Scenario 4 results show that underinvesting in Delta levees results in lower benefits and higher overall losses and costs to remediate assets, and that investing in Delta levees is a cost-effective adaptation strategy.

It should be noted that salinity modeling was not conducted for this scenario because the scenario involved no future funding for levee improvements on a small number of islands in the southeast corner of the Delta and in the Suisun Marsh. These islands were either small or located far enough away to have a negligible impact on salinity levels. Previous studies conducted by the Department of Water Resources (DWR) and other organizations have confirmed that these specific areas are not particularly sensitive to salinity changes in the Sacramento-San Joaquin Delta. Based on this existing knowledge, there was no need to model salinity for these islands under this scenario.