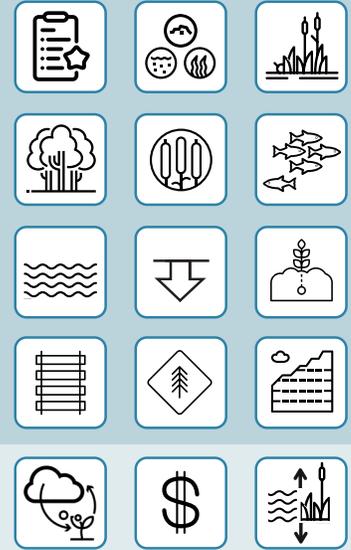
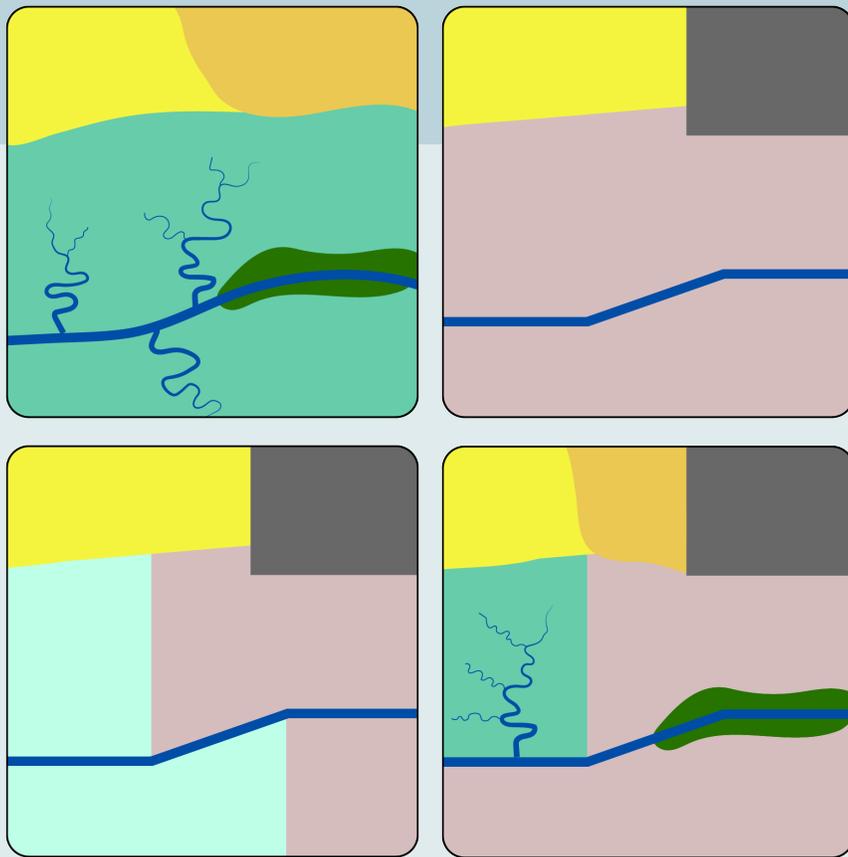


# LANDSCAPE SCENARIO PLANNING TOOL

## User Guide



## **SUGGESTED CITATION**

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## **VERSION**

v. 2.1.1 (October 2022)

## **REPORT AVAILABILITY**

The Landscape Scenario Planning tool and this user guide are available online at [www.sfei.org](http://www.sfei.org).

## **IMAGE PERMISSION**

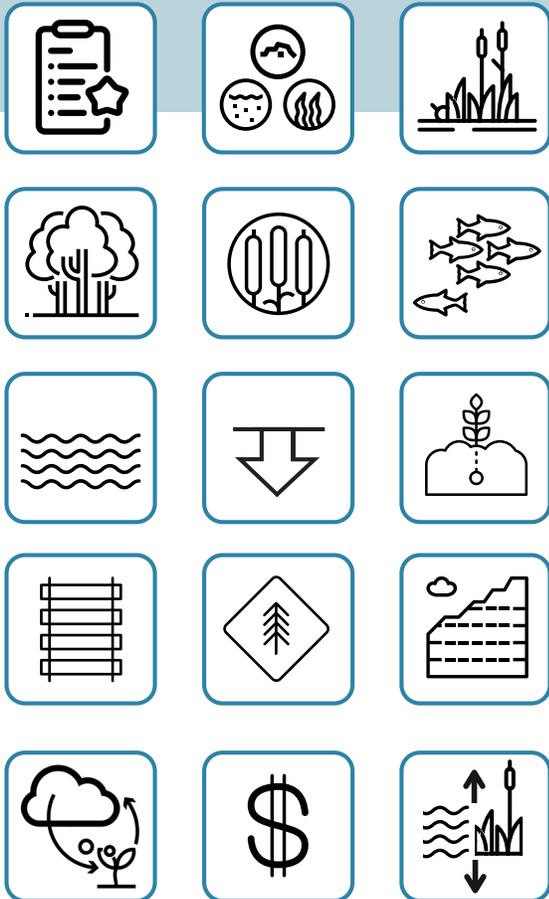
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# LANDSCAPE SCENARIO PLANNING TOOL

## User Guide



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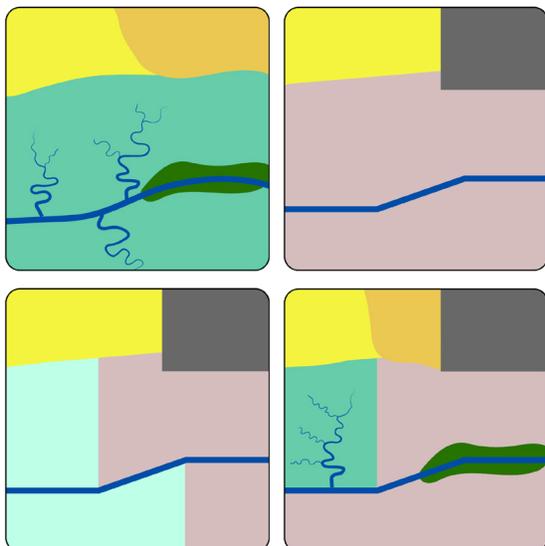
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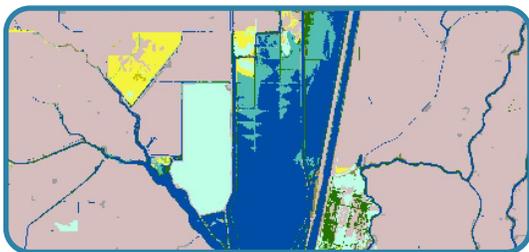
# SUMMARY

# LANDSCAPE SCENARIO PLANNING TOOL

A standardized, science-based tool for analyzing and comparing land-use scenarios.

## How the tool works

- The tool takes data from **detailed landscape maps** to measure change in metrics of interest for Delta planners:
  - ecosystem function (like support for native fish)
  - landscape processes (like flooding & subsidence)
  - infrastructure
  - agriculture



## Users can:

- Use packaged data sets & maps to build scenarios of future landscape change
- Compare how each scenario impacts key ecosystem functions, crop lands, and infrastructure
- Integrate results from multiple models
- Take advantage of science-based metrics in the planning process

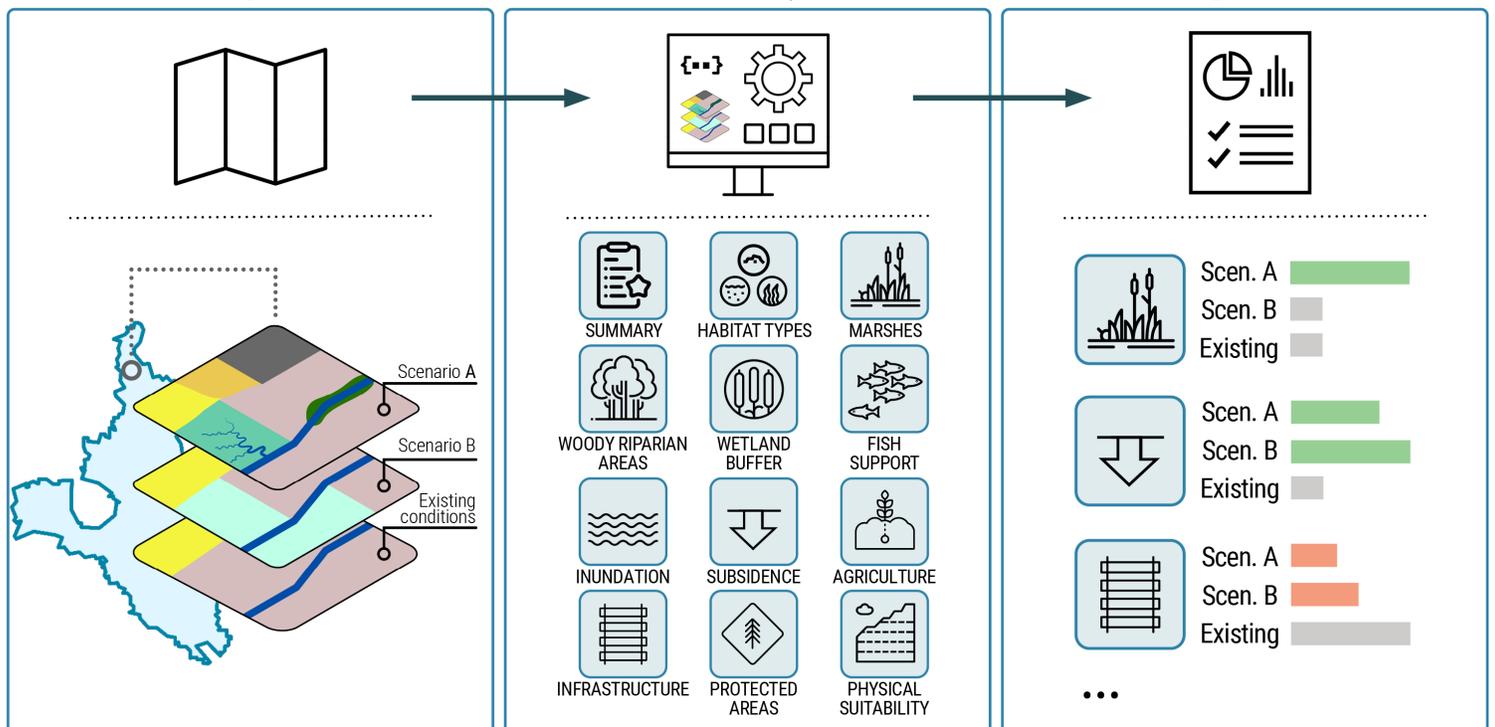
## Helping decision makers to:

- Identify preferred alternatives for funding or implementation
- Quantify tradeoffs between scenarios
- Track cumulative progress toward performance measures
- Plan for long-term change, like sea-level rise and subsidence reversal

Alternative land-use scenarios are input into the tool

The tool evaluates scenarios with analysis modules

The tool outputs detailed report & data files



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# Tool Overview

## Version

This user guide was written for version 2.1.1 of the tool. For the latest version of the tool and user guide, visit the project website ([www.sfei.org/projects/landscape-scenario-planning-tool](http://www.sfei.org/projects/landscape-scenario-planning-tool)).

## What is the Landscape Scenario Planning Tool?

The Landscapes Scenario Planning Tool (LSPT) is a standardized, science-based resource for analyzing and comparing land-use scenarios in the Sacramento-San Joaquin Delta and Suisun Marsh. The tool takes data from detailed landscape maps and calculates metrics related to ecosystem function (like support for native fish), landscape processes (like flooding and subsidence), infrastructure, and agriculture, along with other key topics relevant to restoration and land-use planning in the region.

The tool is modular by design, and currently supports 14 individual modules, each with a suite of analyses and metrics. The modular design means that new and additional analyses can be added to the tool over time (including, for example, metrics related to water supply, flood control, and recreation). The tool is also spatially flexible, allowing users to analyze the landscape at multiple scales. For example, it can quantify how a single proposed project would alter metrics in its immediate surroundings, or how a larger regional strategy comprising many individual projects would cumulatively impact the region.

To assist with the process of scenario development (the creation and digitization of alternative restoration and land use scenarios), the tool comes packaged with several useful resources. These include standardized spatial datasets that can inform the development of science-based restoration scenarios, such as maps of elevation and historical and contemporary habitat types. Another set of resources are spatially explicit maps of restoration opportunities and landscape potential, based on SFEI's "A Delta Renewed" (SFEI-ASC 2016), which serve as a pre-developed menu of physically-appropriate potential projects for users developing their own alternative land-use scenarios. These resources have also been made available via a project web-map available through the project website for use outside of the tool.

## Who is the tool for and how can it be used?

The tool can help land-use planners, agency staff, and other stakeholders and decision-makers in a number of ways.

- 1) By quickly evaluating key metrics in a repeatable and standardized way, the tool can help people designing potential projects to anticipate how those projects will affect a suite of metrics, including performance measures tracked under the Delta Plan.
- 2) For those evaluating proposed projects, the tool can assist with identifying preferred alternatives for funding or implementation.
- 3) For regional planning, the LSPT makes it easier to quantify the cumulative impacts of multiple potential projects and understand tradeoffs.
- 4) As projects are implemented and the landscape develops, the tool can be used to track on the ground progress by comparing past land-use with current land-use. The tool can also be used to plan for long-term change, like sea-level rise and subsidence reversal, by evaluating anticipated landscape changes associated with those processes.
- 5) The tool can be a vehicle for operationalizing the work of researchers. Specifically, models and analyses meant to inform restoration and land-use planning can be integrated into the tool, where they can leverage results from other analyses and directly inform practitioners.

## **Tool licensing**

This project is licensed under the GNU Lesser General Public License -- see the "License" file for details or the GNU website (<https://www.gnu.org/licenses/gpl-3.0.en.html>) for general information. In summary, you may copy this software, modify this software with changes tracked, and redistribute this software or derivative versions thereof as long as they remain under the GNU Lesser General Public License.

## **Tool format and installation**

The Landscapes Scenario Planning Tool is an ArcPy Toolbox designed for ArcGIS Pro (version 3.0 or greater) and Python 3.7 with ArcPy (installed with ArcGIS). Python libraries used are either packaged by default with Python or pre-installed with ArcGIS/ArcPy (e.g. NumPy).

The LSPT is meant to work out-of-the-box and no specific installation process is required aside from downloading and unzipping the tool contents. The ArcPy Toolbox can be downloaded by navigating to the project website ([www.sfei.org/projects/landscape-scenario-planning-tool](http://www.sfei.org/projects/landscape-scenario-planning-tool)), clicking the "Resources" tab, and clicking the "Download tool" button, which will open a form to receive the tool download link via email. The zipped folder containing the tool should be unzipped in the user's preferred directory, and then navigated to within ArcGIS. See "Tool Workflow" for additional instructions.

The [advanced license of ArcGIS](#) is required for several of the ArcPy tools utilized, such as the [Erase](#) and [Aggregate Polygons](#). Some workarounds have been built-in to circumvent these issues where alternative processes were possible, but it cannot be guaranteed that the full LSPT tool will run without the advanced

license. Because of the raster analyses performed, certain modules (fish support, inundation, subsidence, and carbon) also require the Spatial Analyst extension.

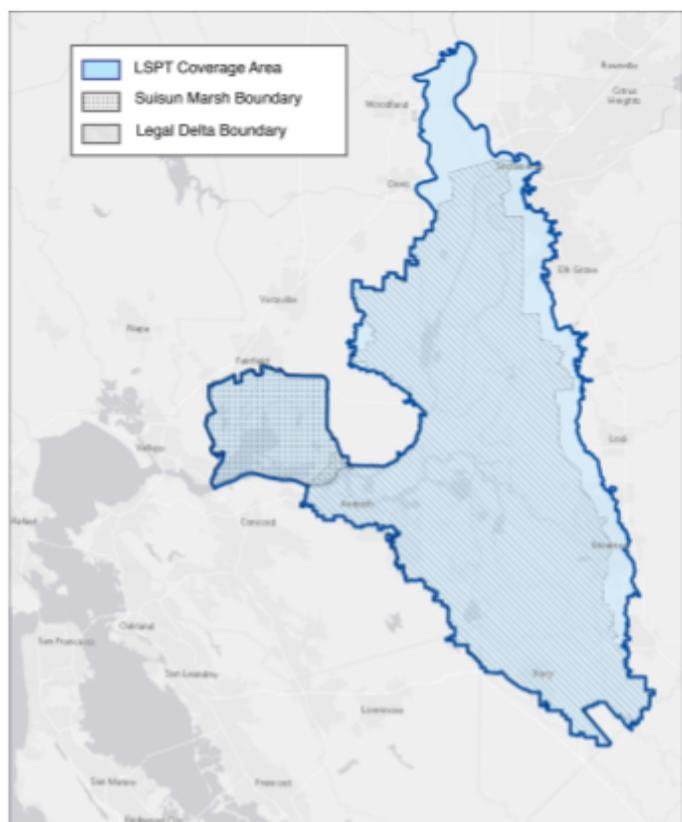
## Hardware and storage requirements

Being an ArcPro Toolbox, the LSPT naturally mirrors the hardware requirements for ArcGIS Pro with a minimum requirement of a multi-core CPU with 8 GB of memory/RAM and further recommending a 4-core CPU with 16 GB of RAM. The LSPT runs analyses on the full tool coverage area (see next section: [Tool coverage and analysis areas](#)), which for certain analyses can become computationally intensive. **In particular, the [Marsh Network Connectivity](#) module may take several hours to complete, and the [Carbon and greenhouse gas emissions](#) module will utilize a heavy memory load.** As such, it is recommended to run these specific modules overnight or during some other idle/low-use period, and for the Carbon module, the hardware requirements are upped to a minimum recommended 16 GB of RAM and preferably more. If using the minimum 16 GB memory capacity, ensure ample memory is available during tool runs, and not competing with other memory-intensive programs.

The disk space required for each workspace varies by the analyses run and the number of user scenarios. Likewise, the workspace size may balloon up during processing with intermediary outputs and other temporary layers. When completed, workspaces with three scenarios (historical, modern, and one user scenario) take up roughly 2 GB of space with every analysis run except the carbon module and 14 GB of space with the carbon module. Additional user scenarios will increase storage requirements roughly proportionally to the number of scenarios and, with the carbon module in particular, 1-5 GB or more of head space may be temporarily used during active processing. Outputs from the [Output Statistic tool](#) may require a similar amount of space as the workspace, particularly if using the maximum extent for the analysis area.

## Tool coverage and analysis areas

There are two relevant spatial domains when using the LSPT: the maximum tool “coverage area” and the user-defined “analysis area/s.” The maximum tool coverage area represents the geography supported by the tool. It is the area within which users can define scenarios that the tool is able to evaluate. The current coverage area of the tool (Figure 1) is a combination of three previously defined extents in the region: the SFEI Delta

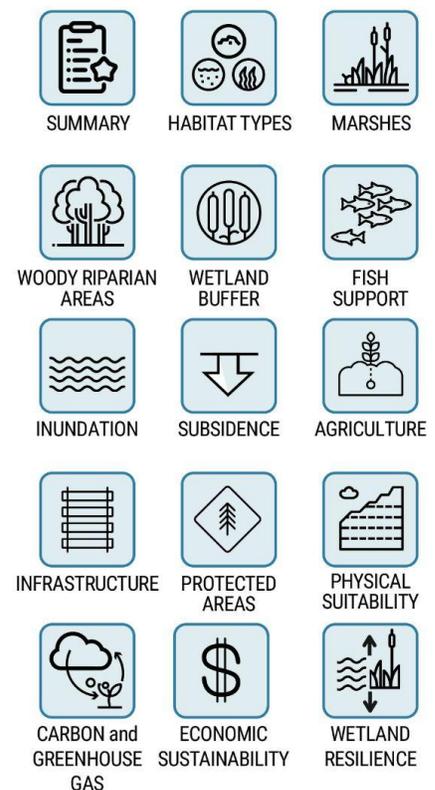


Landscapes study extent (Whipple et al. 2012) and the extents of the legal Delta and Suisun Marsh as defined in the Delta Plan (DSC 2013). The SFEI Delta Landscapes study extent was defined by Whipple et al. (2012) as the contiguous lands in the Delta lying below the 25 ft (7.6 m) NAVD88 contour. This area is meant to capture the full extent of the Delta’s historical tidal wetlands, adjacent non-tidal freshwater wetlands, and upland transitional areas. The study area was generally defined as “the contiguous lands lying below 25 feet (7.6 m) in elevation.” This differs from the extent of the legal Delta and encompasses an area of about 800,000 acres, including parts of Sacramento, Yolo, Solano, Contra Costa, and San Joaquin counties. The Delta Plan (DSC 2013), is a legally enforceable management plan for achieving coequal goals mandated by the state legislature to provide a more reliable water supply and protect, restore, and enhance the Delta ecosystem. The Delta Plan covers the extent of the legal Delta and Suisun Marsh (see Figure 1).

**When a user runs the LSPT, the impacts of their scenario(s) are evaluated over the entire tool coverage area, no matter how small or constrained the modifications in the scenario might be. After these results have been processed, the user can then define a specific “analysis area” to clip and summarize the tool results to.** This analysis area can be any geography within the coverage area, ranging from a project footprint to the full coverage area itself. With this framework, the effects of one scenario can easily be examined across multiple analysis areas and scales. The tool comes pre-packaged with a variety of potential analysis areas that users can select (including the portions of individual counties, the legal Delta, and Suisun Marsh that lie within the coverage area), but users can also supply custom analysis areas. See the “Output Statistics” section below for how users set the analysis area.

## Tool modules

The LSPT is modular by design, and currently supports 14 individual modules, each with a suite of analyses and metrics (Table 1). Users can choose to only run individual tool modules, or to run all in concert. The table below lists the modules and provides basic information on each, along with a summary of the needed data inputs. Modules that quantify a Delta Plan performance measure are also noted. Each module is described in more detail in the “Analysis Module” section below.



**Table 1.** Landscape Scenario Planning Tool analysis modules and description of analyses and inputs.

Module	Primary analyses	User-defined data inputs	Key pre-defined data inputs
Summary 	<ul style="list-style-type: none"> <li>Compiles results from all other modules and presents them in a single <b>integrated table</b>, facilitating comparison of scenarios</li> <li>Performs other basic assessments (e.g., total extent of the analysis area and the counties it overlaps)</li> </ul>	<ul style="list-style-type: none"> <li>Scenario land use modifications</li> <li>Scenario levee centerlines (optional)</li> </ul>	<ul style="list-style-type: none"> <li>County boundaries</li> </ul>
Habitat types 	<ul style="list-style-type: none"> <li>Determines <b>total extent and net change of each habitat type</b></li> <li>Evaluates <b>progress towards Delta Plan performance measure acreage targets</b></li> </ul>	<ul style="list-style-type: none"> <li>Scenario land use modifications</li> </ul>	<ul style="list-style-type: none"> <li>Historical habitat types (Whipple et al., 2012)</li> <li>Modern habitat types (SFEI-ASC 2014)</li> </ul>
Marshes 	Analyzes metrics related landscape ecology of marshes, including: <ul style="list-style-type: none"> <li><b>Marsh extent</b></li> <li><b>Marsh patch sizes</b></li> <li><b>Marsh nearest large neighbor distance</b></li> <li><b>Marsh shape</b> (core area ratio)</li> </ul>	<ul style="list-style-type: none"> <li>Scenario land use modifications</li> </ul>	<ul style="list-style-type: none"> <li>Historical habitat types (Whipple et al., 2012)</li> <li>Modern habitat types (SFEI-ASC 2014)</li> <li></li> </ul>
Marsh network connectivity 	Analyzes <b>marsh network connectivity</b> , including where new/additional marshes would most improve connectivity (results are presented with Marshes in output report, but split into two modules in the tool due to computation time)	<ul style="list-style-type: none"> <li>Scenario land use modifications</li> </ul>	<ul style="list-style-type: none"> <li>100 ha hex-grid (defines grid where each unit is analyzed for potential contribution to network connectivity)</li> </ul>
Woody riparian area 	Analyzes metrics related landscape ecology of woody riparian areas, including: <ul style="list-style-type: none"> <li><b>Woody riparian extent</b></li> <li><b>Woody riparian patch sizes</b></li> </ul>	<ul style="list-style-type: none"> <li>Scenario land use modifications</li> </ul>	<ul style="list-style-type: none"> <li>Historical habitat types (Whipple et al. 2012)</li> <li>Modern habitat types (SFEI-ASC 2014)</li> </ul>
Wetland buffer 	Analyzes metrics related to the wetland buffer (the area around open water and perennial wetlands), including: <ul style="list-style-type: none"> <li><b>Wetland buffer extent</b></li> <li><b>Wetland buffer composition</b> (natural vs. highly modified habitat types)</li> </ul>	<ul style="list-style-type: none"> <li>Scenario land use modifications</li> </ul>	<ul style="list-style-type: none"> <li>Historical habitat types (Whipple et al. 2012)</li> <li>Modern habitat types (SFEI-ASC 2014)</li> </ul>
Fish support 	Analyzes metrics related to support for native fish, including: <ul style="list-style-type: none"> <li><b>Marsh area and marsh to open water ratio</b></li> <li><b>Connectivity of large wetlands</b> along fish migration corridors</li> <li>The extent and quality of <b>channel edges</b></li> <li><b>Water temperature</b></li> </ul>	<ul style="list-style-type: none"> <li>Scenario land use modifications</li> <li>Scenario levee centerlines (optional)</li> </ul>	<ul style="list-style-type: none"> <li>Historical habitat types (Whipple et al. 2012)</li> <li>Modern habitat types (SFEI-ASC 2014)</li> <li>Water temperature rasters (3 different</li> </ul>

			rasters quantifying the number of days each cell is above a particular temperature threshold during a specified window of time) (Anchor QEA, LLC 2017)
<p>Inundation</p> 	<ul style="list-style-type: none"> <li>Analyzes <b>baseline inundation conditions</b> using <b>Delta Plan performance measure</b> methods (including the extent of hydrologically connected and regularly inundated areas)</li> <li>Evaluates how <b>scenario changes</b> in area of tidal marsh affect extent of inundation</li> </ul>	<ul style="list-style-type: none"> <li>Scenario land use modifications</li> </ul>	<ul style="list-style-type: none"> <li>Modern habitat types</li> <li>Hydrologically connected areas (DSC 2019)</li> <li>Regularly inundated areas (Pekel et al. 2016)</li> </ul>
<p>Subsidence</p> 	<ul style="list-style-type: none"> <li>Quantifies <b>extent of shallowly and deeply subsided lands</b> in analysis area</li> <li>Quantifies proportion of subsided lands covered by <b>wetted habitat types</b> (which limit subsidence)</li> <li>Estimates years for wetlands in subsided areas to reach sea level via <b>subsidence reversal</b>, considering sea-level rise</li> </ul>	<ul style="list-style-type: none"> <li>Scenario land use modifications</li> </ul>	<ul style="list-style-type: none"> <li>Geomorphic zones</li> <li>Years for subsidence reversal wetlands to reach sea level (Deverel and Leighton 2010)</li> </ul>
<p>Agriculture</p> 	<p>Quantifies basic metrics of scenario's impacts to agriculture, including:</p> <ul style="list-style-type: none"> <li>Net change in extent of agricultural lands</li> <li>Crop type of converted agricultural lands</li> <li>Area converted from agricultural lands to urban development (<b>Delta Plan performance measure</b>)</li> </ul>	<ul style="list-style-type: none"> <li>Scenario land use modifications</li> </ul>	<ul style="list-style-type: none"> <li>Land IQ Delta Crop Types (CDWR and LandIQ LLC 2020)</li> <li>FMMP farmland grade (California Department of Conservation 2018)</li> </ul>
<p>Economics</p> 	<p>Estimates the scenario's impact on gross agricultural revenue and identifies unquantified costs and benefits associated with land use conversions.</p>	<ul style="list-style-type: none"> <li>Scenario land use modifications</li> </ul>	<ul style="list-style-type: none"> <li>Land IQ Delta Crop Types (CDWR and LandIQ LLC 2020)</li> </ul>
<p>Infrastructure</p> 	<p>Quantifies the <b>extent of infrastructure</b> in the analysis area and <b>potential impacts</b> to infrastructure due to proposed changes in land-use. Infrastructure types evaluated include:</p> <ul style="list-style-type: none"> <li>Roads</li> <li>Railroads</li> <li>Oil and gas wells</li> <li>Gas pipelines</li> <li>Transmission lines</li> <li>Water diversions</li> <li>Levees</li> </ul>	<ul style="list-style-type: none"> <li>Scenario land use modifications</li> <li>Scenario levee centerlines (optional)</li> </ul>	<ul style="list-style-type: none"> <li>Roads (U.S. Census Bureau 2020)</li> <li>Rails (CalTrans Rail Database 2021)</li> <li>Oil and gas wells (California Department of Conservation 2021)</li> <li>Gas pipelines (California Energy Commission)</li> <li>Transmission lines (California Energy Commission 2021)</li> <li>Water diversions</li> </ul>

			(CDFW 2019)
<p>Protected areas</p> 	<p>Identifies the <b>extent and ownership of protected areas</b> within the analysis area and determines whether proposed land use modifications fall within the boundaries of these areas</p>	<ul style="list-style-type: none"> <li>• Scenario land use modifications</li> </ul>	<ul style="list-style-type: none"> <li>• Modern habitat types (SFEI-ASC 2014)</li> <li>• CA Protected Areas Database (GreenInfo Network 2020a)</li> <li>• CA Conservation Easements Database (GreenInfo Network 2020b)</li> </ul>
<p>Physical suitability</p> 	<p>Performs basic screening to identify whether or not proposed habitat types are likely to be <b>physically suitable</b> in the location they were drawn, given the location's elevation</p>	<ul style="list-style-type: none"> <li>• Scenario land use modifications</li> </ul>	<ul style="list-style-type: none"> <li>• Geomorphic zones</li> <li>• Habitat type-geomorphic zone suitability crosswalk (SFEI 2020)</li> </ul>
<p>Carbon and greenhouse gas emissions</p> 	<p>Quantifies basic metrics of scenario's impacts to carbon storage and greenhouse gas emissions, including:</p> <ul style="list-style-type: none"> <li>• Simulates elevation changes due to <b>accretion and subsidence</b> over 40-years</li> <li>• Estimates changes to <b>peat volume and peat carbon storage</b></li> <li>• Simulates annual and 40-year cumulative <b>greenhouse gas emissions and reductions</b> relative to a baseline scenario</li> <li>• Quantifies <b>potential carbon market revenue</b> from emissions reductions</li> </ul>	<ul style="list-style-type: none"> <li>• Scenario land use modifications</li> </ul>	<ul style="list-style-type: none"> <li>• Geomorphic zones</li> <li>• Elevation relative to mean tide level</li> <li>• Sea level rise (OPC 2018)</li> <li>• Historical and modern peat thickness (Deverel et al., 2010)</li> <li>• Historical and modern carbon storage</li> <li>• CWEM model outputs (Morris et al., 2021)</li> <li>• SEDCALC model outputs (Deverel et al., 2014)</li> <li>• SUBCALC models outputs (Deverel et al., 2016)</li> <li>• Organic-soil rice N<sub>2</sub>O emissions (Ye et al., 2016)</li> </ul>

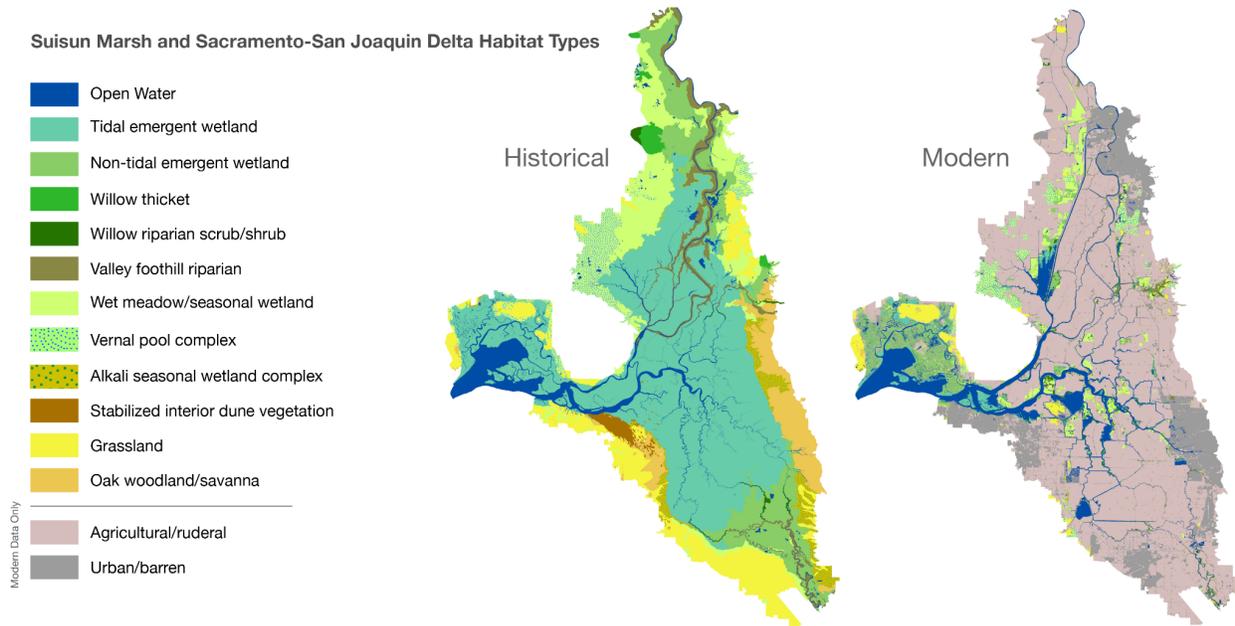
## Habitat types

The LSPT recognizes a standard set of 13 individual habitat types and a binary tidal classification when analyzing land use scenarios (Table 2). This classification scheme was originally developed for the SFEI "Sacramento-San Joaquin Delta Historical Ecology Investigation" (Whipple et al. 2012) to map the historical and modern landscape using a consistent set of land use types, and was refined in subsequent reports (SFEI-ASC 2014). Crosswalks relating these classifications to other schema, including the National Vegetation Classification System (NVCS), California Wildlife Habitat Relationships (CWHR),

Hydrogeomorphic Wetland Classification System (HGM), and the Cowardin wetland classification, are available (see Whipple et al. 2012). The classification system is also consistent with that used in the Delta Plan (DSC 2019). The tool is packaged with spatial layers mapping the historical and modern landscape with these classifications (Figure 2).

**Table 2.** Currently recognized habitat types. Additionally, a binary tidal classification is applied to distinguish between types such as tidal and non-tidal emergent wetland.

Habitat type
agriculture/ruderal
alkali seasonal wetland complex
emergent wetland
grassland
oak woodland/savanna
open water
stabilized interior dune vegetation
urban/barren
valley foothill riparian
vernal pool complex
wet meadow/seasonal wetland
willow riparian scrub/shrub
willow thicket



**Figure 2.** Maps of habitat types for historical (early 1800s) and modern (mid 2010s) conditions used by the Landscape Scenario Planning Tool.

Most users creating scenarios for analysis with the LSPT should exclusively use this established classification scheme when mapping and analyzing alternative land use scenarios. Advanced users can add additional habitat types, but careful consideration needs to be given to how the new habitat type is treated in different modules and analyses. Custom tool modifications are needed to accommodate a new classification, including defining which habitat type groups the new classification should be included in using the habitat types crosswalk document (Table 3). Refer to [Adding a custom habitat type](#) in the “Tool customization section” for additional details. Running the tool with an unsupported habitat type without taking these additional steps will result in an error.

Recognized habitat types and habitat type groups are defined in a single habitat types crosswalk table that can be reused each time it is needed. Analyses are written such that selections made with the recognized habitat types are case-insensitive, though only habitat types formatted exactly as shown in the table below (all lower-case), will be symbolized properly in all summary report maps. For this reason, we encourage users to use the lower-case habitat type names.

**Table 3.** Defined groups for use in different modules and analyses and the Landscape Scenario Planning Tool habitat types that are included.

Habitat type group	Group description	Habitat types
<b>Woody riparian</b>	Utilized in the woody riparian and fish support modules.	willow thicket; willow riparian scrub/shrub; valley foothill riparian

<b>Tidal wetland</b>	Utilized in the fish support, inundation, subsidence, economics, and carbon modules. In the fish support and subsidence modules this group is used to infer which open water polygons are hydrologically connected to Delta's main tidal channel network via surface water connections vs. which are hydrologically disconnected (e.g., located behind a levee on a subsided island). This step effectively assumes that open water areas that are contiguous with areas classified as tidal wetlands must be hydrologically connected to the main Delta channel network. In carbon module, this group is used to assign accretion rates and greenhouse gas emission factors specific to tidal wetland.	emergent wetland (tidal); willow thicket (tidal); willow riparian scrub/shrub (tidal)
<b>Non-tidal wetland</b>	Utilized in the marshes, wetland buffer, fish support, economics, and carbon modules. In the carbon module, non-tidal wetland in subsided areas is assumed to be managed for subsidence reversal.	emergent wetland (non-tidal)
<b>Wetted habitat and open water</b>	Utilized in the subsidence module. Includes habitat types that are generally wetted and thus help to halt ongoing land subsidence.	emergent wetland (tidal); emergent wetland (non-tidal); willow thicket (tidal); willow riparian scrub/shrub (tidal); agriculture/ruderal (rice); open water
<b>Perennial wetlands and open water</b>	Utilized in the wetland buffer module. Defines which habitat types to draw buffers around.	emergent wetland (tidal); emergent wetland (non-tidal); willow thicket (tidal); willow riparian scrub/shrub (tidal); open water
<b>Natural terrestrial</b>	Utilized in the wetland buffer module. Used to distinguish "natural terrestrial" portions of the wetland buffer (those classified with habitat types that have analogs in the historical Delta) from "heavily modified" portions of the wetland buffer (those classified as either urban/barren or agriculture/non-native/ruderal).	willow thicket (non-tidal); willow riparian scrub/shrub (non-tidal); valley foothill riparian; wet meadow/seasonal wetland; vernal pool complex; alkali seasonal wetland complex; stabilized interior dune vegetation; oak woodland/savanna; grassland
<b>Water</b>	Used to select open water for various analyses. This group currently only includes one habitat type but is provided in case advanced users wish to add additional types.	open water
<b>Agriculture</b>	Utilized in agriculture and carbon modules.	agriculture/ruderal

	This group currently only includes one habitat type but is provided in case advanced users wish to add additional types.	
<b>Non-rice agriculture</b>	Utilized in economics and carbon modules. In economics, to demonstrate qualitative costs and benefits of land use conversion from agriculture to other habitat types. Non-rice agriculture is separated from rice due to the difference in costs/benefits for rice vs other crops in many of the listed categories. In carbon module, to assign elevation change and CO2 emission rates based on modeled subsidence.	All agriculture except rice
<b>Rice</b>	Utilized in economics and carbon modules. In economics, to assess qualitative costs and benefits of conversion from non-rice agriculture to rice. In carbon module, to assign greenhouse gas emission factors specific to rice. Rice is assumed to undergo no further subsidence.	rice
<b>Pasture</b>	Utilized in carbon module to assign CH <sub>4</sub> and N <sub>2</sub> O emission rates specific to grazed pasture.	pasture
<b>Urban</b>	Utilized in agriculture module to determine areas of agriculture lost to urban development. This group currently only includes one habitat type but is provided in case advanced users wish to add additional types.	urban/barren

**Scenarios**

By default, the LSPT will, for each project, define a default “historical” and “modern” scenario (sometimes referred to as “baseline”). These represent historical conditions prior to major Euro-American modification (approximately the early 1800s) and modern conditions of the mid-2010s, respectively. On top of the mid-2010s modern conditions, one or more user land use configurations may be added to the project, describing modifications to the present day landcover as defined in the “modern” scenario (see [How scenarios are defined in the tool](#)). Analyses will often report on metrics comparing the performances of these user scenarios against the “modern” conditions, as well as the “modern” conditions against the “historical.”

This “modern”/“baseline” scenario can be adjusted/corrected when [preparing the workspace](#), in accordance with more accurate conditions or to simulate a baseline at a different time period. For

example, there is an option to “Include EcoRestore Projects in Baseline”, which allows users to select the completed or all EcoRestore projects as part of the “modern”/“baseline” scenario. These baseline corrections work similarly to a user scenario, burning land-use changes on top of the “modern” landscape, only using this to update and replace the “modern” scenario.

## **Workspaces**

Projects are defined in “workspaces”, which at their most basic level consist of a workspace folder and file geodatabase. Workspaces are used to organize working data and track scenarios. This also simplifies the tool GUI and inputs required, as once the tool is pointed to an appropriate workspace, it can determine what data exist through expected naming structure and can determine what scenarios and analyses have been added via the tracking table inside each workspace.

The workspace is mainly for the tool’s internal use, as the tool expects certain file structures and naming conventions. As such, while the user can examine datasets within the workspace, it is generally not recommended to edit files in the workspace.

The workspace structure itself consists of:

1. The workspace directory, given a name as defined by the user.
2. `workspace.gdb` – the file geodatabase for the workspace itself.
3. `logfile.txt` – the logfile for any processes run on this workspace/project.

## **Units**

All attribute values for areal metrics are in units of hectares. The one exception is the automatically-generated *Shape\_Area* field, which will conform to the units of the spatial reference (square meters due to enforced meters-based projection).

Length metrics are reported in kilometers – that is, all length-based values in the output Landscape Scenario Summary Report will be converted to kilometers. However, all analyses are done in units of meters, when applicable, to better conform with the enforced spatial reference type. As such, all data fields in the workspace itself are given with length units of meters, where applicable. Output tables however, may vary. See individual analysis module sections in [Analysis modules](#) for specifics.

## Developing Scenarios

### Defining scenarios in the LSPT

In the LSPT, “scenarios” are **alternative land-use scenarios**. They are combinations of potential landscape modifications resulting from restoration, management, and other actions. Scenarios can include changes associated with one project/site or many. “Scenarios” in this context are not, as they are sometimes defined, possible alternative trajectories given other uncertain drivers of change (e.g. a high sea-level rise scenario vs. a low sea-level rise scenario). However, the way that individual land-use scenarios respond to different possible future conditions could be evaluated moving forward as part of new tool modules.

### How scenarios are defined in the tool

Scenarios are defined in the tool using two geospatial data layer inputs:

1. A habitat type modification overlay layer (required)
2. A modified levee network layer (optional)

#### Habitat type modification overlay layer

The habitat type modification overlay layer (“overlay layer”) is the more important of the two layers the LSPT uses to define a scenario. An overlay layer is simply a feature class or shapefile containing polygons with associated habitat types defined in a single field (see the “Habitat types” section above for a list of habitat types the tool currently accommodates by default).

Additional information may optionally be provided by attribute fields for tidal, managed, and crop type definitions. If not supplied for the user scenario, all overlays are considered non-tidal, not-managed, and of unknown crop type. But, given that the tidal classification factors in defining marsh, wetlands, and wetted habitat, **it is strongly recommended to also provide a tidal attribute field with the habitat types**. The tidal field should be an integer type attribute field, wherein any positive, non-zero value is read as tidal, and any other values (including nulls) are read as non-tidal. The managed type field should be a text type attribute field, with values indicating the managed type. As of this current version, it does not yet factor into any analyses. The crop type field should be a text type attribute field, populated from the list of recognized crop type subclass values (Table 4; CDWR and LandIQ LLC 2020). The crop type field will only apply to polygons with the agriculture habitat type. Any values on other habitat types will be ignored.

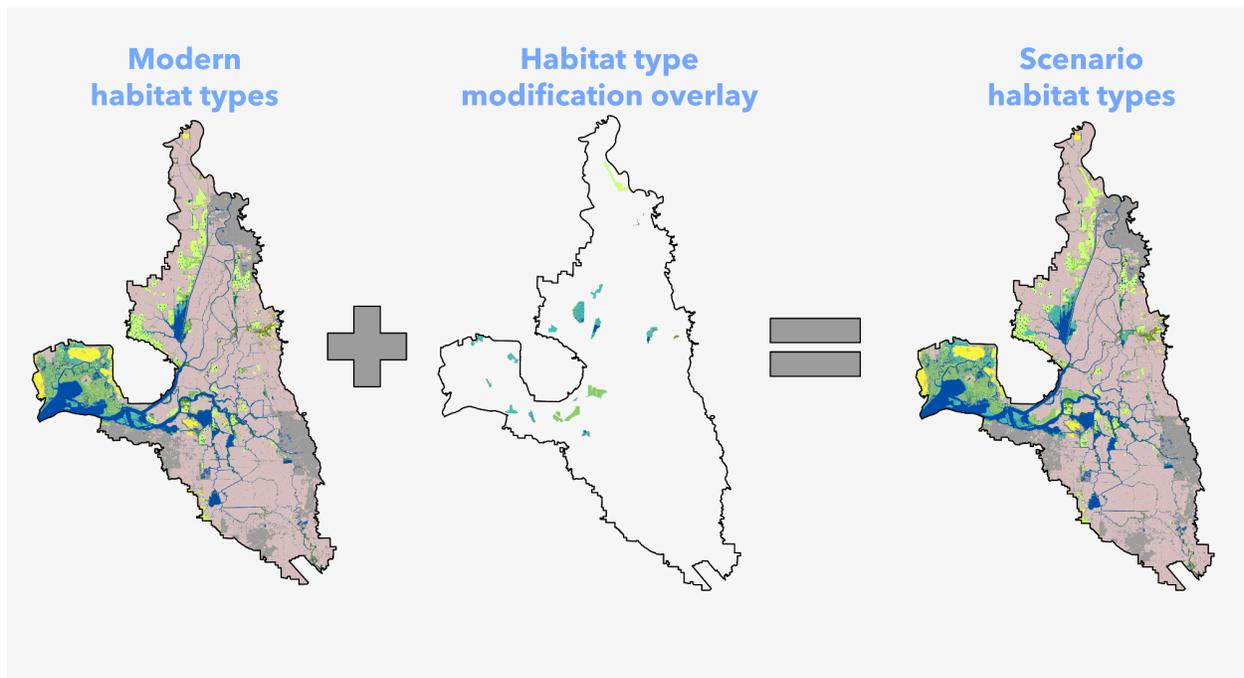
**Table 4.** List of crop types used by the Landscape Scenario Planning Tool, drawn from 2016 crop mapping by CDWR and LandIQ LLC (2020).

Crop type subclass	Crop type class
Alfalfa and Alfalfa Mixtures	Pasture

Almonds	Deciduous Fruits And Nuts
Apples	Deciduous Fruits And Nuts
Beans (Dry)	Field Crops
Bush Berries	Truck Nursery And Berry Crops
Carrots	Truck Nursery And Berry Crops
Cherries	Deciduous Fruits And Nuts
Citrus	Citrus And Subtropical
Cole Crops	Truck Nursery And Berry Crops
Corn, Sorghum and Sudan	Field Crops
Cotton	Field Crops
Flowers, Nursery and Christmas Tree Farms	Truck Nursery And Berry Crops
Grapes	Vineyard
Idle	Other
Kiwis	Citrus And Subtropical
Lettuce/Leafy Greens	Truck Nursery And Berry Crops
Managed Wetland	Managed Wetland
Melons, Squash and Cucumbers	Truck Nursery And Berry Crops
Miscellaneous Deciduous	Deciduous Fruits And Nuts
Miscellaneous Grain and Hay	Grain and Hay
Miscellaneous Grasses	Pasture
Miscellaneous Subtropical Fruits	Citrus And Subtropical
Miscellaneous Truck Crops	Truck Nursery And Berry Crops
Mixed Pasture	Pasture
Olives	Citrus And Subtropical
Onions and Garlic	Truck Nursery And Berry Crops
Peaches/Nectarines	Deciduous Fruits And Nuts
Pears	Deciduous Fruits And Nuts
Peppers	Truck Nursery And Berry Crops
Pistachios	Deciduous Fruits And Nuts
Plums, Prunes and Apricots	Deciduous Fruits And Nuts
Pomegranates	Deciduous Fruits And Nuts
Potatoes and Sweet Potatoes	Truck Nursery And Berry Crops
Rice	Rice
Safflower	Field Crops
Strawberries	Truck Nursery And Berry Crops

Sunflowers	Field Crops
Tomatoes	Truck Nursery And Berry Crops
Urban	Urban
Walnuts	Deciduous Fruits And Nuts
Wheat	Grain and Hay
Young Perennials	Young Perennial

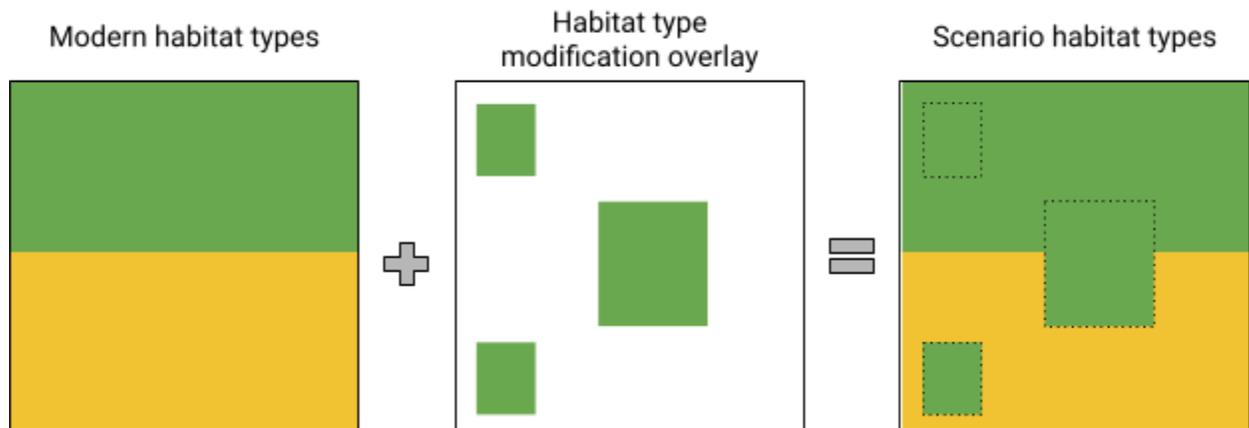
To generate the scenario, the LSPT will “burn” the overlay layer into the modern habitat type layer, replacing the existing underlying habitat types with the habitat types defined in the overlay layer. Areas not included in the overlay layer will remain unchanged in the resulting scenario habitat type map. This process is illustrated below for an example scenario (Figure 3; the projects planned as part of [California’s EcoRestore initiative](#)). Note that the example overlay layer is packaged with the tool for reference and for use as a template (see the “Example\_scenario\_EcoRestore\_overlay” feature class in the data package folder). The modern habitat types layer also comes packaged with the tool (see the “Habitat\_types\_modern\_forLSPT” feature class).



**Figure 3.** Illustration showing how the modern habitat type layer and scenario habitat type modification overlay to generate the scenario habitat type map analyzed by the Landscape Scenario Planning Tool.

While the layer is called the habitat type “*modification*” overlay, note that it is acceptable to include a polygon (or a part of a polygon) in the overlay layer that has the same habitat type classification as the corresponding location in the modern habitat type layer. The tool will still burn the polygon in question

into the modern habitat type layer, but this process will not result in a change in habitat type at the corresponding location (Figure 4):



**Figure 4.** Conceptual illustration showing how the habitat type overlay is combined with modern habitat types and that areas with the same habitat type will not result in altered habitat types in the scenario used by the Landscape Scenario Planning Tool. Colors represent different habitat types.

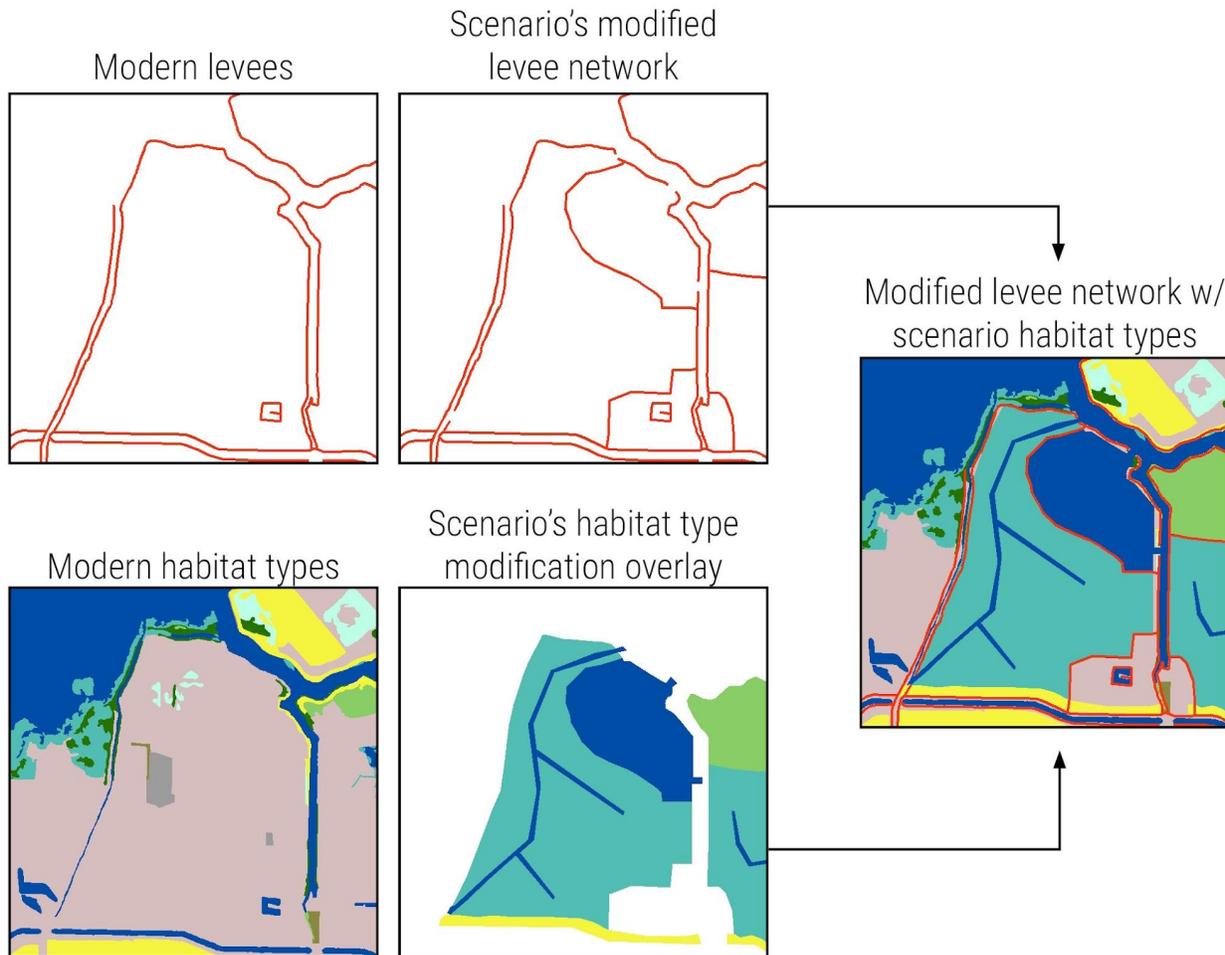
Defining scenarios with the overlay layer (instead of asking users to input the final scenario habitat layer and perform all modifications themselves), minimizes the risk of inadvertently introducing topological errors that can affect the tool's geospatial analyses. Specifically, burning in the features ensures there will not be any inadvertent "gaps" between digitized features or overlaps between modified and unmodified areas. However, it is still important for users to ensure that the scenario overlay *itself* does not contain any overlapping polygons. There is currently no automatic detection or correction of this topology issue and overlapping features will cause some analyses to behave unexpectedly (overlapping polygons will be double-counted in the habitat type extent analyses, for example). Refer to ArcGIS help files on defining, checking, and repairing topologies (available at [this link](#); the key topology rule to enforce on habitat type overlays for use in the LSPT is that features "must not overlap").

Additional guidance for those digitizing/developing overlay layers for use in the LSPT can be found below in the "Digitizing scenarios" section.

#### Modified levee network layer

The modified levee network layer ("levee layer") is a line feature class or shapefile representing the position of levee centerlines in the user's scenario. Note that unlike the habitat type modification overlay, the levee layer should represent the final desired configuration of levees in the scenario (not just levees being added or removed). Changes in the levee network should generally correspond to changes in the habitat type modification overlay. For example, a user that creates a scenario with a new tidal marsh may wish to modify the levee network layer to include the breach required to restore tidal action to the

proposed marsh (Figure 5). In Figure 5, some levees have been breached in the modified levee layer while others have been added. These changes align with the scenario habitat type modification overlay.



**Figure 5.** Example of a modified levee network to match the scenario habitat type modification overlay.

The levee network assigned to a scenario only impacts a subset of the modules and analyses run in the LSPT. If the following analyses are not of interest to a particular user, the user does not need to provide a modified levee layer.

- The levee network is used in the **Infrastructure module** to calculate the net change in length of levees within the analysis area. If a modified levee layer is not defined, this analysis is simply not performed, and the rest of the Infrastructure module analyses are unaffected. Users should include a modified levee layer if they are interested in quantifying the total length of new levees, the total length of removed levees, and resulting net change in length of levees that must be maintained in the proposed scenario.

- The levee network is used in the **Fish support module** to define which marsh and woody riparian habitat type polygons are potentially hydrologically connected to the Delta’s channel network (and thus potentially provide resources to fish). Specifically, levee centerlines are slightly buffered and then erased from the wetland habitat types before the wetland polygons are dissolved into contiguous features and then spatially selected to only include those that are directly adjacent to open water polygons (see the “Fish support” section for additional details). Portions of the wetlands that are entirely “behind” the levee centerline are separated from the open water by this sequence of steps and are not counted as accessible/providing resources to fish. This step is important because, in many locations, woody riparian vegetation covers both sides of a levee and then grades down into woody riparian or other impounded wetlands on the landward side of the levee (including in some cases down onto subsided islands). While these features might be contiguous with the Delta’s channel network as mapped in two dimensions, in reality they are hydrologically disconnected (at least via surface water flows) due to the presence of a levee, and cannot be accessed by fish. Thus, if a user wishes to more accurately account for the hydrological connection of altered wetlands in the user scenario to evaluate support for fish, they should consider including a modified levee layer. Only wetlands on the “water side” of the levee will be counted when evaluating support for fish. **If no modified levee network layer is specified for a scenario by the user, the tool assumes the scenario entails no change in the levee layer and uses the modern levee layer for the “Fish support” calculations.**

Because the Infrastructure module determines the length of levees removed and added by erasing the modern levee layer from the scenario levee layer (and vice-versa), even slight shifts in the position of a levee will be treated as a wholesale removal of one levee and construction of another. To avoid this, **users developing their scenario’s levee layer should almost always start with a fresh copy of the modern levee layer and make edits to that copy directly.** Any attribute fields associated with the levee layer are ignored by the tool.

While only a few modules currently use the levee layer, this functionality expands the range of potential analyses that can be supported in future versions of the tool.

### **Tips and resources for digitizing scenarios**

There is no one right way to develop scenarios for use in the LSPT. In the examples below we highlight a few possible approaches, as well as resources that come packaged with the LSPT to aid users developing their own scenarios.

Users with existing high-quality spatial data representing restoration designs should find it easy to adapt these files for use in the LSPT, simply by adding an attribute field to their polygons and classifying the

land cover using the LSPT-supported habitat types. In absence of this, the easiest way to develop a scenario is perhaps to begin with another scenario. The tool is packaged with a habitat type modification overlay layer for the EcoRestore scenario

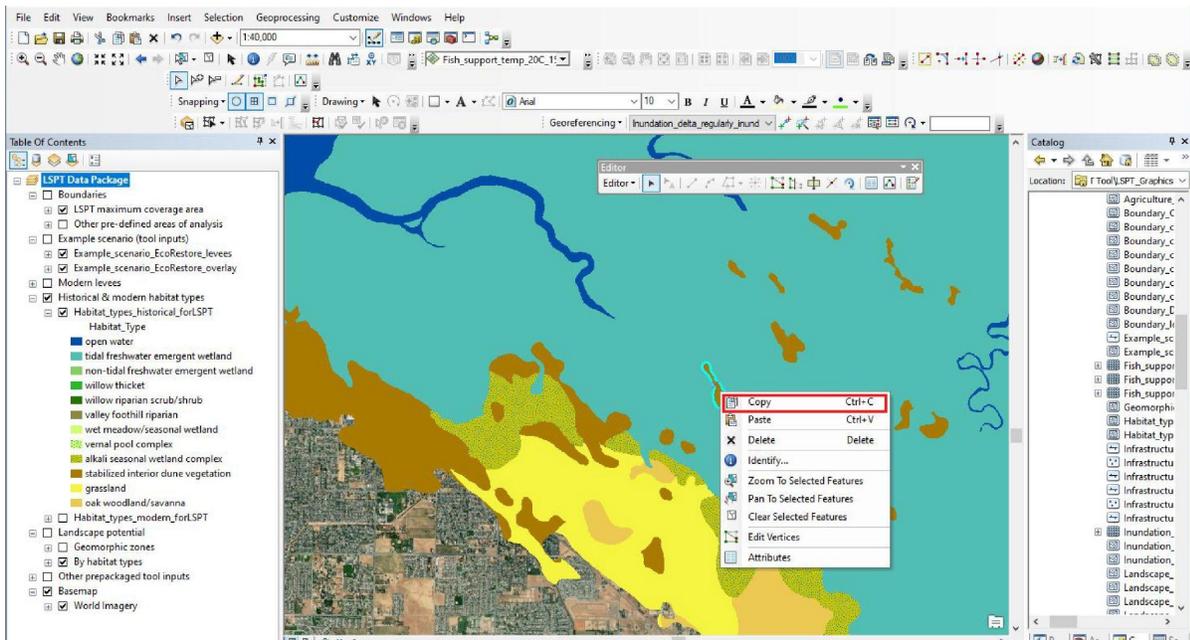
(data\LSPT\_data\_package\_SFEI\LSPT\_data\_package\_SFEI.gdb\Example\_scenario\_EcoRestore\_overlay), which can be used as an example and template. By making a copy of this layer and opening it in an editing session, new polygons can be drawn or copied in from another layer in the same geodatabase (basic information on editing features is available on this [ArcGIS help page](#)) and unwanted features can be deleted. An example of copying features between layers in an editing session is also provided below.

The example scenario layer includes a field titled "Habitat\_Type" where the habitat type of each polygon is defined. This field is shared by other layers packaged with the tool and is always populated with the standardized set of habitat types supported by the LSPT (see the "Habitat types" section above). This consistency makes it easy to copy features from these layers into your scenario while maintaining the habitat data attributes in the same field (note that the other fields are not required by the tool, but may be useful for documenting your work). Layers with populated "Habitat\_Type" fields are as follows:

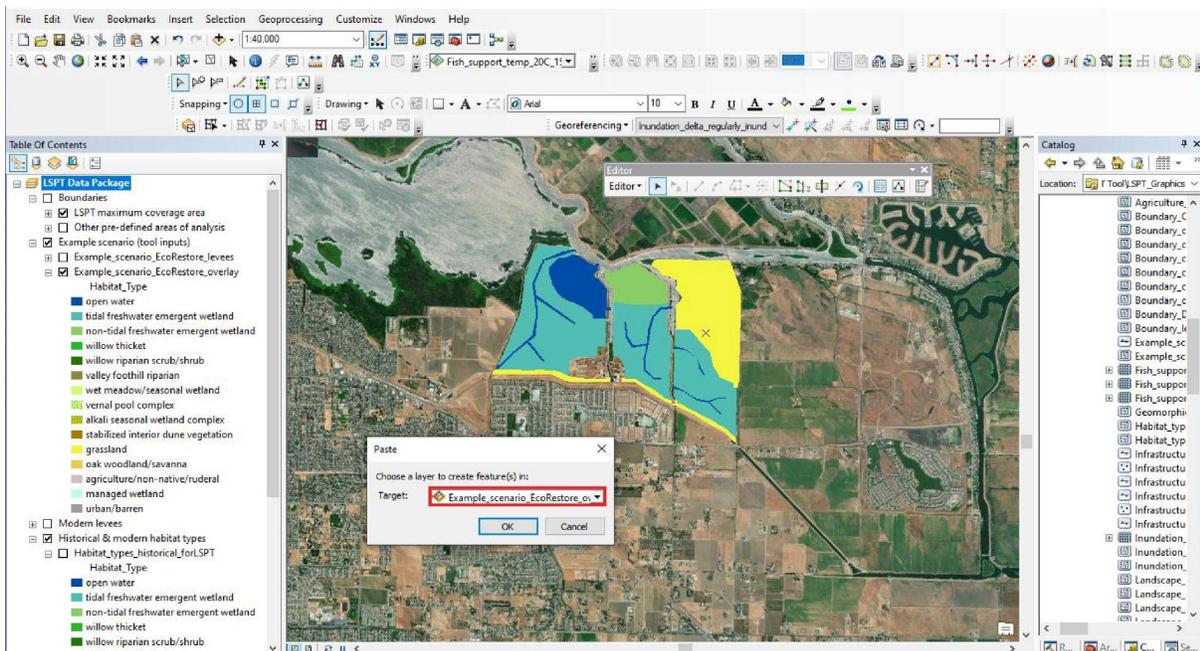
- **Historical habitat type layer**

(data\LSPT\_data\_package\_SFEI\LSPT\_data\_package\_SFEI.gdb\Habitat\_types\_historical\_forLSPT): This layer is an updated and expanded version of the historical Delta habitat types layer developed by Whipple et al. (2012) intended for use in the LSPT (SFEI-ASC 2021a). The tool uses this layer to compare scenarios to the historical, pre-development Delta (early 1800s). **Tool users can use ArcGIS editing tools to copy polygons or portions of polygons directly from this layer and into their own scenario if they wish to evaluate the effects of restoring a historical habitat type in its historical location.** This process is illustrated below and can also be replicated with other layers.

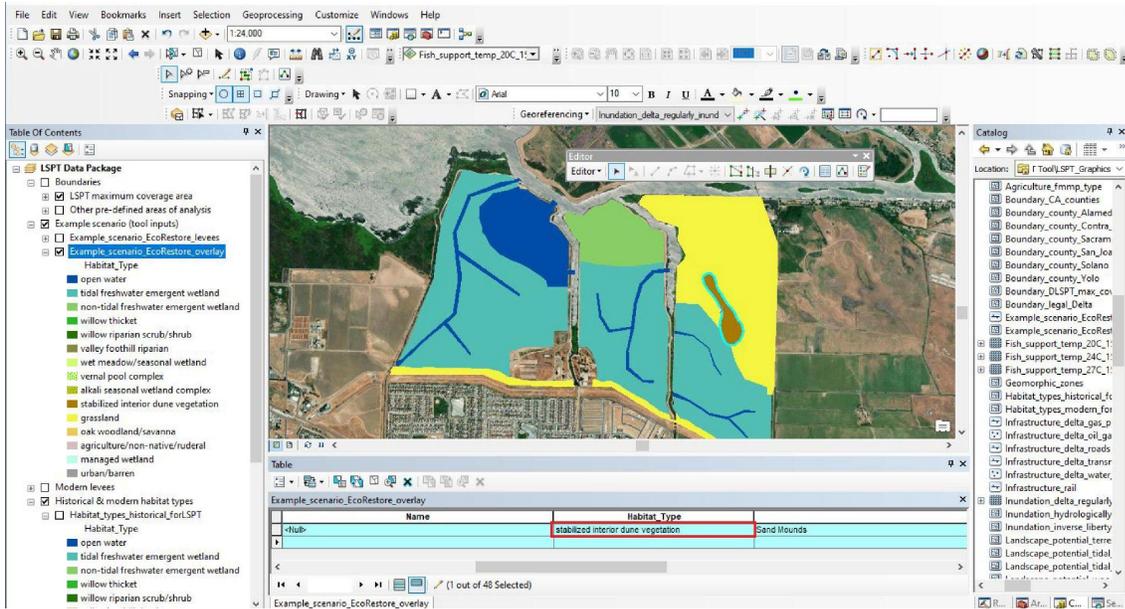
Step #1) In an edit session, copying the selected historical “Stabilized interior dune vegetation” polygon:



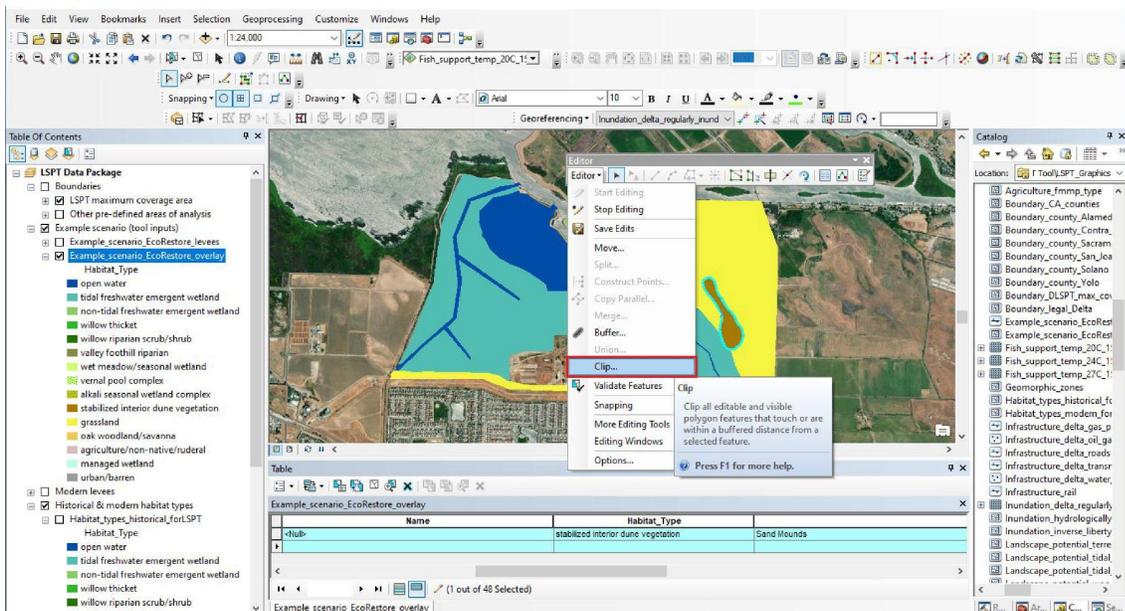
Step #2) Instructing ArcGIS to paste this historical polygon into the example scenario habitat type modification overlay layer (CTRL+V with the scenario overlay layer turned on):



3) The resulting shape highlighted in the scenario overlay layer (with the habitat type pre-populated in the attribute table):



4) Erasing the underlying part of the grassland polygon (yellow) to avoid overlapping features in the overlay layer with the “Clip” function. Make sure “Discard the area that intersects” is selected in the next menu. This step could also be accomplished using topology tools:



- **Modern habitat type layer**

(data\LSPT\_data\_package\_SFEI\LSPT\_data\_package\_SFEI.gdb\Habitat\_types\_modern\_forLSPT): This layer is an updated and expanded version of the modern Delta habitat types layer published in SFEI-ASC (2014) intended for use in the LSPT (SFEI-ASC 2021c). The tool uses this layer to compare

scenarios to the modern Delta (mid 2010s). **Tool users can use ArcGIS editing tools to copy polygons from the modern habitat type layer into their scenario and then alter the habitat type classification in the "Habitat\_Type" field to specify a habitat type conversion in the scenario.** This is convenient because it avoids the need to draw polygons from scratch, and the polygons from the modern habitat type layer already "fit" well with adjacent shapes/habitat types/features on the landscape.

- **Landscape potential layers:** The tool also comes pre-packaged with four "landscape potential" layers, which identify restoration opportunities based on their elevation. These layers were initially derived from a more detailed analysis to identify, map, and quantify opportunities for landscape-scale restoration in the Delta (Safran et al. 2020, version 3.1). Please refer to that document and the layer meta-data for additional information on the datasets and methods. They are also summarized below. Note that landscape potential in these layers is based primarily on physical elevation. The analysis does not consider ownership, infrastructure constraints, or any number of other considerations that influence the suitability/feasibility of potential land uses. **Tool users can use ArcGIS editing tools to copy polygons from the landscape potential layers into their scenarios that are likely to be physically suitable, given their elevation.**

- ***Landscape\_potential\_tidal\_marsh\_intertidal\_areas:*** This layer identifies areas in the intertidal zone that could potentially support tidal emergent wetlands. It does not include areas that already support emergent wetlands or areas currently classified as urban development. The layer has also been annotated with additional fields to further characterize the potential of each feature, including whether each patch of land at intertidal elevation is >100 ha in size ("Intertidal\_patch\_100ha"), >500 ha in size ("Intertidal\_patch\_500ha"), adjacent to a remnant blind channel network ("Adjacent\_to\_remnant\_blind\_Channel"), contiguous with non-urban transgression space ("Contiguous\_with\_undeveloped\_transgression\_space"), and adjacent to historical woody riparian patches ("Adjacent\_to\_historical\_riparian"). The importance of these attributes are described in other resources (SFEI-ASC 2016; Safran et al. 2020).
- ***Landscape\_potential\_tidal\_marsh\_minimally\_subsidied\_areas:*** This layer identifies areas in the shallowly subsided zone that could potentially support tidal emergent wetlands after subsidence-reversal efforts. It does not include areas that already support emergent wetlands or areas currently classified as urban development. For the purposes of the LSPT, a new "Habitat\_Type" field has been pre-populated with the "tidal emergent wetland" classification. Because restoring tidal emergent wetlands in shallowly subsided areas will require subsidence reversal, users developing near-term scenarios may want to instead consider classifying these areas as non-tidal emergent wetland or managed wetland. The layer has also been annotated with additional fields denoting whether each

patch of land at intertidal elevation is >100 ha in size ("Minimally\_subsidied\_100ha") and whether it is >500 ha in size ("Minimally\_subsidied\_500ha").

- ***Landscape\_potential\_woody\_riparian\_on\_natural\_levees:*** This layer identifies areas with the potential to support woody riparian vegetation. Areas were included if they historically supported woody riparian vegetation on natural levees, are still located above the local elevation of MHHW, and do not currently support hydrologically connected woody riparian habitat types, urban development, or open water. The "Habitat\_Type" field is populated with either "valley foothill riparian" or "willow riparian scrub/shrub," depending on the woody riparian habitat type that was supported historically. Removing areas currently classified as open water from this layer helped prevent areas where channels have migrated or been widened from being identified as opportunities for woody riparian restoration, even though they formerly supported woody riparian vegetation. This methodology makes the simplifying assumption that many areas that historically supported woody riparian vegetation could still do so today, at least with modifications to engineered levees that currently limit connections between streams and the adjacent land. Future phases of this work should refine this analysis, evaluating detailed present-day topographic, edaphic, and hydrologic conditions. The layer potentially underestimates opportunities in areas that did not historically support woody riparian vegetation but could today given changes in environmental conditions (e.g. along new channel courses such as Paradise Cut).
- ***Landscape\_potential\_terrestrial\_habitat\_type\_terrestrial\_areas:*** This layer identifies areas that are in either the tidal-terrestrial zone (referred to as the "sea-level rise accommodation" band in the Delta Plan) or the terrestrial zone (referred to as the "floodplain" elevation band in the Delta Plan), subtracting urban areas and existing natural habitat type types (including terrestrial habitat types, woody riparian types, non-tidal marshes, and open water), and then clipping the resulting layer to the areas that also historically supported terrestrial habitat types, including Wet meadow/Seasonal wetland, Vernal pool complex, Alkali seasonal wetland complex, Stabilized interior dune vegetation, Grassland, and Oak woodland/savanna (SFEI-ASC 2014). This land, predictably, falls mostly on the periphery of the Delta. In this analysis, we assume that areas that historically supported a particular terrestrial habitat could potentially support that habitat type again, but consideration of contemporary landscape conditions, such as groundwater and soil conditions, are also important and should be considered in future versions of this analysis. The "Habitat\_Type" field has been pre-populated with the historical terrestrial habitat type.

Some additional considerations for digitizing scenarios specific to each tool module are included in the “Key considerations and caveats” sub-sections in the “Analysis Modules” section.

### **Pulling habitat projects from EcoAtlas**

EcoAtlas ([ecoatlas.org](https://ecoatlas.org)) is an online tool for visualizing the condition and extent of wetlands in California. Project managers can add project information to EcoAtlas via Project Tracker ([ptrack.ecoatlas.org](https://ptrack.ecoatlas.org)), a data entry tool for uploading and editing information on wetland restoration, mitigation, and habitat conservation projects throughout California. The Project Tracker database has been designed to record information on project status and designs, including spatially-explicit maps of planned land cover modifications.

The LSPT package includes an additional tool for guidance in developing scenarios that leverage the habitat projects available in EcoAtlas and the associated Project Tracker. This tool is packaged with the LSPT as the **Pull\_EcoAtlas\_Sites.pyt** toolbox. Running this tool will download the latest Habitat Projects with site geometries intersecting the maximum extent of the LSPT analysis area via a request to the EcoAtlas API (<https://api.ecoatlas.org>). As such, it will require an active internet connection.

The basic data model for Project Tracker centers around projects. Each project can contain any number of sites, which forms the basic spatial unit and individual features created by this tool. In turn, each site is linked to one or more activities and events. These one-to-many relations are important for understanding the structure of the outputs and filtering behavior.

The tool will attempt to crosswalk the habitat types for each site into an appropriate and recognized [habitat type](#) for the LSPT as well as possible tidal status. Attribute data for habitat and subhabitat type is contained in the site activities, and it is possible for a single site to be linked to multiple habitat types. Each activity and site is crosswalked to a list of possible LSPT habitat types.

To run the tool, simply provide a location to create the outputs. Additional parameters are provided for filtering the sites by project type, site status, activity type, and crosswalked habitat. To disable the filter entirely, clear all sections from the parameter. With the many-to-one relationships in the data model being queried, filtering by activity type and crosswalked habitat will filter individual site activities first, then filter out sites that do not have at least one remaining associated activity.

Name	Type
 site_activities	File Geodatabase Table
 site_events	File Geodatabase Table
 sites	File Geodatabase Feature Class

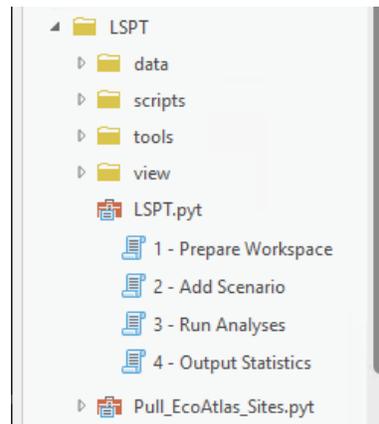
Outputs are provided in a geodatabase with three datasets. The **sites** feature dataset contains the spatial layer for all captured sites and associated attributes. The two tables – **site\_activities** and **site\_events** – link activities and events respectively to each site by the *Site\_ID*. Each record in **site** and **site\_activities** will be crosswalked to potential LSPT habitat type and tidal values with the attributes *LSPT\_Habitat* and *LSPT\_Tidal*.

This EcoAtlas pull tool can be used to develop new scenarios based on Project Tracker data, including both project footprints polygons and restoration design habitat polygons. Habitat polygons can be used to create scenarios of the future landscape once projects have been completed. Project footprint polygons can be combined with user assumptions to create future scenarios, or combined with habitat data from different time periods to track change over time. Project Tracker data can also be used as a check on user scenarios in development, to confirm scenario details align with Project Tracker data and avoid conflicts in their designs with planned land uses. Processes are in place to encourage regular updates to Project Tracker, including the Delta Conservancy's policy that Conservancy-funded projects be submitted to and regularly updated in Project Tracker as a condition of their grants, and Council's inclusion of Project Tracker as a data source for updating Delta Plan Performance Measures. The LSPT can take advantage of the tracking and mapping of project activities via EcoAtlas and Project Tracker to support cross-program and inter-agency communication and coordination.

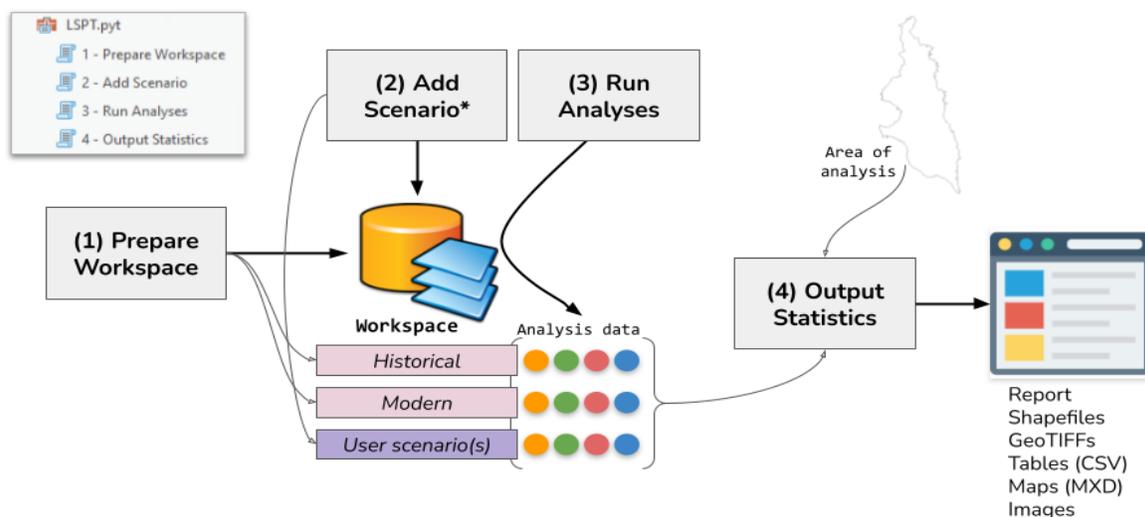
Due to the collaborative nature of data entered into Project Tracker, there are different levels of detail provided for different habitat projects, and projects are updated with different frequency. Users are responsible for confirming that Project Tracker data used in scenarios is accurate and up to date. Due to limitations of processing the data structure and uncertain nature of the crosswalks, especially in a many-to-one-relationship, further manual processing of the output data will be necessary before it is ready for use as an input user scenario in the LSPT.

## Tool Workflow

To use the toolbox, simply navigate to the LSPT.pyt toolbox in ArcGIS, either through the file catalog window or by adding it as a new toolbox to the toolbox window.



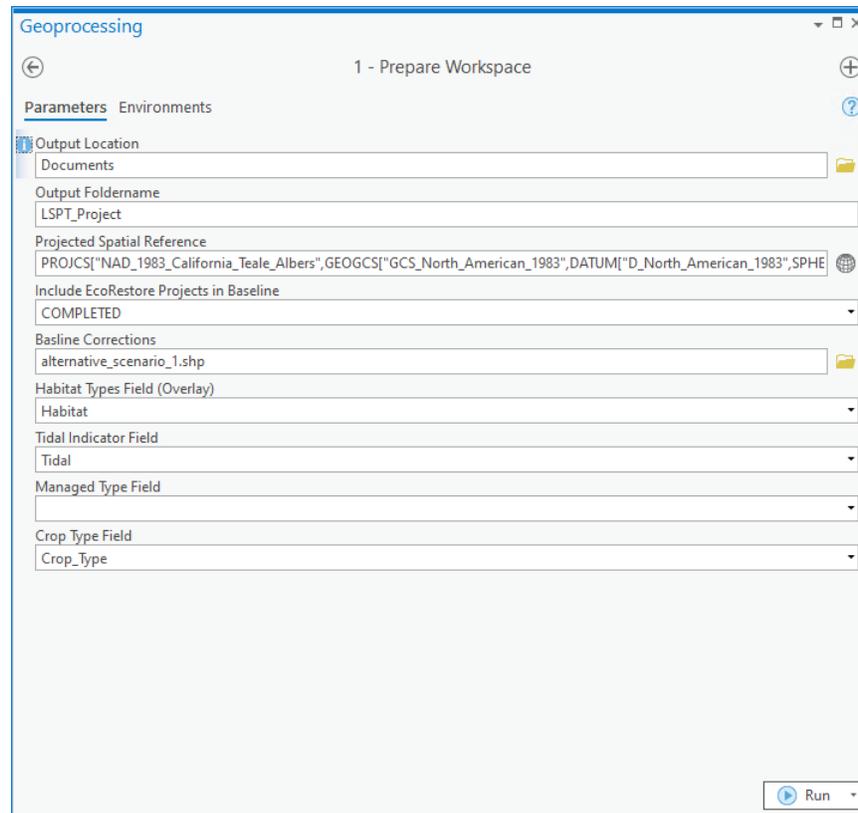
LSPT consists of four specific tools (Figure 6). These are meant to be run in order, but certain tools can be repeated. Generally the procedure is as follows: (1) prepare the workspace, (2) add scenario(s) to the workspace, (3) run analyses, and (4) output statistics. The tool components and work flow are summarized in the figure below and described in detail on the following pages.



**Figure 6.** Diagram showing the Landscape Scenario Planning Tool's four primary components and how they relate.

## 1. Prepare Workspace

Prepares the workspace for a project and prepares the historical and modern data. The modern scenario is used as the baseline scenario for which to compare user-added scenarios against. Options here allow for some modification and correction of this baseline scenario.



### Inputs:

- **Output Location** -- The location in which workspace will be created.
- **Output Foldername** -- The name of the workspace folder to be created.
- **Projected Spatial Reference** -- An enforced spatial reference for all data (must be projected type with linear units of meters) -- a suggested spatial reference to use is California Teale-Albers NAD83 (EPSG: 3310), which is provided as a prj file in the main tool directory.
- **Include EcoRestore Projects in Baseline**-- Selects how EcoRestore projects will be used to update the baseline modern scenario. Currently, the available options are *NONE*, for no EcoRestore projects included in baseline, *COMPLETED*, for all EcoRestore projects completed to scheduled to be completed in the current year, or *ALL*, to include all EcoRestore projects, regardless of status.
- **Baseline Corrections** -- An optional correction layer to adjust the baseline modern scenario.

- **Habitat Types Field** – If the *Baseline Corrections* input is given, the field that defines the habitat type. Habitat type values must be from the accepted/recognized list (not case sensitive – see the [Habitat types](#) section).
- **Tidal Indicator Field** – If the *Baseline Corrections* input is given, the field that defines polygons as tidal or non-tidal. Expected to be an integer type, with any positive, non-zero value read as tidal.
- **Managed Type Field** – If the *Baseline Corrections* input is given, an optional field that defines the managed type, if applicable.
- **Crop Type Field** – If the *Baseline Corrections* input is given, an optional field that defines the specific crop type for polygons with the agriculture habitat type.

#### Processes:

- Copies datasets into workspace.
- Prepares historical/modern habitat types.
- Adds baseline scenario modifications and corrections, if specified.
- Adds EcoRestore modifications, if specified.
- Extracts open water.

#### Outputs:

- The workspace folder with geodatabase
- Within the geodatabase:
  - `_tracking`
    - The tracking table for scenarios and analyses run on each.
  - `_alias`
    - The crosswalk table for scenario internal/workspace names to display names.
  - `_ecorestore`
    - A tracking table for EcoRestore corrections made to the baseline scenario.
  - `ca_counties`
  - `geomorphic_zones`
  - `historical_habitat`
  - `modern_habitat`
  - `historical_open_water`
  - `modern_open_water`
  - `modern_levee_centerlines`
  - `ecorestore`
  - `ecorestore_baseline`
  - `baseline_change`

## 2. Add Scenario

Defines and adds a scenario to a workspace. Scenarios can be defined from a combination of the scenario overlay and EcoRestore projects, just a scenario overlay, or just EcoRestore projects. This tool can be run multiple times for multiple scenarios. It can also be used to overwrite an existing scenario.

Note that if overwritten, the tracking table will be cleared for all analyses and the feature dataset for the scenario cleared. However, some vestigial datasets from past analyses on the previous scenario definition may still exist. They will not be factored in the outputs, however, as they are no longer being tracked in the tracking table (unless the analysis is rerun, in which case these datasets will be overwritten).

The screenshot shows the '2 - Add Scenario' dialog box in the Geoprocessing environment. The dialog is titled 'Geoprocessing' and '2 - Add Scenario'. It has tabs for 'Parameters' and 'Environments'. The 'Parameters' tab is active. The parameters are: Workspace Directory (LSPT\_Project), Scenario Internal/Workspace Name (scenario\_a), Scenario Display Name/Alias (Scenario A), Allow Overwrite (unchecked), Scenario Overlay (alternative\_scenario\_1.shp), Habitat Types Field (Overlay) (Habitat), Tidal Indicator Field (Tidal), Managed Type Field (empty), Crop Type Field (Crop\_Type), Include EcoRestore Projects (ALL), and Levee Centerlines Layer (empty). A 'Run' button is at the bottom right.

### Inputs:

- **Workspace Directory** -- The directory of project workspace.
- **Scenario Internal/Workspace Name** -- The name for the scenario ,restricted to be filename safe for workspace/file-geodatabase file names (no spaces or special characters).
- **Scenario Display Name/Alias** -- The scenario name to be used in the tool output report (spaces and other special characters are ok).

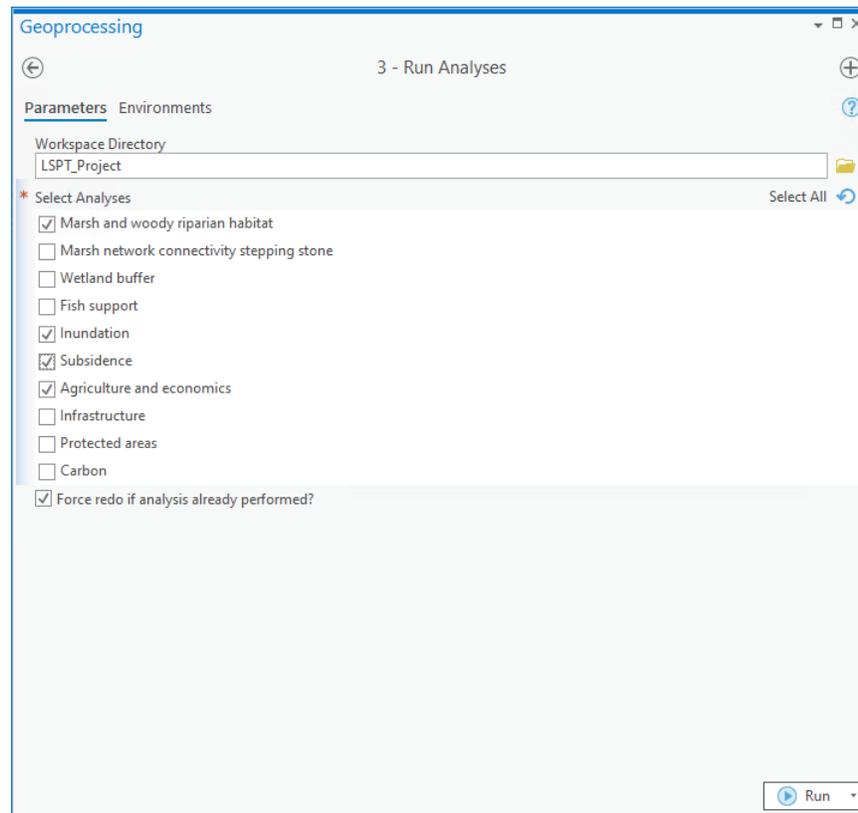
- **Allow Overwrite** -- If checked, allows overwriting an existing scenario with the same internal/workspace name (if not checked, the tool will raise an error if a scenario with the same internal/workspace name already exists).
- **Scenario Overlay** -- Layer consisting of polygons of habitat type changes/modifications related to scenario.
- **Habitat Types Field (Overlay)** -- The field/attribute name in the overlay layer which defines habitat type. Habitat type values must be from the accepted/recognized list (not case sensitive -- see the [Habitat types](#) section).
- **Tidal Indicator Field** -- An optional field/attribute name in the overlay layer which defines polygons as tidal or non-tidal. Expected to be an integer type, with any positive, non-zero value read as tidal.
- **Managed Type Field** -- An optional field/attribute name in the overlay layer which defines the managed type, if applicable.
- **Crop Type Field** -- An optional field/attribute name in the overlay layer which defines the specific crop type for polygons with the agriculture habitat type.
- **Include EcoRestore Projects** -- Selects EcoRestore projects for inclusion in this scenario. Currently, the available options are *NONE*, for no EcoRestore projects included, *COMPLETED*, for all EcoRestore projects completed to scheduled to be completed in the current year, or *ALL*, to include all EcoRestore projects, regardless of status. Note this applies *on-top of* the EcoRestore projects that may already be included in the baseline scenario created in *Prepare Workspace*.
- **Levee Centerlines Layer** -- An optional levees layer for the scenario.
  - If not supplied, no change from modern levees is assumed
  - Levees factor into the Infrastructure analysis and in the Fish support analysis to determine connectivity of large patches

#### Processes:

- Prepares habitat layer for the scenario by burning the scenario overlay layer into the modern habitat type layer.
- Performs basic habitat analysis on the resulting layer (see the [Habitat](#) section under “Analysis modules”).
- Performs physical suitability analysis (see the [Physical suitability](#) section under “Analysis modules”).
- Performs levee change analysis (see the [Levees](#) section under “Analysis modules”).

### 3. Run Analyses

Runs analyses on all scenarios in the workspace. See section [Analysis modules](#) for further details on predefined inputs, predefined parameters, processes, and outputs.



#### Inputs:

- **Workspace Directory** -- The directory of project workspace.
- **Select Analyses** -- The name(s) of analyses to run.
- **Force redo if analysis already performed?** -- If checked, runs analyses on all scenarios no matter what. If not checking, will skip redoing analysis if it was already performed on a scenario.

Most modules will take 5-10 minutes to complete (depending on hardware and number of scenarios). However, certain modules are more intensive – particularly “Marsh and woody riparian habitat” (~40+ min), “Marsh network connectivity stepping stone” (6+ hours), “Fish support” (~30+ min), and “Carbon and greenhouse gas emissions” (~60+ min). The longest duration is “Marsh network connectivity stepping stone” -- hence, this analysis is separated from the Marshes section in which its outputs are included. The most intensive analysis by computational requirements is the “Carbon and greenhouse gas emissions” analysis, which will require significant disk space and memory (for more information, see

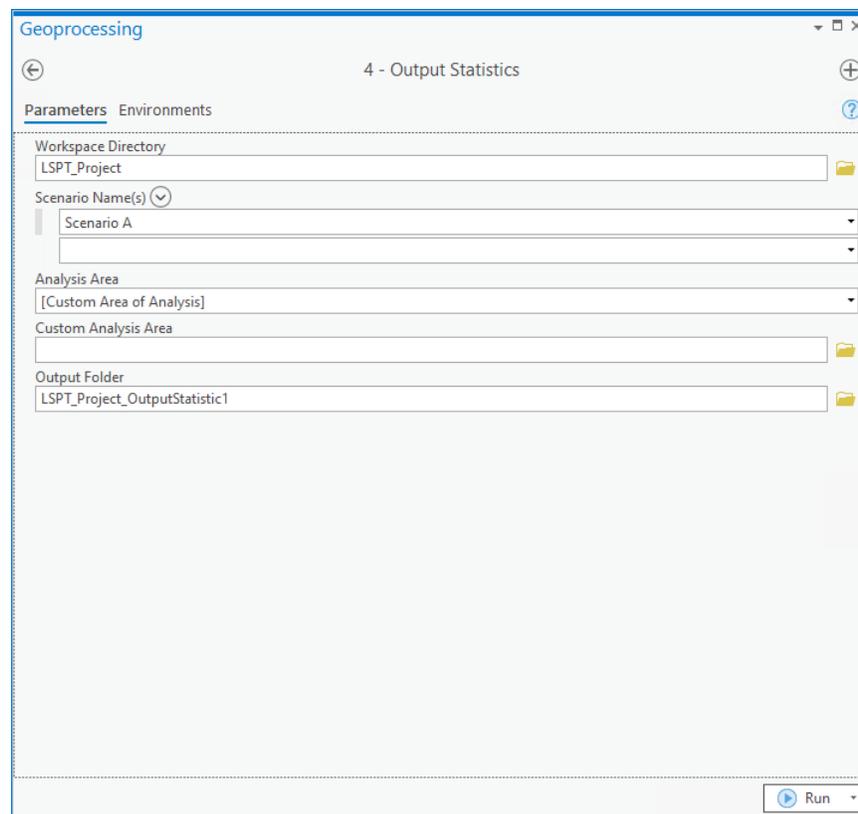
[hardware and storage requirements](#)). These latter two modules are best run during an otherwise idle/low-usage period, such as overnight.

If adding a new scenario after having run this tool, you will have to rerun **Run Analyses** to run analyses on the new scenario. However, you can uncheck **Force redo if analysis already performed?** to skip rerunning analyses for previous scenarios that have already been run.

Note that LSPT analyses performed in the **Add Scenario** and **Run Analyses** tools are always run over the full LSPT coverage area. Smaller areas of analysis over which to subset/summarize the full results are then defined in the **Output Statistics** tool (which can be run multiple times with different analysis areas, if desired).

#### 4. Output Statistics

Outputs formatted data, shapefiles, and maps, which are clipped to a user-defined area of analysis and then consolidated into an dynamically-generated and interactive report.



#### Inputs:

- **Workspace Directory** – The directory of project workspace.

- **Scenario Name(s)** – Name(s) of scenario(s) desired to report on in output. Once the workspace directory is selected, this box will be populated with choices using the scenario display names.
- **Analysis Area** – The area of analysis, which may be selected from this predefined list or defined as custom along with the next parameter.
- **Custom Analysis Area** – If a custom area of analysis is selected above, use this to define the polygon shapefile or feature class demarcating the custom area of analysis.
- **Output Folder** – The folder in which to place the formatted outputs and report.

### Processes:

For each analysis that has been run in the workspace, for the scenario(s) specified:

- Clips relevant data to the area of analysis.
- Exports clipped data (as shapefiles or geoTIFFs).
- Calculates statistics on clipped outputs.
- Outputs tabular data (CSV) of statistics.
- Prepares map documents (ArcGIS project) and exports map images (PNG).
- Adds relevant data to report.

### Outputs:

The folder output contains:

- Folder: output/data
  - Tabular data (CSVs).
- Folder: output/map
  - Map documents (as an ArcGIS project).
- Folder: output/shp
  - Spatial data (shapefiles and geoTIFFs).
- For specific file outputs, see relevant subsections under the [Analysis modules](#) section.

The folder report contains the Landscape Scenario Summary Report, a web-browser-based, interactive application for viewing analysis results.

## **Viewing results**

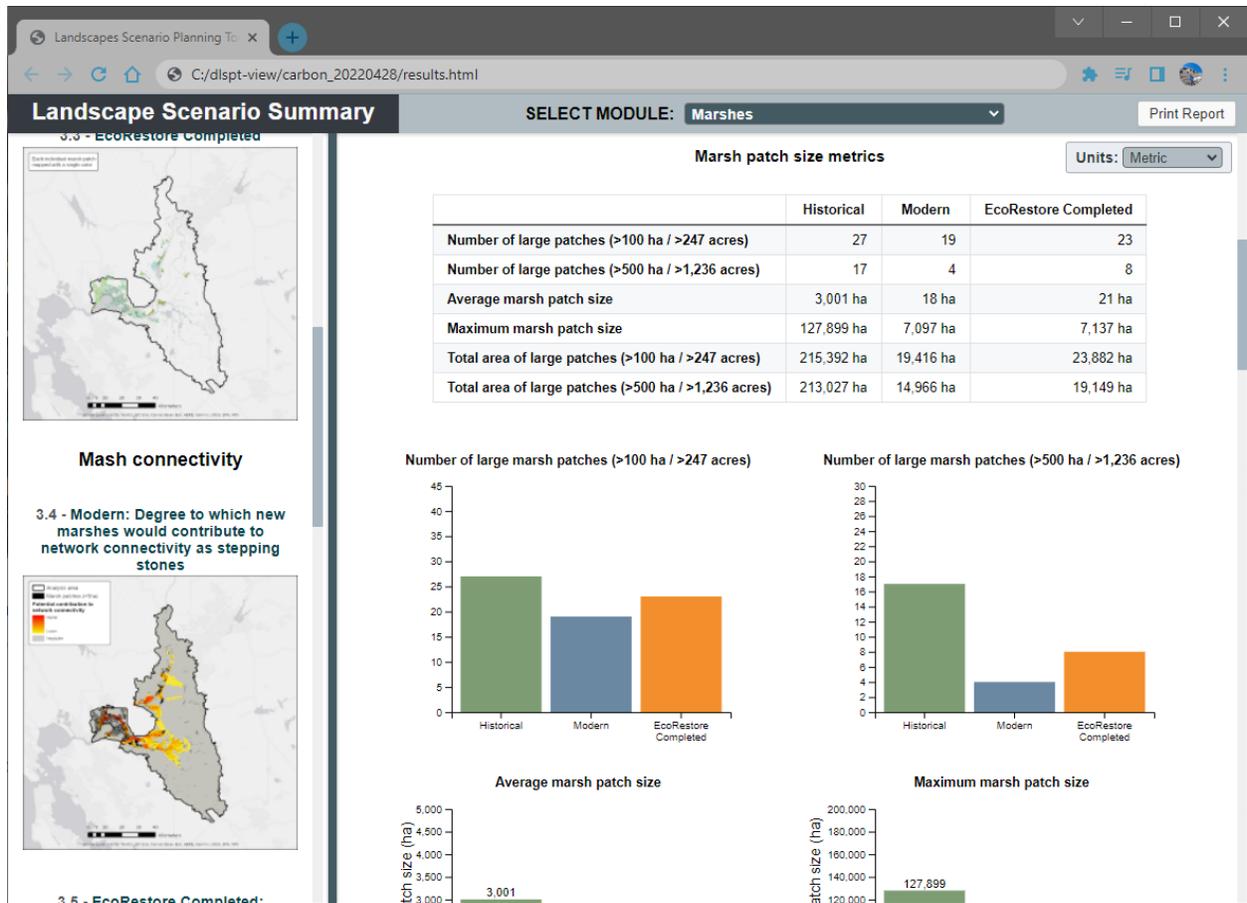
Within the workspace, the naming format uses the internal/workspace name for scenarios as dataset name prefix. When applicable, data layers are stored in the feature dataset named after the scenario internal/working name (there are exceptions such as tables/rasters which cannot be stored in a feature

dataset). For the output data from the final tool, for ease of creating dynamically-generated files and to avoid potential invalid filename errors, user scenarios in filenames are simply called “vision1”, “vision2”, “vision3”, etc. The formatted display names for the scenarios are applied in report and output table columns.

Results from the Output Statistics tool are organized into an output folder and a report folder. The output folder contains tabular data (as CSVs), spatial data (as shapefiles and geoTIFFs), and map templates (in an ArcGIS project). For a description of each raw tool output file refer to the “File inventory” sub-sections within the “Analysis Module” section below. For units of applicable attribute values, see section [Units](#) under “Tool overview.”

Note that shapefiles will occasionally show truncated attribute names due to the ten character limit. In these cases, it may be useful to refer to the raw dataset in the workspace, which does not have as restrictive an attribute length limit and will list attributes in the same order as the output. Map templates in the ArcGIS project may have several hidden/broken layers – these are intentional and are used to create the legend dynamically.

To view the Landscape Scenario Summary Report, simply open `report/results.html` in your web browser. It does not require an internet connection and the file can be shared via packaging and sending the contents of the report folder (i.e., zipping the entire folder and sharing it via email).



The Landscape Scenario Summary Report is organized into three main components. The top menu-bar has the controls for viewing the outputs of different modules. The button on the top-right opens the entire mode in a print-friendly layout for printing or saving to PDF.

The rest of the screen is devoted to side-by-side displays of the maps (left panel) and rest of the results (right panel). The panel widths may be adjusted by dragging the vertical bar separating the two panels to the left or right. When a different module is selected from the top menu-bar, the panels will automatically update.

For supported modules, a unit selection dropdown menu will appear floating in the upper right corner. Changing units here will update units in the tables to the appropriate type. However, it will not affect units in text boxes, graphs, or maps.

The Landscape Scenario Summary Report was built with Javascript, [Vue.js](#) (2.6.10), and [D3.js](#) (5.12.0). It should be supported on all modern browsers (e.g. Internet Explorer 11+, Edge, Firefox, Chrome, Safari).

## Common errors

### Scenario naming

The scenario internal/workspace name must abide by certain naming conventions. See name/alias rules in [Defining feature class properties](#). Additionally, no special characters are recommended, as this may cause issues down the line in invalid layer or table names. As a general rule, stick to alphanumeric characters and underscores in the internal/workspace name.

You may supply a more properly-formatted name as the scenario display name/alias, which will be used in all formatted reports.

### Finding more specific error messages

If the error message in the output is vague, it may be worth checking the log file (logfile.txt in the workspace directory) for a more detailed error message including full stack trace.

### ERROR: Cannot create plan with name '\_\_\_\_\_', name is reserved

Certain scenario internal/workspace names are reserved within the workspace for internal use. These include “tmp”, “historical”, and “modern.”

### ERROR: Could not create feature dataset with plan name. Ensure plan name is valid as a feature dataset name

The scenario internal/workspace name must abide by certain naming conventions. See “Scenario naming” subsection at the top of this section.

### Error code: 00144

If an error message with the above error code appears, the version of ArcGIS running does not have the required license or extension. Certain modules require the Spatial Analyst extension to be enabled.

## Tool customization (modifying internal inputs/parameters)

### Adding a custom habitat type

To add a new custom habitat type, add a new row to the habitat types crosswalk table located at data\tables\habitat\_types\_crosswalk.csv. The first column is habitat type label (case insensitive, but for consistency leave lowercase). The second column indicates the tidal classification. Mark “1” where a group definition is required for only tidal variations of this new habitat type. Mark “0” if this group definition is for only non-tidal variations of this new habitat type. Leave blank for a group definition that

applies to any of this habitat type (ignoring tidal/non-tidal). If tidal and/or non-tidal variations of the habitat types are expected and handled differently, you may need multiple rows for the new habitat classification, one for each tidal and non-tidal. For each of the other columns in this row, mark "1" where this new habitat type fits in the grouping defined by the column.

In most cases, data is passed to the summary report already grouped via the habitat types crosswalk, propagating changes made in the habitat type crosswalk table to the report. However, a few exceptions use hard-coded values or other crosswalk tables that must also be updated when applicable. The Delta Plan habitat targets table must also be updated if the custom habitat type falls under Delta Plan habitat type group. Habitat groups in the "Habitat change" section of the table in the "Summary" module are currently hard-coded, and updating these requires a modification and rebuild of the summary report application, which is not covered here.

Additionally, map symbologies cannot be dynamically updated, and the habitat types and scenario overlay maps will not show custom habitat type classes unless the map template is manually modified to accommodate them.

#### Adding or modifying crop groups and prices

The table for mapping crop groups and estimated revenue by crop type is located at `data\tables\crop_types_crosswalk.csv`. The column `CROP_GROUP` determines the grouping mapped for the crop type on which several metrics are summarized. Each crop type must be unique (thus only supports a one-to-one mapping to one crop group). The column `REVENUE_PER_ACRE` represents the estimated revenue in dollars per acre of this crop type.

#### Updating an input to a custom dataset

Updating an input dataset can have unexpected and undesirable results. As such, it is only recommended for advanced users, and all work should be properly backed up before saving changes.

To update a specific input, change the value associated with the relevant variable in the file `scripts/common/Inputs.py` to point to the new input dataset. There may be a relevant attribute field parameter to update as well. Note that some inputs are expected to have specific values and attributes which are hard-coded. Some of these are noted in comments above the variable assignment. Others may not be and will require looking into the scripts for the associated module analysis and output scripts.

## Analysis Modules

The sections below provide additional information on each analysis module, including background information on why the module is relevant to landscape planning, details on the analysis methods, lists of the relevant inputs, outputs, and tool parameters, and other key considerations/caveats when using the module and interpreting its results.

### Habitat Types

#### Summary:

Changes in the extent of different habitat types within the Delta are a basic way of understanding how the system has changed, and restoration goals are often linked to specific acreage targets for different habitat types. Habitat types, as discussed here, denote broad classifications of ecological communities determined largely by vegetation type, as well as climatic and hydrologic characteristics; these broad types are not meant to represent habitat for particular species. This module quantifies the extent of and net change in habitat types for user scenarios as compared to the modern and historical Delta. This module also compares the amount of habitat types expected under different scenarios to the Delta Plan's restoration goals for different natural communities.

Note that the habitat types analyses are prepared by default when adding scenarios. As such, it does not appear on the Run Analyses tool.

#### Tool analysis methods:

- For user scenarios, creates habitat vision by erasing the scenario overlay from modern habitat then merging the overlay on top.
- Creates "change polygons" by determining wherever the scenario's habitat type differs from the modern habitat type.

#### Key considerations and caveats:

Habitat types used in these analyses are broad classifications and do not account for differences in habitat quality, including differences in hydrology or vegetation structure and composition, between polygons of the same habitat type.

Habitat types must be from one of the recognized values. See [Habitat types](#) in the Tool Overview section for more information.

As noted in the “developing scenarios” section, it is important to ensure the scenario overlay contains no overlapping polygons. There is currently no automatic detection or correction of such topology issues and as a result, such overlaps will be double-counted in areal calculations.

File inventory:

All outputs are in units of hectares (where applicable).

Input / Output	Name / Desc.	File Name
input	Historical Delta habitat types	data\LSPT_data_package_SFEI\LSPT_data_package_SFEI.gdb\Habitat_types_historical_forLSPT
input	Modern Delta habitat types	data\LSPT_data_package_SFEI\LSPT_data_package_SFEI.gdb\Habitat_types_modern_forLSPT
input	Delta Plan restoration targets	data\tables\delta_targets.csv
output - workspace	Copy of input user scenario overlays	{scenario}_scenario_overlay
output - workspace	New habitat vision with scenario overlays	{scenario}_habitat_vision
output - workspace	Open water in habitat vision for scenarios	{scenario}_open_water
output - workspace	Changed habitat cover in habitat vision for scenarios	{scenario}_changed
output - report	Habitat cover for scenarios	{scenario}_habitat.shp
output - report	Habitat metrics for all scenarios	habitat.csv
output - report	Copy of habitat targets	habitat_targets.csv

**Levees**

Summary:

Note that levee analyses are executed by default when adding scenarios (assuming the optional levee layer is supplied) because of dependencies on levees in other modules (e.g. Fish support). While they are treated as their own analysis in the tool code, the results are grouped under the “Infrastructure” section in the report. See the “Infrastructure” below for more information.

The levee analysis is only run on user scenarios, as it measures change from modern conditions. If no levee layer is provided for a scenario, no related results are included in the “Infrastructure” section of the output report.

Tool analysis methods:

- Erases scenario levees from modern levees and vice versa to determine added and removed levee centerlines.

### Key considerations and caveats:

As noted in the “Developing Scenarios” section, change analysis on the inputted scenario levee layer is done via simple overlap/erase with the modern levee layer. As such, even a small offset will be treated as if the levee was removed and added a slight distance away. To avoid such errors, begin with the default modern levee layer packaged with this tool, and make modifications on a copy of that.

### File inventory:

All outputs in units of kilometers (where applicable).

Input / Output	Name / Desc.	File Name
input	Modern delta levees	data\LSPT_data_package_SFEI\LSPT_data_package_SFEI.gdb\Levees_modern_forLSPT
output - workspace	Copy of input user scenario levees	{scenario}_levee_centerlines
output - workspace	Levee change (added) in scenarios	{scenario}_levee_centerlines_added
output - workspace	Levee change (removed) in scenarios	{scenario}_levee_centerlines_removed
output - report	Levees for scenarios	{scenario}_levee.shp
output - report	Levee change (added) in scenarios	{scenario}_levee_added.shp
output - report	Levee change (removed) in scenarios	{scenario}_levee_removed.shp
output - report	Levee metrics for all scenarios	levee_metrics.csv

## **Marshes**

### Summary:

Tidal and non-tidal emergent wetlands (marshes) dominated the Delta landscape historically, but are largely absent from the Delta today. Marshes provide habitat for many species and influence water quality, carbon storage, and nutrient cycling. This module summarizes the extent and configuration of marsh patches in the user scenarios, as compared to the historical and modern Delta and Suisun Marsh. This includes the size distribution of marsh patches, the distance of marsh patches to the nearest large patch, and the shape of marsh patches (core:edge ratio). In addition to the total amount of marsh in an area, the way that marshes are configured in the landscape also affects the benefits they provide. Large marsh patches support more habitat complexity, greater species diversity, and larger wildlife populations than smaller marsh patches. Connections between marsh patches are important for wildlife dispersal, gene flow, and population resilience. The average nearest large neighbor distance is a very simplified measurement of marsh connectivity. The shape of marsh patches affects their function. Areas of a patch close to its outer edge generally experience different abiotic conditions than areas within its “core,” are less accessible to many predators of marsh wildlife, and are more buffered from human disturbance in

the modern landscape. This module uses metrics developed as part of the Delta Landscapes project. More details about the methodology can be found in *A Delta Transformed* (SFEI-ASC 2014).

Note that in the Run Analyses tool, the Marshes module appears as “Marsh and woody riparian habitat” as the analyses are grouped to remove redundancy from certain overlapping processes. Because they are computationally expensive, this module does not run the marsh network connectivity analyses, which are instead split into a separate analysis in the Run Analyses tool. See the “Marsh network connectivity” section below for more information.

#### Tool analysis methods:

- Creates marsh patches:
  - Selects marsh habitat type group polygons.
  - Dissolves and splits into single-part polygons.
  - Aggregates polygons to determine grouping of nearby polygons.
  - Buffers and dissolves (single-part) to create individual features from groups.
  - Intersects above output with output from first dissolve to identify individual patch groups in original geometry.
  - Dissolves single-part polygons back into the final patch layer.
- Determines and marks large patches by query on patch area.
- Performs patch core analysis via inner buffer.
- Performs nearest neighbor analysis via near table tool.

#### Key considerations and caveats:

This analysis assumes the areas identified as marsh in the user-defined scenarios will become or remain marsh. This may be less likely in certain areas due to climate change and sea-level rise or other factors.

During the output/final step, limiting the outputs by the area of analysis will clip patches to the area of analysis. However, many statistics will be reported for the full patch sizes and full extent.

Determination of large patches and the statistics for average and maximum patch size are computed assuming the full patch sizes of patches within the area of analysis (whether the full size is contained within the area of analysis or not). Conversely, areal totals are reported after clipping the patch size to the area of analysis. For example, if a large patch (> 100 ha) is clipped such that only 4 ha of its intersection with the area of analysis remains, it is still counted as a large patch (> 100 ha) while only adding 4 ha to the total large patch area in the area of analysis.

Core area and core/edge area ratios are reported after clipping to the area of analysis.

Nearest distance statistics are reported for the entire dataset. That is, the nearest distance value for a patch may be referring to a patch outside the area of analysis.

For outputs of the patches shapefile and the marsh metrics tables, all fields except “Patch\_Marsh\_CoreArea” and “Area\_Hectares” are reporting original numbers before clipping to the area of analysis.

Predefined parameters:

For habitat types considered marsh, see “[Habitat types](#)” in the “Tool Overview” section.

Parameter	Value	Citation	Notes
Buffer tolerance	0.1 m		Needed to force polygons that are connected at one point to aggregate into a single patch
Patch aggregation distance	60 m	SFEI-ASC 2014	
Edge width	50 m	SFEI-ASC 2014	
Large marsh patch size	100 ha	SFEI-ASC 2014	
Mean black rail dispersal distance	5.48 km	Hall 2015	

File inventory:

All output metrics in length units of hectares and meters (where applicable), unless otherwise noted.

Input / Output	Name / Desc.	File Name	Notes
output - workspace	Marsh patches for scenarios	{scenario}_marsh_patches	near distances in meters
output - workspace	Changed marsh patches for user scenarios	{scenario}_marsh_patches_changed	
output - workspace	Marsh patch cores for scenarios	{scenario}_marsh_cores	
output - workspace	Marsh and water areas for scenarios	{scenario}_marsh_water	
output - report	Marsh patches for scenarios	{scenario}_patches.shp	Near distances in meters. Field Patch_Marsh_Area refers to the full patch area before clipping to the analysis area. Fields Area_Hectares and Patch_Marsh_CoreArea report area after clipping to analysis area
output - report	Changed marsh patches for user scenarios	{scenario}_patches_changed.shp	
output - report	Marsh patch cores for scenarios	{scenario}_cores.shp	
output - report	Open water areas for scenarios	{scenario}_water.shp	

output - report	Marsh metrics for scenarios	{scenario}_marsh_metrics.csv	
output - report	Open-water-to-marsh metrics for all scenarios	openwater.csv	

## Marsh network connectivity

### Summary:

Connections between marsh patches are important for wildlife dispersal, gene flow, and population resilience. The likelihood that a marsh patch will be colonized (or re-colonized after a disturbance event) by native wildlife is expected to increase with proximity to other marsh patches. The functional connectivity of marshes for wildlife depends on how each marsh is positioned on the landscape relative to every other marsh and how accessible each habitat patch is for dispersing animals. The analysis performed in this module assesses the probability that two marsh birds (black rails, *Laterallus jamaicensis coturniculus*) randomly placed would end up in the same marsh patch (and hence reproduce) via dispersal. Here the black rail can serve as a useful proxy for other marsh wildlife to inform how the connectivity of the whole marsh network has changed over time. Due to its computationally intensive nature, this analysis is split out as the “Marsh network connectivity” analysis in the Run Analysis tool. However both are grouped under the Marshes section in the output report. The stepping stone analysis is not run for the historical scenario.

### Tool analysis methods:

- Filters marsh patches to those greater than minimum considered patch size.
- Runs a graph-based network analysis to determine connectivity of filtered patches (see below for additional details)
- For stepping stone, runs a modified version of the above analysis on each 100-ha cell in the hex grid.

Marsh network connectivity metrics are based on the “probability of connectivity” index (PC; Saura and Pascual-Hortal 2007) using the area of aggregated marsh polygons and the distance, edge-to-edge, between these polygons. Dispersal probabilities between patches for Black Rails were estimated using the negative exponential of empirically-derived, mean natal dispersal distances (5.58 km; Hall et al. 2018). Ordered rankings for marsh patches for their importance to landscape-scale connectivity were calculated with  $dPC_k$ , which is the percentage of change in connectivity caused by removal of each individual patch from the extent of the hex grid. In addition, for each patch we calculated the three additive components that comprise total connectivity as quantified by the  $dPC_k$  (Saura and Rubio 2010): (i)  $dPC_{intra_k}$ , or the amount patch  $k$ 's area contributes to connectivity; (ii)  $dPC_{flux_k}$ , or how well connected patch  $k$  is to other

patches in the marsh network; (iii)  $dPCconnector_k$  or patch  $k$ 's contributions to the connectivity between other patches, in other words, how well it serves as a stepping-stone habitat. Each of these connectivity components is attributed to each patch in the network in its own corresponding field, allowing advanced users to explore the results further.

While the contribution of each individual patch to the total network connectivity was determined by iteratively *removing* each patch from the network and quantifying the impact on connectivity, determining areas where new marshes would most improve connectivity as stepping stone habitat used the opposite process—iteratively *adding* individual hypothetical patches to the network and quantifying how much they increase stepping-stone connectivity ( $dPCconnector_k$ ).

#### Key considerations and caveats:

This analysis uses a binary model of the landscape (marsh and non-marsh) that simplifies the complexities of how species interact with their surroundings.

To optimize the calculations, only patches over the minimum considered patch size are taken into account.

The output stepping stone connectivity is limited to the LSPT study extent as defined by the 100 ha hex-grid (created on the NAD83 California Albers projection [EPSG:3310]). However, patches located outside of the grid can still influence the grid itself.

#### Predefined parameters

For habitat types considered marsh, see "[Habitat types](#)" in the "Tool Overview" section.

Parameter	Value	Citation	Notes
Minimum considered patch size	5 ha		
Area of analysis (for whole Delta and Suisun Marsh)	4,034.44 sq km		Calculated on the NAD83 California Albers projection (EPSG:3310)
Mean black rail dispersal distance	5.48 km	Hall 2015	

#### File inventory:

All outputs use length units of kilometers (where applicable).

Input / Output	Name / Desc.	File Name
input	Delta 100 ha hex-grid (defines each feature analyzed for potential contribution to network connectivity)	data\LSPT_data_package_SFEI\LSPT_data_package_SFEI.gdb\Marsh_network_connectivity_100ha_hexgrid
output - workspace	Connectivity marsh patches for scenarios	{scenario}_connectivity_patches
output - workspace	Near table of connectivity patches for scenarios	{scenario}_connectivity_near

output - workspace	Connectivity stepping-stone hex grid for scenarios	{scenario}_connectivity_grid
output - workspace	Connectivity stepping-stone near table for scenarios	{scenario}_connectivity_grid_near
output - report	Connectivity marsh patches for scenarios	{scenario}_connectivity_patches.shp
output - report	Connectivity stepping-stone hex grid for scenarios	{scenario}_connectivity_grid.shp
output - report	Connectivity metrics for scenarios	connectivity_{scenario}.csv

## Woody riparian areas

### Summary:

Woody riparian areas interface between aquatic environments and more terrestrial areas and provide structurally complex environments that support diverse species. Woody riparian habitat in the Delta supports several endemic riparian species, provides shade and food resources for fish, and nesting and roosting sites for waterbirds. This module quantifies the extent and patch size distribution of woody riparian habitat types in the user scenarios, as compared to the historical and modern Delta. This module uses metrics developed as part of the Delta Landscapes project. More details about the methodology can be found in *A Delta Transformed* (SFEI-ASC 2014).

Under the Run Analyses tool, this appears as "Marsh and woody riparian habitat" as the analyses are grouped to remove redundancy from certain overlapping processes. However, the outputs are treated as separate sections in the report.

### Tool analysis methods:

- Creates riparian patches using a similar process as in the marshes module, but starting with woody riparian habitat type group polygons.

### Key considerations and caveats:

As opposed to marsh patch metrics, all woody riparian patch metrics are all given after clipping to the area of analysis.

### Predefined parameters:

For habitat types considered woody riparian, see "[Habitat types](#)" in the "Tool Overview" section.

Parameter	Value	Citation	Notes
Patch aggregation distance	100 ha	SFEI-ASC 2014	

### File inventory:

All outputs in units of hectares (where applicable).

Input / Output	Name / Desc.	File Name
output - workspace	Woody riparian patches for scenarios	{scenario}_riparian_patches
output - report	Woody riparian patches for scenarios	{scenario}_riparian_patches.shp
output - report	Woody riparian patch metrics for all scenarios	riparian.csv

## **Wetland buffer**

### Summary:

Terrestrial areas near perennial wetlands and open water provide a range of benefits, depending on various factors, especially that include their distance to the wetlands or open water. Protecting a buffer around wetlands and aquatic areas provides space for a variety of other important ecological processes operating across estuarine-terrestrial transition zones, including providing the terrestrial habitat required by semi-aquatic reptiles and amphibians. These buffers can also act as protection from environmental stressors such as contaminants and invasive species. This module quantifies the amount of terrestrial area near marsh and open water, and quantifies the amount of buffer composed of natural upland habitat types versus highly modified human dominated habitat types within the analysis area.

### Tool analysis methods:

- Buffers polygons of perennial wetlands and open water habitat type groups.
- Intersects buffer with habitat to get habitat types in wetland buffer.
- Extracts land cover by habitat type of natural terrestrial in the wetland buffer; remainder is assumed to be highly modified.

### Predefined parameters:

For habitat types considered “perennial wetlands,” “open water,” and “natural terrestrial” , see “[Habitat types](#)” in the “Tool Overview” section.

Parameter	Value	Citation	Notes
Buffer width	290 m	Semlitsch and Bodie 2003	

### File inventory:

Input / Output	Name / Desc.	File Name
output - workspace	Wetland buffer for scenarios	{scenario}_wtbuffer
output - workspace	Habitat types in buffer zone for scenarios	{scenario}_wtbuffer_habitat
output - workspace	Natural habitat in buffer zone for scenarios	{scenario}_wtbuffer_natural

output - report	Wetland buffer for scenarios	{scenario}_marsh_water.shp
output - report	Habitat types in buffer zone for scenarios	{scenario}_wtbuffer.shp
output - report	Natural habitat in buffer zone for scenarios	{scenario}_wtbuffer_natural.shp
output - report	Wetland buffer metrics for all scenarios	wtbuffer_metrics.csv

## Fish support

### Summary:

Wetland loss and other landscape scale changes have dramatically altered fish habitats in the Delta. Historically, much of the Delta was characterized by slow-water habitat, highly productive floodplains, and marsh-influenced habitats that provided many resources and opportunities for native fish. Aquatic habitats are characterized by wider, deeper, straighter channels that are often leveed off from adjacent wetland and floodplain habitats. In addition, the fish community in the Delta today is dominated by non-native species, and many native species are in decline. This module assesses several aspects of fish habitat that are thought to support native fish in the Delta. These analyses include the amount of marsh area, the marsh to open water ratio, connectivity of large wetlands, extent and quality of channel edges, and percent of scenario wetlands that are within specified water temperature thresholds in the analysis area. These analyses build on metrics developed for the Delta Landscapes project (SFEI-ASC 2014) and work done in collaboration with the Collaborative Adaptive Management Team (CAMT) to identify suitable rearing habitat for Chinook salmon in the Delta (SFEI-ASC 2020). For juvenile salmonids migrating out through the Delta, the distribution of habitat types along their migratory pathways affects the likelihood and frequency of finding suitable conditions necessary for growth and survival.

This analysis requires the Marshes module (which appears as “Marsh and woody riparian habitat” in the Run Analyses tool) to have been run first.

### Tool analysis methods:

- Prepares hydrologically “connected wetland patches:”
  - Selects tidal and nontidal marsh habitat type and woody riparian habitat type group polygons from which to create contiguous wetland polygons.
  - Erases levee centerlines (buffered by 1 m) from selection.
  - Filters, via a spatial selection, contiguous polygons intersecting with connected open water (water types contiguous with any features belonging to the tidal wetland habitat type group). Because levees were erased from the wetland patches above, this operation only selects parts of wetlands on the “water side” of the levee (most wetland areas on the

- landward side of the levees are no longer contiguous with connected open water areas after the levees are erased and are thus not selected).
- Creates hydrologically “connected wetland patches” (same process as making patches in Marshes module).
  - Determines large wetland patches via query on patch area.
  - Prepares hydrologically “connected tidal wetland patches” using same method as above, only limiting polygon selection to tidal marsh habitat types.
  - Creates inter-wetland distance rasters using cost distance to connected wetland patches via open water (requires spatial analyst license).
  - Clips connected tidal wetland patches within 2 km of connected open water via buffer and clip.
  - Channel edge analysis:
    - Selects marsh habitat type and woody riparian habitat type group polygons from which to create contiguous wetland polygons.
    - Erases levee centerlines (buffered by 1 m) from selection.
    - Determines channel edges as boundaries of contiguous wetland polygons (after being split by levees) with connected open water via an intersection. This only attributes the area of the wetland polygons on the “water side” of the levee to the channel edge.
    - For each wetland polygon:
      - Calculates the total polygon area per length of channel edge.
    - For distinct channel edge line-part:
      - Calculates the assigned area as a proportion of its length to the total channel edge length of the polygon it is assigned.
      - Calculates the assigned area per length.
  - Temperature analysis:
    - Only done for user scenarios.
    - Converts temperature rasters to polygons, buffers warm water areas (as defined in each raster) 1 kilometer.
    - Unions resulting layers with connected wetland patches (see “Prepares hydrologically “connected wetland patches” above) to identify which parts of patches are near (<1 km) from warm water and which parts are far (>1 km).

Key considerations and caveats:

Pixel size for raster analyses is fixed to 10 meters, for ease of subsequent calculations.

Channel edges are defined by intersecting open water polygons with adjacent habitat types. If a scenario is meant to include new channels, these features must be explicitly digitized as polygons and included in

the scenario habitat type modification overlay to be captured by the tool. If users already have digitized channel lines, these features can be buffered by their typical width and then added to the overlay layer.

### Predefined parameters:

Wetland patches are formed from habitat type polygons that are part of the “Marsh” or “Woody riparian” habitat type groups (see “[Habitat types](#)” in the “Tool Overview” section for more details).

Parameter	Value	Citation	Notes
Large wetland patch size	100 ha	SFEI-ASC 2014	

### File inventory:

Unless specifically noted otherwise below, all length units for outputs and attribute data given in meters, including assigned area per channel edge in ha m<sup>-1</sup>.

Input / Output	Name / Desc.	File Name	Notes
input	Temperature exceedance 20° (>15 days Nov-May)	data\LSPT_data_package_SFEI\LSPT_data_package_SFEI.gdb\Fish_support_temp_20C_15days_NovMay	
input	Temperature exceedance 24° (>15 days Jun-Oct)	data\LSPT_data_package_SFEI\LSPT_data_package_SFEI.gdb\Fish_support_temp_24C_15days_JunOct	
input	Temperature exceedance 27° (>15 days Jun-Oct)	data\LSPT_data_package_SFEI\LSPT_data_package_SFEI.gdb\Fish_support_temp_27C_15days_JunOct	
output - workspace	Copy of temperature exceedance raster	20c_novmay_fish_temp_exceedance	
output - workspace	Copy of temperature exceedance raster	24c_junoct_fish_temp_exceedance	
output - workspace	Copy of temperature exceedance raster	27c_junoct_fish_temp_exceedance	
output - workspace	Areas within 1 km of available temp. data	27c_junoct_fish_temp_exceedance_ava il_1km	
output - workspace	Connected open water areas for scenarios	{scenario}_open_water_connected	
output - workspace	Connected wetland patches (“fish patches”) for scenarios	{scenario}_fish_patches	
output - workspace	Subset of connected wetland patches (“fish patches”) that have been altered in user scenarios	{scenario}_fish_patches_changed	
output - workspace	Subset of connected wetland patches (“fish patches”) that are considered large in user scenarios	{scenario}_fish_large_patches	
output - workspace	Cost distance raster to connected wetland patches for scenarios	{scenario}_fish_distance_patches	- pixel units in meters
output - workspace	Cost distance raster to large connected wetland patches for scenarios	{scenario}_fish_distance_large_patches	- pixel units in meters
output - workspace	Portions of connected wetland patches	{scenario}_fish_wetland_within_2km	

	within 2 km of connected open water		
output - workspace	Contiguous wetland polygons for channel edge analysis for scenarios	{scenario}_fish_weighted_edge_patches	
output - workspace	Channel edges for scenarios	{scenario}_fish_weighted_edge_shorelines	- length and assigned area given in meters and ha/m
output - workspace	Connected wetland patches with temperature exceedance data for scenarios	{scenario}_fish_temperature	
output - report	Copy of temperature exceedance raster	20c_novmay_temp_exceedance.tiff	
output - report	Copy of temperature exceedance raster	24c_junoct_temp_exceedance.tiff	
output - report	Copy of temperature exceedance raster	27c_junoct_temp_exceedance.tiff	
output - report	Cost distance raster to connected wetland patches for scenarios	{scenario}_fish_distance_all.tiff	- pixel units in meters
output - report	Cost distance raster to large connected wetland patches for scenarios	{scenario}_fish_distance_large.tiff	- pixel units in meters
output - report	Connected open water areas for scenarios	{scenario}_fish_connected_water.shp	
output - report	Connected wetland patches for scenarios	{scenario}_fish_patches.shp	
output - report	Large connected wetland patches for scenarios	{scenario}_fish_large_patches.shp	
output - report	Portions of connected wetland patches within 2 km of connected open water for patches	{scenario}_fish_wetland_within_2km.shp	
output - report	Channel edges for scenarios	{scenario}_weighted_shoreline.shp	
output - report	Subset of connected wetland patches that have been altered as part of user scenarios	{scenario}_fish_patches_changed.shp	
output - report	Connected wetland patches with temperature exceedance data for scenarios	{scenario}_fish_temp_patches.shp	
output - report	Connected wetland patches within 2 km of connected open water metrics for all scenarios	fish_wetland_within_2km.csv	
output - report	Distance to large connected wetland patch metrics for all scenarios	fish_distances_large.csv	
output - report	Average distance to connected wetland patch metrics for all scenarios	fish_avg_distance.csv	
output - report	Channel edge metrics for scenarios	{scenario}_fish_weighted_shorelines.csv	- length and assigned area given in meters and ha/m
output - report	Connected wetland patches with temperature exceedance metrics for all scenarios	fish_temperature.csv	

## **Inundation**

### Summary:

Most wetlands and floodplain habitats in the Delta region have been lost due to being drained, leveed, and converted to agricultural land use (SFEI-ASC 2014). As noted in the Delta Plan (DSC 2019), restoring functional tidal and riverine floodplains is expected to result in enhanced primary productivity, an improved food web, and improved transfer of nutrients that can better support a healthy and functioning ecosystem (Ahearn et al. 2006, Cloern et al. 2016). Some agricultural land and floodways can provide functions similar to natural wetlands, including greatly increased aquatic food production compared to other converted land uses (Moyle, Crain, and Whitener 2007; Corline et al. 2017; Katz et al. 2017).

Restoration of land-water connections provide ecosystem benefits that require hydrologic connectivity that allows the flow of water onto the land surface and does so frequently enough (Matella and Merenlender 2013). The Delta Plan Performance Measures thus consider both the area of “hydrologically connected” lands and the portion of these connected lands that are non-tidal floodplain areas “regularly inundated” at least once every two years. This module quantifies the baseline area of hydrologically connected and regularly inundated areas within the analysis area. The tool also estimates how scenarios are expected to alter hydrologically connected area based on changes in the mapped extent of tidal emergent wetlands. The tool does not estimate change to regularly inundated non-tidal floodplain area, which is generally dependent on fine-scale levee configuration changes and water management actions that the tool cannot currently predict.

For baseline inundation conditions within the analysis area, the maps/methods used to establish the Delta Plan Performance Measures and the baseline for the LSPT. The LSPT baseline includes the full extent of tidal wetlands, which are classified as hydrologically connected (drawn from the baseline modern 2015-2016 conditions and, depending on user input, EcoRestore restoration projects). For scenario impacts, the tool quantifies how changes to the extent of tidal marshes would be expected to alter the extent of hydrologically connected areas.

### Tool analysis methods:

- Prepares inundation reclass polygon from inundation raster, removing Liberty Island (requires ArcGIS Spatial Analyst extension).
- Selects tidal wetland habitat type group.
- Unions inundation reclass polygon, tidal wetland layer, and hydrologically connected layer.
- Clips result by the legal Delta and Suisun Marsh boundaries.

Key considerations and caveats:

The analysis is limited to the legal Delta and Suisun Marsh due to spatial limits of datasets used for analysis.

The analysis is based off of the Draft Delta Plan Performance Measure 4.15 (May 2020).

Predefined parameters:

For habitat types considered part of the tidal wetlands group see "[Habitat types](#)" in the "Tool Overview" section.

File inventory:

Input / Output	Name / Desc.	File Name	Notes
input	Hydrologically connected areas	data\LSPT_data_package_SFEI\LSPT_data_package_SFEI.gdb\Inundation_hydrologically_connected	
input	Inundation raster	data\LSPT_data_package_SFEI\LSPT_data_package_SFEI.gdb\Inundation_regularly_inundated	
input	Liberty Island inverse	data\LSPT_data_package_SFEI\LSPT_data_package_SFEI.gdb\Inundation_inverse_liberty_island	- for removing Liberty Island from regularly inundated areas (now perennial open water)
input	Legal Delta and Suisun Marsh	data\LSPT_data_package_SFEI\LSPT_data_package_SFEI.gdb\Boundary_LegalDelta_SuisunMarsh	- for clipping inundation, marks spatial limit of analysis
output - workspace	Copy of hydrologically connected areas	hydrologically_connected	
output - workspace	Vectorized inundation	inundation	
output - workspace	Inundation for scenarios	{scenario}_inundation	
output - report	Inundation for scenarios	{scenario}_inundation.shp	
output - report	Copy of Legal Delta and Suisun Marsh extent	legal_delta_suisun.shp	
output - report	Inundation metrics for all scenarios	inundation_metrics.csv	

## **Subsidence**

### Summary:

The majority of formerly tidal areas in the Delta are currently below sea level due to conversion of land to agriculture, urban development, management of wetlands, and other land uses. The low elevation of these areas makes them more susceptible to risk of flooding from rising sea levels or high intensity rain events. Subsided lands also put the reliability of the state's water supply at risk by increasing the likelihood of saltwater intrusion in the event of a levee-failure event. Land uses that keep soils dry most of the year—like some forms of agriculture and urban development— generally allow subsidence to continue.

Subsidence-reversal is a process that halts subsidence caused by organic soil oxidation and leads to increases in land elevation through accumulation of new soil. Examples of subsidence-reversal actions include 1) fill placement and 2) accreting organic material via natural wetland process (sometimes referred to as "tule farming"). Some forms of cultivation (notably rice and other wetland-based farming) may provide a compromise that allows for agricultural income with less impacts to elevation and greenhouse gas flux. Pilot subsidence-reversal wetlands have shown that accretion rates vary over space and time and are influenced by management practices (Miller et al. 2008; Stumpner et al. 2018), with an average of about 3-4 cm of vertical accretion per year (Miller et al. 2008).

This module quantifies the current extent of deeply and shallowly subsided lands, the proportion of subsided lands covered by wetted habitat types, and the number of years it would take for existing subsided areas to reach sea level via subsidence reversal.

The analysis is only run on user scenarios with some preparation done on the modern scenario.

### Tool analysis methods:

- Finds subsided lands not covered by connected open water.
- Clips subsided lands to wetted and open water habitat type group on subsided lands.
- Erases scenario's wetted and open water habitat types on subsided lands from the modern's equivalent and vice-versa to determine areas gained and lost in the scenario.
- Extracts years to SLR raster by habitat vision and by wetted habitat types (not including open water) in the habitat vision (requires spatial analyst extension). This analysis is currently limited to the legal Delta.

Predefined parameters:

For habitat types considered part of the wetted habitat and open water group see “[Habitat types](#)” in the “Tool Overview” section.

File inventory:

Input / Output	Name / Desc.	File Name	Notes
input	Geomorphic zones	data\LSPT_data_package_SFEI\LSPT_data_package_SFEI.gdb\Geomorphic_Zones	See metadata for detailed description of source elevation and tidal datum datasets
input	Years to SLR	data\LSPT_data_package_SFEI\LSPT_data_package_SFEI.gdb\Subsidence_years_to_rising_sea_level_via_wetlands	
output - workspace	Subsided lands	modern_subsidied_lands	
output - workspace	Wetted habitat on subsided lands for scenarios	{scenario}_wetted_habitat	
output - workspace	Wetted habitat gain on subsided lands for user scenarios	{scenario}_wetted_habitat_gain	
output - workspace	Wetted habitat loss on subsided lands for user scenarios	{scenario}_wetted_habitat_loss	
output - workspace	Years to sea-level-rise on subsided lands for user scenarios	{scenario}_subsidence_yrs_slr	
output - workspace	Years to sea-level-rise on new subsided lands for user scenarios	{scenario}_subsidence_yrs_slr_new	
output - report	Subsided lands	subsided_lands.shp	
output - report	Modern wetted habitat	wetted_habitat.shp	
output - report	Wetted habitat gain on subsided lands for user scenarios	{scenario}_wetted_habitat_gain.shp	
output - report	Wetted habitat loss on subsided lands for user scenarios	{scenario}_wetted_habitat_loss.shp	
output - report	Years to sea-level-rise on subsided lands for user scenarios	{scenario}_subsidence_slr.tif	
output - report	Years to sea-level-rise on new subsided lands for user scenarios	{scenario}_subsidence_slr_new.tif	
output - report	Subsidence metrics for all scenarios	subsided_land.csv	
output - report	Wetted habitat metrics for all scenarios	wetted_habitat.csv	
output - report	Years to sea-level-rise metrics for all scenarios	years_to_slr_all.csv	
output - report	Years to sea-level-rise on new subsided lands metrics for all scenarios	years_to_slr_new.csv	

## Agriculture

### Summary:

Agriculture dominates the Delta landscape, and is among the qualities that define the Delta as a special place. Agriculture is a primary land use, a food source, a key economic sector, and a way of life in the Delta. The Delta's agricultural economy is vital to the region and contributes to California's important agricultural economy. When planning and siting restoration projects, there is a need to balance ecosystem restoration with continued agriculture in the region. This module quantifies the change in extent of agricultural lands, the crop type of converted agricultural lands, and the extent of agricultural lands converted to urban areas (a Delta Plan performance measure).

### Tool analysis methods:

- Extracts all agriculture in modern habitat using the agriculture habitat type group.
- For each user scenario, extracts agriculture in habitat vision by habitat type.
- Unions scenario agriculture with modern agriculture to identify polygons of lost and gained agriculture
- Determines lost crop and FMMP type from lost agriculture. For crop types, gained and changed crop types are also tallied.
- Determines areas where agriculture is lost to urban by intersecting "lost agricultural areas" with the scenario habitat types and selecting urban habitat type group from the result.
- Gets crop type and FMMP type lost by clipping these datasets to the "lost agriculture" layer.

### Key considerations and caveats:

Crop type and FMMP type loss is only analyzed within the spatial constraint of areas of agriculture lost according to habitat type. That is, if the land cover in the modern habitat layer does not indicate it was previously agriculture but there is a crop type or FMMP type attribute value there, it will not be counted. This ensures that the total areas of crop type or FMMP type lost cannot exceed the total area of agriculture lost by habitat change.

### File inventory:

Input / Output	Name / Desc.	File Name	Notes
input	Crop and FMMP type from modern habitat layer	data\LSPT_data_package_SFEI\LSPT_data_package_SFEI.gdb\Habitat_types_modern_forLSPT_20210908	Uses attribute Crop2016 and FMMP2016
output - workspace	Agriculture habitat cover for scenarios	{scenario}_agriculture	
output - workspace	Modern crop types on agriculture	modern_crop_type	

output - workspace	Modern FMMP types on agriculture	modern_fmmp	
output - workspace	Agriculture habitat cover changed for user scenarios	{scenario}_agriculture_change	
output - workspace	Crop types lost for user scenarios	{scenario}_crop_lost	
output - workspace	Crop types gained for user scenarios	{scenario}_crop_gained	
output - workspace	Crop types changed for user scenarios	{scenario}_crop_changed	
output - workspace	FMMP types lost for user scenarios	{scenario}_fmmp_lost	
output - report	Agriculture habitat cover for scenarios	{scenario}_agriculture.shp	
output - report	Modern crop types on agriculture	modern_crop_type.shp	
output - report	Modern FMMP types on agriculture	modern_fmmp.shp	
output - report	Crop types on agriculture lost for user scenarios	{scenario}_crop_lost.shp	
output - report	Crop types on agriculture gained for user scenarios	{scenario}_crop_gained.shp	
output - report	Crop types changed on neither gained nor lost agriculture for user scenarios	{scenario}_crop_changed.shp	
output - report	FMMP types lost for user scenarios	{scenario}_fmmp_lost.shp	
output - report	Agriculture habitat cover changed for user scenarios	{scenario}_agriculture_change.shp	
output - report	Agriculture habitat cover lost to urban for user scenarios	{scenario}_ag_lost_to_urban.shp	
output - report	Agriculture metrics for all scenarios	ag_metrics.csv	
output - report	Crop type metrics for all scenarios	ag_crop_metrics.csv	
output - report	Crop type group metrics for all scenarios	ag_crop_group_metrics.csv	
output - report	FMMP type metrics for all scenarios	ag_fmmp_metrics.csv	

## Economics

### Summary:

Economic viability is a key element of establishing sound trajectories of change toward more resilient future landscapes. This module provides agricultural revenue estimates for the scenario(s) evaluated, as well as a qualitative assessment of other economic costs and benefits associated with land use conversions. Together, these analyses can facilitate the consideration of economic tradeoffs and co-benefits of selected scenario(s).

### Tool analysis methods:

- Uses crop type gained, lost, and changed layers from the Agriculture module to determine changed crop types by area.
- Crosswalks crops types to estimated gross revenue based on estimated yield and price per yield values. (Unspecified crop types are tallied separately.)
- Identifies land use conversions in key categories (e.g. non-tidal wetland to tidal wetland, non-rice agriculture to non-tidal wetland) for reference in the qualitative cost/benefit analysis tables in the tool output.

### Key considerations and caveats:

Revenue reported in this module is *gross revenue only*. Estimates of net revenue or profit require knowledge of spatially-explicit production costs, land and establishment costs, debts, and other operating costs associated with specific agricultural operations. Agricultural gross revenue values used in this module are based on average crop yields and prices for Sacramento, San Joaquin, Contra Costa, Yolo, and Solano counties. Actual revenues vary by site and over time, depending on various factors such as land characteristics, management, disturbances, and crop prices.

### Predefined parameters

For habitat types considered “tidal wetland,” “non-tidal wetland,” “natural terrestrial,” “rice,” and “non-rice agriculture”, see “[Habitat types](#)” in the “Tool Overview” section. The crop type crosswalk table is used to estimate crop price values for estimated revenue change.

Parameter	Value	Citation	Notes
Crop Yield	Varies by crop	<a href="#">USDA National Agricultural Statistics Service</a>	Regional values are based on county-level data (averaged across Sacramento, San Joaquin, Contra Costa, Yolo, and Solano counties) from 2014-2017. These data were summarized by researchers in the UC Merced Water Systems Management Lab to support the OpenDAP model (lab website: <a href="https://wsm.ucmerced.edu/">https://wsm.ucmerced.edu/</a> ).
Crop Price Per Yield	Varies by crop	<a href="#">USDA National Agricultural Statistics Service</a>	Regional values are based on county-level data (averaged across Sacramento, San Joaquin, Contra Costa, Yolo, and Solano counties) from 2014-2017

### File inventory:

Input / Output	Name / Desc.	File Name	Notes
input - workspace	Crop types lost for user scenarios	{scenario}_crop_lost	
input -	Crop types gained for user	{scenario}_crop_grained	

workspace	scenarios		
input - workspace	Crop types changed for user scenarios	{scenario}_crop_changed	
output - workspace	Modern nontidal wetlands	modern_nontidal_wetland	
output - workspace	Land use conversions	{scenario}_econ_landuse_convs	
output - report	Crop type group change metrics for all scenarios	ag_crop_group_change.csv	
output - report	Revenue changes by crop type for all scenarios	ag_revenue_acres.csv	
output - report	Unidentified crop types gained/lost for all scenarios	ag_revenue_unidentified.csv	
output - report	Relevant land use changes for all scenarios	unquantified_costs_benefits.csv	

## Infrastructure

### Summary:

Infrastructure includes roads, levees, railways, transmission lines, water diversions, and oil and gas wells. For a given land-use scenario, compatibility with existing infrastructure is an important factor determining the project's cost and feasibility. In some cases, it may be possible to change existing infrastructure in order to achieve a given land use scenario. In other cases, high cost or regulations limit the degree to which infrastructure may be altered or removed, limiting the set of feasible scenarios. This module quantifies the total extent of infrastructure in the analysis area and identifies infrastructure that might be impacted by changes in land-uses associated with each scenario..

The analysis is only run on user scenarios with some preparation done on the modern scenario. While the levee analysis is handled separately, it is put under the infrastructure section in the report.

### Tool analysis methods:

- Copies inputs as modern.
- For each user scenario, extracts affected infrastructure via clip with habitat change layer.

### File inventory:

All output metrics in length units of kilometers (where applicable).

Input / Output	Name / Desc.	File Name
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input	Roads	data\LSPT_data_package_SFEI\LSPT_data_package_SFEI.gdb\Infrastructure_delta_roads
input	Railways	data\LSPT_data_package_SFEI\LSPT_data_package_SFEI.gdb\Infrastructure_rail
input	Oil and gas wells	data\LSPT_data_package_SFEI\LSPT_data_package_SFEI.gdb\Infrastructure_delta_oil_gas_wells
input	Gas pipelines	data\LSPT_data_package_SFEI\LSPT_data_package_SFEI.gdb\Infrastructure_delta_gas_pipelines
input	Transmission lines	data\LSPT_data_package_SFEI\LSPT_data_package_SFEI.gdb\Infrastructure_delta_transmission_lines
input	Water diversions	data\LSPT_data_package_SFEI\LSPT_data_package_SFEI.gdb\Infrastructure_delta_water_diversions
output - workspace	Copy of roads	modern_roads
output - workspace	Copy of railways	modern_rail
output - workspace	Copy of oil and gas wells	modern_wells
output - workspace	Copy of gas pipelines	modern_gaslines
output - workspace	Copy of transmission lines	modern_tlines
output - workspace	Copy of water diversions	modern_water_diversions
output - workspace	Roads on changed habitat cover areas for user scenarios	{scenario}_roads
output - workspace	Railways on changed habitat cover areas for user scenarios	{scenario}_rail
output - workspace	Oil and gas wells on changed habitat cover areas for user scenarios	{scenario}_wells
output - workspace	Gas pipelines on changed habitat cover areas for user scenarios	{scenario}_gaslines
output - workspace	Transmission lines on changed habitat cover areas for user scenarios	{scenario}_tlines
output - workspace	Water diversions within 1 km of changed habitat cover areas for user scenarios	{scenario}_water_diversions
output - report	Copy of roads	modern_roads.shp
output - report	Copy of railways	modern_rail.shp
output - report	Copy of oil and gas wells	modern_wells.shp
output - report	Copy of gas pipelines	modern_gaslines.shp
output - report	Copy of transmission lines	modern_tlines.shp
output - report	Copy of water diversions	modern_water_diversions.shp
output - report	Roads on changed habitat cover areas for user scenarios	{scenario}_roads.shp
output - report	Railways on changed habitat cover areas for user scenarios	{scenario}_rail.shp
output - report	Oil and gas wells on changed habitat cover areas for user scenarios	{scenario}_wells.shp

output - report	Gas pipelines on changed habitat cover areas for user scenarios	{scenario}_gaslines.shp
output - report	Transmission lines on changed habitat cover areas for user scenarios	{scenario}_tlines.shp
output - report	Water diversions within 1 km of changed habitat cover areas for user scenarios	{scenario}_diversions.shp
output - report	Infrastructure metrics (excluding water diversions) for all scenarios	infrastructure_metrics.csv
output - report	Water diversion metrics for all scenarios	diversion_metrics.csv

## Protected areas

### Summary:

The Delta community has a long standing interest in focusing conservation efforts on existing public lands. This module quantifies areas designated as protected or held under a conservation easement (defined by the California Protected Areas Database and the California Conservation Easement Database), and notifies the user if any land use modifications in their scenarios occur within protected areas.

Three maps generated: existing protection status and land use; scenario changes in protected areas

The analysis is only run on user scenarios with some preparation done on the modern scenario.

### Tool analysis methods:

- Imports inputs as modern and merges into combined protected areas layer.
- Intersects combined protected areas layer with modern habitat.
- For each user scenario, intersects combined protected areas layer with habitat vision and intersects separately with changed habitat layer.

### File inventory:

Input / Output	Name / Desc.	File Name
input	CPAD fee/title units	data\LSPT_data_package_SFEI\LSPT_data_package_SFEI.gdb\Protected_area_CPAD_2020
input	CCED easements	data\LSPT_data_package_SFEI\LSPT_data_package_SFEI.gdb\Protected_area_CCED_2020
output - workspace	CPAD fee/title units	modern_pareas_feetitle
output - workspace	CCED easements	modern_pareas_easements
output - workspace	Merged protected areas	modern_pareas_merged
output - workspace	Habitat types in protected areas for scenarios	{scenario}_pareas_habitat
output - workspace	Changed habitat cover in protected areas for	{scenario}_pareas_changed

	user scenarios	
output - report	Merged protected areas	modern_pareas_merged.shp
output - report	CPAD fee/title units	modern_pareas_feetitle.shp
output - report	CCED easements	modern_pareas_easements.shp
output - report	Habitat types in protected areas for scenarios	{scenario}_pareas_habitat.shp
output - report	Changed habitat cover areas for user scenarios	{scenario}_pareas_changed.shp
output - report	Changed habitat cover in protected areas for user scenarios	{scenario}_pareas_in_changed.shp
output - report	Protected area metrics for modern	protected_areas_metrics.csv
output - report	Protected area metrics for all user scenarios	protected_areas_by_plan_metrics.csv

## Physical suitability

### Summary:

Not all potential actions to restore or enhance Delta ecosystem functions are physically suitable in all parts of the Delta. Individuals planning restoration and management actions must therefore carefully consider whether these actions are appropriate for a site's particular landscape position. Important factors that determine what types of activities are appropriate now and in the future include a site's elevation, degree of tidal and fluvial influence, salinity, soil type, and local effects of climate change (including expected sea-level rise and temperature changes), which all vary spatially across the Delta. This module evaluates the suitability of a location in the Delta for proposed scenario land use modifications. Suitability is determined from habitat type and geomorphic zone.

Geomorphic zones are defined based on a combination of land surface elevation and local tidal datums and are comparable to the "elevation bands" defined and mapped in the Delta Plan (DSC 2019). They include the deeply subsided zone (areas with land surface elevations below shallowly subsided elevations), shallowly subsided zone (Suisun: -4.5 ft MLLW - MTL; Delta: -8 ft MLLW - MLLW), intertidal zone (Suisun: MTL - MHHW; Delta: MLLW - MHHW), tidal-terrestrial zone (areas <10 ft above MHHW; referred to as the "sea-level rise accommodation" band in the Delta Plan), and the terrestrial zone (>10 ft above MHHW; referred to as the "floodplain" elevation band in the Delta Plan).

The elevation data used to develop this dataset was a synthesis of multiple topobathymetric digital elevation models compiled and mosaiced by SFEI staff. These data sources were (in order of priority):

1. 2018 LEAN corrected Suisun Marsh DEM (Buffington et al. 2018)
2. 2017 Delta LiDAR (DWR and USGS 2019)
3. 2017 USGS SF Bay Delta DEM 10-m (Fergoso et al. 2017)

4. 2012 DWR SF Bay Delta DEM 10-m (Wang and Ateljevich 2012)
5. 2013 USGS ConED Topobathymetric Model of San Francisco Bay, California (USGS 2013)
6. 2019 USGS National Elevation Dataset (USGS 2019)

Tidal datums were derived from a map developed by Siegel and Gillenwater (2020).

Elevation cutoffs between zones are in line with those defined in the Delta Plan. Work to define what landscape restoration and management actions are appropriate in each geomorphic zone is summarized in the Delta Plan (DSC 2019; Appendix 4A), as well as work by SFEI and partners (SFEI-ASC 2016, Delta Conservancy 2019). Details about the suitability of each habitat type in each zone as defined in this module are also detailed in the table in Appendix 1.

This analysis is run only on the user’s input scenarios. Development of this module was also supported by the US Fish and Wildlife Service.

Tool analysis methods:

- Intersects scenario overlay with geomorphic zones.
- Applies flag type and class to attributes based on habitat type and elevation zone.

File inventory:

Input / Output	Name / Desc.	File Name	Notes
input	Geomorphic zones	data\LSPT_data_package_SFEI\LSPT_data_package_SFEI.gdb\Geomorphic_Zones	See metadata for detailed description of source elevation and tidal datum datasets
input	Elevation flags crosswalk table	data\tables\elevation_notifications_v7.csv	See Appendix 1
output - workspace	Geomorphic zones	geomorphic_zones	
output - workspace	Physical suitability for user scenarios	{scenario}_scenario_suitability	
output - report	Geomorphic zones	geomorphic_zones.shp	
output - report	Physical suitability for user scenarios	{scenario}_suitability.shp	
output - report	Copy of elevation flags crosswalk table	suitability_elevation_crosswalk.csv	
output - report	Physical suitability metrics for user scenarios	suitability_metrics.csv	

## Carbon and greenhouse gas emissions

### Summary:

Tidal wetlands in the historical Delta once stored an estimated 290 million metric tons of peat carbon. Since the 1800s, wetland drainage for agriculture and other development caused significant losses of peat carbon, primarily due to organic matter oxidation. Drainage has also led to land subsidence, and continued subsidence presents risks to levees, future farmland arability, and salinity management. Where soils remain wet for most or all of the year, as in remnant or restored tidal marshes, impounded wetlands on subsided land, and rice farms or other types of wetland agriculture, the Delta's peatlands can sequester carbon and build elevations, benefiting the climate, expanding opportunities for intertidal habitat restoration, and in some cases creating a potential revenue source by generating carbon credits. Ecosystems in the Delta affect the climate not only through carbon sequestration or loss and CO<sub>2</sub> uptake or emissions, but also through emissions of other greenhouse gasses – notably methane (CH<sub>4</sub>) and nitrous oxide (N<sub>2</sub>O).

This module estimates historical, modern, and future elevation and peat carbon storage; emissions or uptake of CO<sub>2</sub>, CH<sub>4</sub>, and N<sub>2</sub>O; and potential revenue from the sale of carbon offsets. Future changes are evaluated 40 years into the future for baseline conditions and user scenarios, and incorporate a mean sea level rise rate of 1.1 ft by 2060 (the high-likelihood sea level rise scenario from the Ocean Protection Council's 2018 guidance (OPC, 2018)).

### Tool analysis methods:

- Classifies analysis area into analysis categories based on habitat type, tidal/non-tidal, crop type, geomorphic zone, and presence of organic soil:

Analysis category	Definition
Tidal wetland	Tidal emergent wetland, tidal willow riparian scrub/shrub, and tidal willow thicket
Impounded wetland	Non-tidal emergent wetland below MLLW
Rice (organic soil)	Rice where % SOM > 6 (within rice N <sub>2</sub> O emissions layer extent)
Pasture (organic soil)	Pasture within SUBCALC 40-yr CO <sub>2</sub> emissions extent
Croplands (organic soil)	Agriculture/ruderal within SUBCALC 40-yr CO <sub>2</sub> emissions extent, excluding rice and pasture
Grassland (organic soil)	Grassland within SUBCALC 40-yr CO <sub>2</sub> emissions extent
Seasonal wetland (organic soil)	Wet meadow/seasonal wetland within SUBCALC 40-yr CO <sub>2</sub> emissions extent

Rice (mineral soil)	Rice where % SOM $\leq$ 6 (outside rice N <sub>2</sub> O emissions layer extent)
Pasture (mineral soil)	Pasture outside SUBCALC 40-yr CO <sub>2</sub> emissions extent
Croplands (mineral soil)	Agriculture/ruderal outside SUBCALC 40-yr CO <sub>2</sub> emissions extent, excluding rice and pasture
Grassland/oak woodland/savanna	Oak woodland/savanna and grassland outside SUBCALC 40-yr CO <sub>2</sub> emissions extent
Other wetland	Non-tidal emergent wetland at or above MLLW, non-tidal willow riparian scrub/shrub, non-tidal willow thicket, wet meadow/seasonal wetland outside SUBCALC 40-yr CO <sub>2</sub> emissions extent, alkali seasonal wetland complex, vernal pool complex, valley foothill riparian
Urban/barren/water	Urban/barren and open water

- Elevation and peat volume analysis:
  - Determines future (40-yr) change in peat elevation (central value (M) and confidence interval (L-H)) according to analysis category:

Analysis category	Method
Tidal wetland	CWEM 40-yr accretion
Impounded wetland	SEDCALC 40-yr elevation change
Rice (organic soil)	Assume no change in elevation
Pasture (organic soil)	SUBCALC 40-yr elevation
Croplands (organic soil)	SUBCALC 40-yr elevation
Grassland (organic soil)	SUBCALC 40-yr elevation
Seasonal wetland (organic soil)	If not scenario-modified: SUBCALC 40-yr elevation If scenario-modified (not seasonal wetland in modern scenario): mean of SUBCALC elevation from seasonal wetland
Rice (mineral soil)	Assume no change in elevation
Pasture (mineral soil)	Assume no change in elevation
Croplands (mineral soil)	Assume no change in elevation
Grassland/oak woodland/savanna	Assume no change in elevation
Other wetland	Assume no change in elevation
Urban/barren/water	Assume no change in elevation

- Adjusts elevation changes relative to mean tide level (including sea level rise).
- Computes difference in elevation changes relative to baseline elevation change.
- Greenhouse gas emissions analysis:
  - Assigns GHG emission rates to historical tidal wetlands. CO<sub>2</sub> uptake = 0.2035 (0.162-0.245) kg CO<sub>2</sub> m<sup>-2</sup> yr<sup>-1</sup> (based on vertical accretion and peat carbon density from (Callaway et al., 2012 and Vaughn et al., *in prep*); CH<sub>4</sub> emissions = 11 (5-24) g CH<sub>4</sub> m<sup>-2</sup> yr<sup>-1</sup> (Arias-Ortiz et al., 2021); N<sub>2</sub>O emissions assumed to be zero.
  - Determines modern and future mean annual CO<sub>2</sub> emission rates over 40-yr simulation period according to analysis category:

Analysis category	CO <sub>2</sub> method
Tidal wetland	CWEM 40-yr accretion / 40 x area x 37 (33-41) mg C cm <sup>-3</sup> (Vaughn et al., <i>in prep</i> ), converted to units of CO <sub>2</sub> (equals CO <sub>2</sub> uptake)
Impounded wetland	SEDCALC 40-yr carbon accumulation / 40, converted to units of CO <sub>2</sub> (equals CO <sub>2</sub> uptake)
Rice (organic soil)	Assume no net CO <sub>2</sub> emissions
Pasture (organic soil)	SUBCALC 40-yr agriculture CO <sub>2</sub> emissions / 40
Croplands (organic soil)	SUBCALC 40-yr agriculture CO <sub>2</sub> emissions / 40
Grassland (organic soil)	If not scenario-modified: SUBCALC 40-yr CO <sub>2</sub> emissions / 40 If scenario-modified (not seasonal wetland in modern scenario): mean of SUBCALC 40-yr CO <sub>2</sub> emissions from grassland / 40
Seasonal wetland (organic soil)	If not scenario-modified: SUBCALC 40-yr CO <sub>2</sub> emissions / 40 If scenario-modified (not seasonal wetland in modern scenario): mean of SUBCALC 40-yr CO <sub>2</sub> emissions from seasonal wetland / 40
Rice (mineral soil)	Assume CO <sub>2</sub> uptake rate of 0.04 (0-0.08) kg CO <sub>2</sub> m <sup>-2</sup> yr <sup>-1</sup> (Kroodsma and Field, 2006)
Pasture (mineral soil)	Assume CO <sub>2</sub> uptake rate of 0.04 (0-0.08) kg CO <sub>2</sub> m <sup>-2</sup> yr <sup>-1</sup> (Kroodsma and Field, 2006)
Croplands (mineral soil)	Assume CO <sub>2</sub> uptake rate of 0.04 (0-0.08) kg CO <sub>2</sub> m <sup>-2</sup> yr <sup>-1</sup> (Kroodsma and Field, 2006)
Grassland/oak woodland/savanna	Assume CO <sub>2</sub> emission rate of 0.14 (-0.21-0.49) kg CO <sub>2</sub> m <sup>-2</sup> yr <sup>-1</sup> (Ma et al., 2007)
Other wetland	Assume CO <sub>2</sub> uptake rate of 0.062 (0-0.12) kg CO <sub>2</sub> m <sup>-2</sup> yr <sup>-1</sup> (Bridgham et al., 2006, freshwater wetlands)
Urban/barren/water	Assume no net CO <sub>2</sub> emissions

- Determines modern and future mean annual CH<sub>4</sub> emission rates over 40-yr simulation period according to analysis category:

Analysis category	CH <sub>4</sub> emission rate (g CH <sub>4</sub> m <sup>-2</sup> yr <sup>-1</sup> )
Tidal wetland	11 (5-24) (Arias-Ortiz et al., 2021)
Impounded wetland	63 (53-73) (Hemes et al., 2019)
Rice (organic soil)	16 (10-22) (Hemes et al., 2019)
Pasture (organic soil)	8.77 (4.39-13.16) (IPCC per-head emission rate (Dong et al., 2006) applied to reported stocking densities in Delta pastures)
Croplands (organic soil)	Assume no net CH <sub>4</sub> emissions
Grassland (organic soil)	Assume no net CH <sub>4</sub> emissions
Seasonal wetland (organic soil)	7.6 (0-15.2) (Bridgham et al., 2006, freshwater wetlands)
Rice (mineral soil)	16 (10-22) (Hemes et al., 2019)
Pasture (mineral soil)	8.77 (4.39-13.16) (IPCC per-head emission rate (Dong et al., 2006) applied to reported stocking densities in Delta pastures)
Croplands (mineral soil)	Assume no net CH <sub>4</sub> emissions
Grassland/oak woodland/savanna	Assume no net CH <sub>4</sub> emissions
Other wetland	7.6 (0-15.2) (Bridgham et al., 2006, freshwater wetlands)
Urban/barren/water	Assume no net CH <sub>4</sub> emissions

- Determines modern and future mean annual N<sub>2</sub>O emission rates over 40-yr simulation period according to analysis category:

Analysis category	N <sub>2</sub> O method
Tidal wetland	Assume no N <sub>2</sub> O emissions
Impounded wetland	Assume no N <sub>2</sub> O emissions
Rice (organic soil)	Rice N <sub>2</sub> O emissions raster, based on soil organic matter content (Ye et al., 2016)
Pasture (organic soil)	Assume N <sub>2</sub> O emission rate of 3.7 (1.5-5) g N <sub>2</sub> O m <sup>-2</sup> yr <sup>-1</sup> (Teh et al., 2011)
Croplands (organic soil)	Calculate N <sub>2</sub> O emissions in units of CO <sub>2</sub> e as 0.153 (0.043-0.263) x CO <sub>2</sub> emissions (Deverel et al., 2017)

Grassland (organic soil)	Calculate N <sub>2</sub> O emissions in units of CO <sub>2</sub> e as 0.153 (0.043-0.263) x CO <sub>2</sub> emissions (Deverel et al., 2017)
Seasonal wetland (organic soil)	Calculate N <sub>2</sub> O emissions in units of CO <sub>2</sub> e as 0.153 (0.043-0.263) x CO <sub>2</sub> emissions (Deverel et al., 2017)
Rice (mineral soil)	Assume N <sub>2</sub> O emission rate of 0.14 (0-0.32) g N <sub>2</sub> O m <sup>-2</sup> yr <sup>-1</sup> (Verhoeven et al., 2017)
Pasture (mineral soil)	Assume N <sub>2</sub> O emission rate of 1.79 (0.830-2.75) g N <sub>2</sub> O m <sup>-2</sup> yr <sup>-1</sup> (Verhoeven et al., 2017)
Croplands (mineral soil)	Assume N <sub>2</sub> O emission rate of 0.33 (0.25-0.41) g N <sub>2</sub> O m <sup>-2</sup> yr <sup>-1</sup> (De Gryze et al., 2010; Verhoeven et al., 2017)
Grassland/oak woodland/savanna	Assume no N <sub>2</sub> O emissions
Other wetland	Assume no N <sub>2</sub> O emissions
Urban/barren/water	Assume no N <sub>2</sub> O emissions

- Converts CH<sub>4</sub> and N<sub>2</sub>O to units of CO<sub>2</sub>e using the IPCC AR5 global warming potentials (28 for CH<sub>4</sub> and 265 for N<sub>2</sub>O)
- Calculates mean annual greenhouse gas emissions as the sum of CO<sub>2</sub>, CH<sub>4</sub>, and N<sub>2</sub>O, propagating uncertainties from the individual greenhouse gasses at present and over 40-yr simulation period.
- Calculates cumulative greenhouse gas emissions over 10, 20, 30, or 40 years according to analysis category:

Analysis category	Cumulative emissions method
Tidal wetland	(Annual CH <sub>4</sub> emissions) x [10, 20, 30, or 40] - ((CWEM [10, 20, 30, or 40-yr] accretion) x area x 37 (33-41) mg C cm <sup>-3</sup> (Vaughn et al., <i>in prep</i> ), converted to units of CO <sub>2</sub> )
Impounded wetland	(Annual CH <sub>4</sub> emissions) x [10, 20, 30, or 40] - (SEDCALC [10, 20, 30, or 40-yr] carbon accumulation, converted to units of CO <sub>2</sub> )
Rice (organic soil)	(Annual CH <sub>4</sub> and N <sub>2</sub> O emissions) x [10, 20, 30, or 40]
Pasture (organic soil)	(Annual CH <sub>4</sub> and N <sub>2</sub> O emissions) x [10, 20, 30, or 40] + (SUBCALC [10, 20, 30, or 40-yr] CO <sub>2</sub> emissions)
Croplands (organic soil)	(Annual N <sub>2</sub> O emissions) x [10, 20, 30, or 40] + (SUBCALC [10, 20, 30, or 40-yr] agriculture CO <sub>2</sub> emissions)
Grassland (organic soil)	(Annual N <sub>2</sub> O emissions) x [10, 20, 30, or 40] + (SUBCALC [10, 20, 30, or 40-yr] agriculture CO <sub>2</sub> emissions)

Seasonal wetland (organic soil)	(Annual CH <sub>4</sub> and N <sub>2</sub> O emissions) x [10, 20, 30, or 40] + (SUBCALC [10, 20, 30, or 40-yr] CO <sub>2</sub> emissions)
Rice (mineral soil)	Annual GHG emissions x [10, 20, 30, or 40]
Pasture (mineral soil)	Annual GHG emissions x [10, 20, 30, or 40]
Croplands (mineral soil)	Annual GHG emissions x [10, 20, 30, or 40]
Grassland/oak woodland/savanna	Annual GHG emissions x [10, 20, 30, or 40]
Other wetland	Annual GHG emissions x [10, 20, 30, or 40]
Urban/barren/water	Assume no net GHG emissions

- Determines cumulative greenhouse gas emissions reductions by subtracting baseline cumulative GHG emissions from scenario cumulative GHG emissions at 10, 20, 30, and 40 years
- Peat carbon storage analysis:
  - Calculates change in peat carbon storage over 40 years as mean annual CO<sub>2</sub> emissions x 40, converted to units of carbon
  - Calculates difference in peat carbon storage over 40 years between scenarios and baseline
- Potential carbon market revenue analysis:
  - Calculates marketable offsets as (cumulative greenhouse gas emissions reductions) x (1 - (uncertainty - 0.10)) x (1 - risk score)
  - Calculates potential revenue as (cumulative marketable offsets) x price

Key considerations and caveats:

The analysis is limited to the historical footprint of the tidal marsh within the Delta, equivalent to the historical extent of Delta peatlands.

All analyses in this module assume the scenario habitat configuration is realized at the start of the modeling period, irrespective of physical suitability. For example, tidal marsh is modeled as a vegetated tidal marsh in the present day, even if it is sited in a deeply subsided location. Analyses also assume that there are no levee failures or other changes to water management in a given habitat type.

All metrics are presented with an uncertainty range in parentheses. This uncertainty range roughly equals a 95% confidence interval and was determined by propagating uncertainties in underlying data or model predictions through the tool calculations.

File inventory:

For this module's output tables, graphs, and maps, positive numbers indicate carbon losses or greenhouse gas emissions from the ecosystem to the atmosphere, whereas negative numbers indicate uptake or sequestration.

Input / Output	Name / Desc.	File Name
input	SEDCALC 10-year carbon accumulation (g C cm <sup>-2</sup> )	data\LSPT_data_package_SFEI\carbon_module_rasters\sedcalc\1_1_ft_2027_carbon_cum_gC_cm2_LZW.tif
input	SEDCALC 20-year carbon accumulation (g C cm <sup>-2</sup> )	data\LSPT_data_package_SFEI\carbon_module_rasters\sedcalc\1_1_ft_2037_carbon_cum_gC_cm2_LZW.tif
input	SEDCALC 30-year carbon accumulation (g C cm <sup>-2</sup> )	data\LSPT_data_package_SFEI\carbon_module_rasters\sedcalc\1_1_ft_2047_carbon_cum_gC_cm2_LZW.tif
input	SEDCALC 40-year carbon accumulation (g C cm <sup>-2</sup> )	data\LSPT_data_package_SFEI\carbon_module_rasters\sedcalc\1_1_ft_2057_carbon_cum_gC_cm2_LZW.tif
input	SEDCALC 40-yr elevation change (cm)	data\LSPT_data_package_SFEI\carbon_module_rasters\sedcalc\1_1_ft_2056_topodifference_16bit.tif
input	SUBCALC 40-yr elevation (m)	data\LSPT_data_package_SFEI\carbon_module_rasters\ubcalc\sub_40yr_OM_H_extent_wBacon.tif
input	SUBCALC 40-yr elevation (m)	data\LSPT_data_package_SFEI\carbon_module_rasters\ubcalc\sub_40yr_OM_L_extent_wBacon.tif
input	SUBCALC 40-yr elevation (m)	data\LSPT_data_package_SFEI\carbon_module_rasters\ubcalc\sub_40yr_OM_M_extent_wBacon.tif
input	SUBCALC 10-yr agriculture CO <sub>2</sub> emissions (MT CO <sub>2</sub> ac <sup>-1</sup> )	data\LSPT_data_package_SFEI\carbon_module_rasters\ubcalc_ag_flux\flux_2018_2027_tC02_ac_OM_H_ag_defaul_t_LZW.tif
input	SUBCALC 10-yr agriculture CO <sub>2</sub> emissions (MT CO <sub>2</sub> ac <sup>-1</sup> )	data\LSPT_data_package_SFEI\carbon_module_rasters\ubcalc_ag_flux\flux_2018_2027_tC02_ac_OM_L_ag_defaul_t_LZW.tif
input	SUBCALC 10-yr agriculture CO <sub>2</sub> emissions (MT CO <sub>2</sub> ac <sup>-1</sup> )	data\LSPT_data_package_SFEI\carbon_module_rasters\ubcalc_ag_flux\flux_2018_2027_tC02_ac_OM_M_ag_defaul_t_LZW.tif
input	SUBCALC 20-yr agriculture CO <sub>2</sub> emissions (MT CO <sub>2</sub> ac <sup>-1</sup> )	data\LSPT_data_package_SFEI\carbon_module_rasters\ubcalc_ag_flux\flux_2018_2037_tC02_ac_OM_H_ag_defaul_t_LZW.tif
input	SUBCALC 20-yr agriculture CO <sub>2</sub> emissions (MT CO <sub>2</sub> ac <sup>-1</sup> )	data\LSPT_data_package_SFEI\carbon_module_rasters\ubcalc_ag_flux\flux_2018_2037_tC02_ac_OM_L_ag_defaul_t_LZW.tif
input	SUBCALC 20-yr agriculture CO <sub>2</sub> emissions (MT CO <sub>2</sub> ac <sup>-1</sup> )	data\LSPT_data_package_SFEI\carbon_module_rasters\ubcalc_ag_flux\flux_2018_2037_tC02_ac_OM_M_ag_defaul_t_LZW.tif
input	SUBCALC 30-yr agriculture CO <sub>2</sub> emissions (MT CO <sub>2</sub> ac <sup>-1</sup> )	data\LSPT_data_package_SFEI\carbon_module_rasters\ubcalc_ag_flux\flux_2018_2047_tC02_ac_OM_H_ag_defaul_t_LZW.tif

input	SUBCALC 30-yr agriculture CO <sub>2</sub> emissions (MT CO <sub>2</sub> ac <sup>-1</sup> )	data\LSPT_data_package_SFEI\carbon_module_rasters\ubcalc_ag_flux\flux_2018_2047_tCO2_ac_OM_L_ag_defaul_t_LZW.tif
input	SUBCALC 30-yr agriculture CO <sub>2</sub> emissions (MT CO <sub>2</sub> ac <sup>-1</sup> )	data\LSPT_data_package_SFEI\carbon_module_rasters\ubcalc_ag_flux\flux_2018_2047_tCO2_ac_OM_M_ag_defaul_t_LZW.tif
input	SUBCALC 40-yr agriculture CO <sub>2</sub> emissions (MT CO <sub>2</sub> ac <sup>-1</sup> )	data\LSPT_data_package_SFEI\carbon_module_rasters\ubcalc_ag_flux\flux_2018_2057_tCO2_ac_OM_H_ag_defaul_t_LZW.tif
input	SUBCALC 40-yr agriculture CO <sub>2</sub> emissions (MT CO <sub>2</sub> ac <sup>-1</sup> )	data\LSPT_data_package_SFEI\carbon_module_rasters\ubcalc_ag_flux\flux_2018_2057_tCO2_ac_OM_L_ag_defaul_t_LZW.tif
input	SUBCALC 40-yr agriculture CO <sub>2</sub> emissions (MT CO <sub>2</sub> ac <sup>-1</sup> )	data\LSPT_data_package_SFEI\carbon_module_rasters\ubcalc_ag_flux\flux_2018_2057_tCO2_ac_OM_M_ag_defaul_t_LZW.tif
input	Rice N <sub>2</sub> O emissions (g N <sub>2</sub> O m <sup>-2</sup> )	data\LSPT_data_package_SFEI\carbon_module_rasters\ubcalc_ag_flux\n2o_rice_high.tif
input	Rice N <sub>2</sub> O emissions (g N <sub>2</sub> O m <sup>-2</sup> )	data\LSPT_data_package_SFEI\carbon_module_rasters\ubcalc_ag_flux\n2o_rice_low.tif
input	Rice N <sub>2</sub> O emissions (g N <sub>2</sub> O m <sup>-2</sup> )	data\LSPT_data_package_SFEI\carbon_module_rasters\ubcalc_ag_flux\n2o_rice_medium.tif
input	SUBCALC 10-yr CO <sub>2</sub> emissions (MT CO <sub>2</sub> ac <sup>-1</sup> )	data\LSPT_data_package_SFEI\carbon_module_rasters\ubcalc_flux\flux_2018_2027_tCO2_ac_OM_H_LZW.tif
input	SUBCALC 10-yr CO <sub>2</sub> emissions (MT CO <sub>2</sub> ac <sup>-1</sup> )	data\LSPT_data_package_SFEI\carbon_module_rasters\ubcalc_flux\flux_2018_2027_tCO2_ac_OM_L_LZW.tif
input	SUBCALC 10-yr CO <sub>2</sub> emissions (MT CO <sub>2</sub> ac <sup>-1</sup> )	data\LSPT_data_package_SFEI\carbon_module_rasters\ubcalc_flux\flux_2018_2027_tCO2_ac_OM_M_LZW.tif
input	SUBCALC 20-yr CO <sub>2</sub> emissions (MT CO <sub>2</sub> ac <sup>-1</sup> )	data\LSPT_data_package_SFEI\carbon_module_rasters\ubcalc_flux\flux_2018_2037_tCO2_ac_OM_H_LZW.tif
input	SUBCALC 20-yr CO <sub>2</sub> emissions (MT CO <sub>2</sub> ac <sup>-1</sup> )	data\LSPT_data_package_SFEI\carbon_module_rasters\ubcalc_flux\flux_2018_2037_tCO2_ac_OM_L_LZW.tif
input	SUBCALC 20-yr CO <sub>2</sub> emissions (MT CO <sub>2</sub> ac <sup>-1</sup> )	data\LSPT_data_package_SFEI\carbon_module_rasters\ubcalc_flux\flux_2018_2037_tCO2_ac_OM_M_LZW.tif
input	SUBCALC 30-yr CO <sub>2</sub> emissions (MT CO <sub>2</sub> ac <sup>-1</sup> )	data\LSPT_data_package_SFEI\carbon_module_rasters\ubcalc_flux\flux_2018_2047_tCO2_ac_OM_H_LZW.tif
input	SUBCALC 30-yr CO <sub>2</sub> emissions (MT CO <sub>2</sub> ac <sup>-1</sup> )	data\LSPT_data_package_SFEI\carbon_module_rasters\ubcalc_flux\flux_2018_2047_tCO2_ac_OM_L_LZW.tif
input	SUBCALC 30-yr CO <sub>2</sub> emissions (MT CO <sub>2</sub> ac <sup>-1</sup> )	data\LSPT_data_package_SFEI\carbon_module_rasters\ubcalc_flux\flux_2018_2047_tCO2_ac_OM_M_LZW.tif
input	SUBCALC 40-yr CO <sub>2</sub> emissions (MT CO <sub>2</sub> ac <sup>-1</sup> )	data\LSPT_data_package_SFEI\carbon_module_rasters\ubcalc_flux\flux_2018_2057_tCO2_ac_OM_H_LZW.tif
input	SUBCALC 40-yr CO <sub>2</sub> emissions (MT CO <sub>2</sub> ac <sup>-1</sup> )	data\LSPT_data_package_SFEI\carbon_module_rasters\ubcalc_flux\flux_2018_2057_tCO2_ac_OM_L_LZW.tif
input	SUBCALC 40-yr CO <sub>2</sub> emissions (MT CO <sub>2</sub> ac <sup>-1</sup> )	data\LSPT_data_package_SFEI\carbon_module_rasters\ubcalc_flux\flux_2018_2057_tCO2_ac_OM_M_LZW.tif
input	CWEM 10-yr accretion (cm)	data\LSPT_data_package_SFEI\carbon_module_rasters\cwem.gdb\s1r_1_1_2060_MedSed_10yr_10m

input	CWEM 20-yr accretion (cm)	data\LSPT_data_package_SFEI\carbon_module_rasters\cwem.gdb\slr_1_1_2060_MedSed_20yr_10m
input	CWEM 30-yr accretion (cm)	data\LSPT_data_package_SFEI\carbon_module_rasters\cwem.gdb\slr_1_1_2060_MedSed_30yr_10m
input	CWEM 40-yr accretion (cm)	data\LSPT_data_package_SFEI\carbon_module_rasters\cwem.gdb\slr_1_1_2060_MedSed_40yr_10m
input	Estimated change in mean sea level due to sea level rise (ft)	data\LSPT_data_package_SFEI\LSPT_data_package_SFEI.gdb\IDW_MSL_1_poly
input	Elevation relative to mean tide level (cm)	data\LSPT_data_package_SFEI\carbon_module_rasters\DEM_ref_MTL_10m_LZW.tif
input	Historical carbon storage (kg C m <sup>-2</sup> )	data\LSPT_data_package_SFEI\carbon_module_rasters\storage\carbon_storage_hist.tif
input	Modern carbon storage (kg C m <sup>-2</sup> )	data\LSPT_data_package_SFEI\carbon_module_rasters\storage\carbon_storage_mod.tif
input	Historical peat thickness (m)	data\LSPT_data_package_SFEI\carbon_module_rasters\storage\peat_thickness_hist.tif
input	Modern peat thickness (m)	data\LSPT_data_package_SFEI\carbon_module_rasters\storage\peat_thickness_mod.tif
output - workspace	Estimated change in mean sea level due to sea level rise (ft)	msl_slr_1ft
output - workspace	Elevation relative to mean tide level (cm)	elv_ref_mtl
output - workspace	Scenario landcover classification for grouping output statistics by region.	{scenario}_carbon_regions
output - workspace	Scenario landcover classification for elevation submodule.	{scenario}_carbon_model_regions
output - workspace	Scenario landcover classification for elevation submodule – rasterized.	{scenario}_carbon_model_regions_rast
output - workspace	Scenario landcover classification for GHG emissions model.	{scenario}_carbon_landcover
output - workspace	Scenario landcover classification for GHG emissions model – rasterized.	{scenario}_carbon_landcover_rast
output - workspace	Absolute elevation change over 40-yr simulation (cm)	{scenario}_carbon_elevation_change_l
output - workspace	Absolute elevation change over 40-yr simulation (m)	{scenario}_carbon_elevation_change_m
output - workspace	Absolute elevation change over 40-yr simulation (h)	{scenario}_carbon_elevation_change_h
output - workspace	Elevation change relative to baseline over 40-yr simulation (cm)	{scenario}_carbon_elevation_relative_mod_l
output - workspace	Elevation change relative to baseline over 40-yr simulation (m)	{scenario}_carbon_elevation_relative_mod_m
output - workspace	Elevation change relative to baseline over 40-yr simulation (h)	{scenario}_carbon_elevation_relative_mod_h
output - workspace	Elevation change relative to mean tide level (accounting for sea level rise) over 40-yr simulation (cm)	{scenario}_carbon_elevation_relative_mtl_l

output - workspace	Elevation change relative to mean tide level (accounting for sea level rise) over 40-yr simulation (cm)	{scenario}_carbon_elevation_relative_mtl_m
output - workspace	Elevation change relative to mean tide level (accounting for sea level rise) over 40-yr simulation (cm)	{scenario}_carbon_elevation_relative_mtl_h
output - workspace	Estimated annual CO <sub>2</sub> flux (kg CO <sub>2</sub> m <sup>-2</sup> )	{scenario}_carbon_co2_annual_l
output - workspace	Estimated annual CO <sub>2</sub> flux (kg CO <sub>2</sub> m <sup>-2</sup> )	{scenario}_carbon_co2_annual_m
output - workspace	Estimated annual CO <sub>2</sub> flux (kg CO <sub>2</sub> m <sup>-2</sup> )	{scenario}_carbon_co2_annual_h
output - workspace	Estimated annual CH <sub>4</sub> flux (kg CH <sub>4</sub> m <sup>-2</sup> )	{scenario}_carbon_ch4_annual_l
output - workspace	Estimated annual CH <sub>4</sub> flux (kg CH <sub>4</sub> m <sup>-2</sup> )	{scenario}_carbon_ch4_annual_m
output - workspace	Estimated annual CH <sub>4</sub> flux (kg CH <sub>4</sub> m <sup>-2</sup> )	{scenario}_carbon_ch4_annual_h
output - workspace	Estimated annual N <sub>2</sub> O flux (kg N <sub>2</sub> O m <sup>-2</sup> )	{scenario}_carbon_n2o_annual_l
output - workspace	Estimated annual N <sub>2</sub> O flux (kg N <sub>2</sub> O m <sup>-2</sup> )	{scenario}_carbon_n2o_annual_m
output - workspace	Estimated annual N <sub>2</sub> O flux (kg N <sub>2</sub> O m <sup>-2</sup> )	{scenario}_carbon_n2o_annual_h
output - workspace	Estimated annual total GHG flux (kg CO <sub>2</sub> e m <sup>-2</sup> )	{scenario}_carbon_ghg_annual_l
output - workspace	Estimated annual total GHG flux (kg CO <sub>2</sub> e m <sup>-2</sup> )	{scenario}_carbon_ghg_annual_m
output - workspace	Estimated annual total GHG flux (kg CO <sub>2</sub> e m <sup>-2</sup> )	{scenario}_carbon_ghg_annual_h
output - workspace	Estimated cumulative in GHG emissions over 10-yr simulation (kg CO <sub>2</sub> e m <sup>-2</sup> )	{scenario}_carbon_ghg_cumulative_10_l
output - workspace	Estimated cumulative in GHG emissions over 10-yr simulation (kg CO <sub>2</sub> e m <sup>-2</sup> )	{scenario}_carbon_ghg_cumulative_10_m
output - workspace	Estimated cumulative in GHG emissions over 10-yr simulation (kg CO <sub>2</sub> e m <sup>-2</sup> )	{scenario}_carbon_ghg_cumulative_10_h
output - workspace	Estimated cumulative in GHG emissions over 20-yr simulation (kg CO <sub>2</sub> e m <sup>-2</sup> )	{scenario}_carbon_ghg_cumulative_20_l
output - workspace	Estimated cumulative in GHG emissions over 20-yr simulation (kg CO <sub>2</sub> e m <sup>-2</sup> )	{scenario}_carbon_ghg_cumulative_20_m
output - workspace	Estimated cumulative in GHG emissions over 20-yr simulation (kg CO <sub>2</sub> e m <sup>-2</sup> )	{scenario}_carbon_ghg_cumulative_20_h
output - workspace	Estimated cumulative in GHG emissions over 30-yr simulation (kg CO <sub>2</sub> e m <sup>-2</sup> )	{scenario}_carbon_ghg_cumulative_30_l
output - workspace	Estimated cumulative in GHG emissions over 30-yr simulation (kg CO <sub>2</sub> e m <sup>-2</sup> )	{scenario}_carbon_ghg_cumulative_30_m
output - workspace	Estimated cumulative in GHG emissions over 30-yr simulation (kg CO <sub>2</sub> e m <sup>-2</sup> )	{scenario}_carbon_ghg_cumulative_30_h
output - workspace	Estimated cumulative GHG emissions over	{scenario}_carbon_ghg_cumulative_40_l

	40-yr simulation (kg CO <sub>2</sub> e m <sup>-2</sup> )	
output - workspace	Estimated cumulative GHG emissions over 40-yr simulation (kg CO <sub>2</sub> e m <sup>-2</sup> )	{scenario}_carbon_ghg_cumulative_40_m
output - workspace	Estimated cumulative GHG emissions over 40-yr simulation (kg CO <sub>2</sub> e m <sup>-2</sup> )	{scenario}_carbon_ghg_cumulative_40_h
output - workspace	Estimated reduction in cumulative GHG emissions over 10-yr simulation (kg CO <sub>2</sub> e m <sup>-2</sup> )	{scenario}_carbon_ghg_reduction_10_l
output - workspace	Estimated reduction in cumulative GHG emissions over 10-yr simulation (kg CO <sub>2</sub> e m <sup>-2</sup> )	{scenario}_carbon_ghg_reduction_10_m
output - workspace	Estimated reduction in cumulative GHG emissions over 10-yr simulation (kg CO <sub>2</sub> e m <sup>-2</sup> )	{scenario}_carbon_ghg_reduction_10_h
output - workspace	Estimated reduction in cumulative GHG emissions over 20-yr simulation (kg CO <sub>2</sub> e m <sup>-2</sup> )	{scenario}_carbon_ghg_reduction_20_l
output - workspace	Estimated reduction in cumulative GHG emissions over 20-yr simulation (kg CO <sub>2</sub> e m <sup>-2</sup> )	{scenario}_carbon_ghg_reduction_20_m
output - workspace	Estimated reduction in cumulative GHG emissions over 20-yr simulation (kg CO <sub>2</sub> e m <sup>-2</sup> )	{scenario}_carbon_ghg_reduction_20_h
output - workspace	Estimated reduction in cumulative GHG emissions over 30-yr simulation (kg CO <sub>2</sub> e m <sup>-2</sup> )	{scenario}_carbon_ghg_reduction_30_l
output - workspace	Estimated reduction in cumulative GHG emissions over 30-yr simulation (kg CO <sub>2</sub> e m <sup>-2</sup> )	{scenario}_carbon_ghg_reduction_30_m
output - workspace	Estimated reduction in cumulative GHG emissions over 30-yr simulation (kg CO <sub>2</sub> e m <sup>-2</sup> )	{scenario}_carbon_ghg_reduction_30_h
output - workspace	Estimated reduction in cumulative GHG emissions over 40-yr simulation (kg CO <sub>2</sub> e m <sup>-2</sup> )	{scenario}_carbon_ghg_reduction_40_l
output - workspace	Estimated reduction in cumulative GHG emissions over 40-yr simulation (kg CO <sub>2</sub> e m <sup>-2</sup> )	{scenario}_carbon_ghg_reduction_40_m
output - workspace	Estimated reduction in cumulative GHG emissions over 40-yr simulation (kg CO <sub>2</sub> e m <sup>-2</sup> )	{scenario}_carbon_ghg_reduction_40_h
output - workspace	Model confidence ratings for GHG emissions calculations	{scenario}_carbon_ghg_confidence
output - workspace	Historical carbon storage (kg C m <sup>-2</sup> )	historical_carbon_storage
output - workspace	Modern carbon storage (kg C m <sup>-2</sup> )	modern_carbon_storage
output - workspace	Estimated carbon storage after 40-yr simulation (kg C m <sup>-2</sup> )	{scenario}_full_carbon_storage_40yr_l
output - workspace	Estimated carbon storage after 40-yr	{scenario}_full_carbon_storage_40yr_m

	simulation (kg C m <sup>-2</sup> )	
output - workspace	Estimated carbon storage after 40-yr simulation (kg C m <sup>-2</sup> )	{scenario}_full_carbon_storage_40yr_h
output - workspace	Difference in estimate carbon storage after 40-yr simulation between user scenario and baseline scenario (kg C m <sup>-2</sup> )	{scenario}_full_carbon_storage_difference_40yr_m
output - report	Elevation relative to mean tide level (cm)	elv_rel_mtl.tif
output - report	Absolute elevation change over 40-yr simulation (cm)	{scenario}_elevation_change.tif
output - report	Elevation change relative to baseline over 40-yr simulation (cm)	{scenario}_elevation_relative_mod.tif
output - report	Elevation change relative to mean tide level (accounting for sea level rise) over 40-yr simulation (cm)	{scenario}_elevation_relative_mtl.tif
output - report	Scenario landcover classification for grouping output statistics by region.	{scenario}_ghg_regions.tif
output - report	Estimated annual CO <sub>2</sub> flux (kg CO <sub>2</sub> m <sup>-2</sup> )	{scenario}_co2_annual_l.tif
output - report	Estimated annual CO <sub>2</sub> flux (kg CO <sub>2</sub> m <sup>-2</sup> )	{scenario}_co2_annual_m.tif
output - report	Estimated annual CO <sub>2</sub> flux (kg CO <sub>2</sub> m <sup>-2</sup> )	{scenario}_co2_annual_h.tif
output - report	Estimated annual CH <sub>4</sub> flux (kg CH <sub>4</sub> m <sup>-2</sup> )	{scenario}_ch4_annual_l.tif
output - report	Estimated annual CH <sub>4</sub> flux (kg CH <sub>4</sub> m <sup>-2</sup> )	{scenario}_ch4_annual_m.tif
output - report	Estimated annual CH <sub>4</sub> flux (kg CH <sub>4</sub> m <sup>-2</sup> )	{scenario}_ch4_annual_h.tif
output - report	Estimated annual N <sub>2</sub> O flux (kg N <sub>2</sub> O m <sup>-2</sup> )	{scenario}_n2o_annual_l.tif
output - report	Estimated annual N <sub>2</sub> O flux (kg N <sub>2</sub> O m <sup>-2</sup> )	{scenario}_n2o_annual_m.tif
output - report	Estimated annual N <sub>2</sub> O flux (kg N <sub>2</sub> O m <sup>-2</sup> )	{scenario}_n2o_annual_h.tif
output - report	Estimated annual total GHG flux (kg CO <sub>2</sub> e m <sup>-2</sup> )	{scenario}_ghg_annual_l.tif
output - report	Estimated annual total GHG flux (kg CO <sub>2</sub> e m <sup>-2</sup> )	{scenario}_ghg_annual_m.tif
output - report	Estimated annual total GHG flux (kg CO <sub>2</sub> e m <sup>-2</sup> )	{scenario}_ghg_annual_h.tif
output - report	Estimated reduction in cumulative GHG emissions over 10-yr simulation (kg CO <sub>2</sub> e m <sup>-2</sup> )	{scenario}_ghg_reduction_10yr_l.tif
output - report	Estimated reduction in cumulative GHG emissions over 10-yr simulation (kg CO <sub>2</sub> e m <sup>-2</sup> )	{scenario}_ghg_reduction_10yr_m.tif
output - report	Estimated reduction in cumulative GHG emissions over 10-yr simulation (kg CO <sub>2</sub> e m <sup>-2</sup> )	{scenario}_ghg_reduction_10yr_h.tif
output - report	Estimated reduction in cumulative GHG emissions over 20-yr simulation (kg CO <sub>2</sub> e m <sup>-2</sup> )	{scenario}_ghg_reduction_20yr_l.tif

	m <sup>2</sup> )	
output - report	Estimated reduction in cumulative GHG emissions over 20-yr simulation (kg CO <sub>2</sub> e m <sup>-2</sup> )	{scenario}_ghg_reduction_20yr_m.tif
output - report	Estimated reduction in cumulative GHG emissions over 20-yr simulation (kg CO <sub>2</sub> e m <sup>-2</sup> )	{scenario}_ghg_reduction_20yr_h.tif
output - report	Estimated reduction in cumulative GHG emissions over 30-yr simulation (kg CO <sub>2</sub> e m <sup>-2</sup> )	{scenario}_ghg_reduction_30yr_l.tif
output - report	Estimated reduction in cumulative GHG emissions over 30-yr simulation (kg CO <sub>2</sub> e m <sup>-2</sup> )	{scenario}_ghg_reduction_30yr_m.tif
output - report	Estimated reduction in cumulative GHG emissions over 30-yr simulation (kg CO <sub>2</sub> e m <sup>-2</sup> )	{scenario}_ghg_reduction_30yr_h.tif
output - report	Estimated reduction in cumulative GHG emissions over 40-yr simulation (kg CO <sub>2</sub> e m <sup>-2</sup> )	{scenario}_ghg_reduction_40yr_l.tif
output - report	Estimated reduction in cumulative GHG emissions over 40-yr simulation (kg CO <sub>2</sub> e m <sup>-2</sup> )	{scenario}_ghg_reduction_40yr_m.tif
output - report	Estimated reduction in cumulative GHG emissions over 40-yr simulation (kg CO <sub>2</sub> e m <sup>-2</sup> )	{scenario}_ghg_reduction_40yr_h.tif
output - report	Estimated carbon storage after 40-yr simulation (kg C m <sup>-2</sup> )	{scenario}_carbon_storage_40yr_l.tif
output - report	Estimated carbon storage after 40-yr simulation (kg C m <sup>-2</sup> )	{scenario}_carbon_storage_40yr_m.tif
output - report	Estimated carbon storage after 40-yr simulation (kg C m <sup>-2</sup> )	{scenario}_carbon_storage_40yr_h.tif
output - report	Difference in estimate carbon storage after 40-yr simulation between user scenario and baseline scenario (kg C m <sup>-2</sup> )	{scenario}_carbon_storage_40yr_diff.tif
output - report	Historical peat thickness (m)	historical_peat_thickness.tif
output - report	Modern peat thickness (m)	modern_peat_thickness.tif

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Appendix 1: Habitat type suitability by geomorphic zone for Physical Suitability module

Habitat type	Geomorphic zone (SEED)	Elevation zone (Delta P <sub>lan</sub> )	Flag type	Flag class (simple)	Habitat type & geomorphic zone	Flag description
tidal freshwater emergent wetland	Tidal zone (deeply subsided)	Deeply subsided (more than 8 ft below MLLW)	Red	Land currently too low for proposed tidal emergent wetland	Tidal freshwater emergent wetland in a subsided zone	Not currently physically suitable. The land is currently too low to support tidal freshwater emergent wetland. The creation of tidal freshwater emergent wetlands in subsided areas will only be possible through fill placement or long-term sustained reverse subsidence via the creation of non-tidal managed wetlands. Subside reversal wetlands are more likely to recover intertidal elevations in shallowly subsided areas than deeply subsided areas (with time frames on the order of decades instead of centuries). Note that even if they do not ultimately recover intertidal elevations, non-tidal wetlands managed for subsidence reversal can help halt ongoing subsidence, reduce the risk of levee failure, sequester carbon, and provide habitat to waterbirds and other species.
tidal freshwater emergent wetland	Tidal zone (minimally subsided)	Shallowly subsided (up to 8 feet below MLLW)	Red	Land currently too low for proposed tidal emergent wetland	Tidal freshwater emergent wetland in a subsided zone	Not currently physically suitable. The land is currently too low to support tidal freshwater emergent wetland. The creation of tidal freshwater emergent wetlands in subsided areas will only be possible through fill placement or long-term sustained reverse subsidence via the creation of non-tidal managed wetlands. Subside reversal wetlands are more likely to recover intertidal elevations in shallowly subsided areas than deeply subsided areas (with time frames on the order of decades instead of centuries). Note that even if they do not ultimately recover intertidal elevations, non-tidal wetlands managed for subsidence reversal can help halt ongoing subsidence, reduce the risk of levee failure, sequester carbon, and provide habitat to waterbirds and other species.
tidal freshwater emergent wetland	Tidal zone (intertidal)	Intertidal (between MLLW and MHHW)	Green	Land potentially suitable for proposed habitat type	Tidal freshwater emergent wetland in intertidal zone	Potentially suitable. Over the near-term, the intertidal zone is an appropriate place to prioritize the restoration of tidal freshwater emergent wetlands. Over the long-term, with projected sea level rise, upland accommodation space will likely be needed to allow for marsh migration.
tidal freshwater emergent wetland	Tidal-terrestrial zone	Sea level rise projection (0 to +10 ft MHHW)	Yellow	Land currently too high for proposed tidal emergent wetland, but potentially suitable over long-term	Tidal freshwater emergent wetland in tidal-terrestrial zone	Potentially suitable, but there are important complicating factors to consider. Although these areas are currently too high to support tidal marsh, they are likely to become intertidal with sea-level rise over the long-term, assuming there are no barriers to tidal flows. Over the near-term, seasonal wetland or terrestrial habitat types are likely to be more appropriate in this area and can transition to tidal marsh as sea levels rise (managers should prioritize the removal of future barriers to tidal flows).
tidal freshwater emergent wetland	Terrestrial zone	Floodplain (more than 10 feet MHHW)	Red	Land currently too high for proposed tidal emergent wetland	Tidal freshwater emergent wetland in terrestrial zone	Not currently physically feasible. This area is too high to support tidal freshwater emergent wetlands now and with an additional 10 ft of sea-level rise. Seasonal wetlands and terrestrial habitat types are likely to be more appropriate in this area.
non-tidal freshwater emergent wetland	Tidal zone (deeply subsided)	Deeply subsided (more than 8 ft below MLLW)	Yellow	Potentially suitable, but will likely require management	Non-tidal freshwater emergent wetland in a subsided zone	Potentially suitable, but there are important complicating factors to consider. Note that the land is currently too low to support non-tidal freshwater emergent wetlands in their natural landscape position (upstream floodplains) with unimpeded hydrologic connections to occasional floodplain-inundating fluvial flows. Non-tidal emergent wetlands in subsided areas will instead need to be remain saturated via high groundwater and the use of water management infrastructure. Though they would rapidly transition to open water in the event of a levee failure, non-tidal emergent wetlands in the subsided zone (especially managed ones) can help halt and reverse ongoing subsidence, reduce the risk of levee failure, sequester carbon, provide habitat to waterbirds and other species, and potentially enable the restoration of tidal freshwater emergent wetlands in the future.
non-tidal freshwater emergent wetland	Tidal zone (minimally subsided)	Shallowly subsided (up to 8 feet below MLLW)	Yellow	Potentially suitable, but will likely require management	Non-tidal freshwater emergent wetland in a subsided zone	Potentially suitable, but there are important complicating factors to consider. Note that the land is currently too low to support non-tidal freshwater emergent wetlands in their natural landscape position (upstream floodplains) with unimpeded hydrologic connections to occasional floodplain-inundating fluvial flows. Non-tidal emergent wetlands in subsided areas will instead need to be remain saturated via high groundwater and the use of water management infrastructure. Though they would rapidly transition to open water in the event of a levee failure, non-tidal emergent wetlands in the subsided zone (especially managed ones) can help halt and reverse ongoing subsidence, reduce the risk of levee failure, sequester carbon, provide habitat to waterbirds and other species, and potentially enable the restoration of tidal freshwater emergent wetlands in the future.
non-tidal freshwater emergent wetland	Tidal zone (intertidal)	Intertidal (between MLLW and MHHW)	Yellow	Consider alternative habitat type: tidal freshwater emergent wetland	Non-tidal freshwater emergent wetland in intertidal zone	Potentially suitable, but there are important complicating factors to consider. If land in the intertidal zone is hydrologically connected to the channel network, it is likely to naturally support tidal freshwater emergent wetland, not non-tidal freshwater emergent wetland. Tidal freshwater emergent wetlands might be more suitable in this location, particularly given the relatively limited extent of the intertidal zone (where tidal freshwater emergent wetland restoration is feasible).
non-tidal freshwater emergent wetland	Tidal-terrestrial zone	Sea level rise projection (0 to +10 ft MHHW)	Green	Land potentially suitable for proposed habitat type	Non-tidal freshwater emergent wetland in tidal-terrestrial zone	Potentially suitable. Note that fully functional non-tidal freshwater emergent wetlands should generally be located in areas that are hydrologically connected to fluvially-influenced channels and/or have artesian groundwater conditions. If this is not feasible, other seasonal wetland or terrestrial habitat types might be more suitable in this location.
non-tidal freshwater emergent wetland	Terrestrial zone	Floodplain (more than 10 feet MHHW)	Green	Land potentially suitable for proposed habitat type	Non-tidal freshwater emergent wetland in terrestrial zone	Potentially suitable. Note that fully functional non-tidal freshwater emergent wetlands should generally be located in areas that are hydrologically connected to fluvially-influenced channels and/or have artesian groundwater conditions. If this is not feasible, other seasonal wetland or terrestrial habitat types might be more suitable in this location.
managed wetland	Tidal zone (deeply subsided)	Deeply subsided (more than 8 ft below MLLW)	Green	Land potentially suitable for proposed habitat type	Managed wetland in a subsided zone	Potentially suitable. Managed wetlands in subsided areas can help halt ongoing subsidence, reduce the risk of levee failure, sequester carbon, provide habitat to waterbirds and other species, and potentially enable the restoration of tidal freshwater emergent wetlands in the future. Note that managed wetlands are more likely to recover intertidal elevations in shallowly subsided areas than deeply subsided areas (with time frames on the order of decades instead of centuries).
managed wetland	Tidal zone (minimally subsided)	Shallowly subsided (up to 8 feet below MLLW)	Green	Land potentially suitable for proposed habitat type	Managed wetland in a subsided zone	Potentially suitable. Managed wetlands in subsided areas can help halt ongoing subsidence, reduce the risk of levee failure, sequester carbon, provide habitat to waterbirds and other species, and potentially enable the restoration of tidal freshwater emergent wetlands in the future. Note that managed wetlands are more likely to recover intertidal elevations in shallowly subsided areas than deeply subsided areas (with time frames on the order of decades instead of centuries).
managed wetland	Tidal zone (intertidal)	Intertidal (between MLLW and MHHW)	Yellow	Consider alternative habitat type: tidal freshwater emergent wetland	Managed wetland in intertidal zone	Potentially suitable, but there are important complicating factors to consider. If land in the intertidal zone is hydrologically connected to the channel network, it is likely to naturally support tidal freshwater emergent wetland, not managed wetlands. Tidal freshwater emergent wetlands might be more suitable in this location, particularly given the relatively limited extent of the intertidal zone (where tidal freshwater emergent wetland restoration is feasible).
managed wetland	Tidal-terrestrial zone	Sea level rise projection (0 to +10 ft MHHW)	Yellow	Consider alternative habitat type: non-tidal freshwater emergent wetland, seasonal wetland, or terrestrial habitat type	Managed wetland in tidal-terrestrial zone	Potentially suitable, but there are important complicating factors to consider. Although these areas are currently too high to support tidal marsh, they are likely to become intertidal with sea-level rise over the long-term, assuming there are no barriers to tidal flows. Over the near-term, non-tidal freshwater emergent wetland, seasonal wetland, or terrestrial habitat types might be more suitable in this area than managed wetlands and not require active management. These habitat types could then potentially transition to tidal marsh as sea levels rise (managers should prioritize the removal of future barriers to tidal flows).
managed wetland	Terrestrial zone	Floodplain (more than 10 feet MHHW)	Yellow	Consider alternative habitat type: non-tidal freshwater emergent wetland, seasonal wetland, or terrestrial habitat type	Managed wetland in terrestrial zone	Potentially suitable, but there are important complicating factors to consider. Over the near-term, non-tidal freshwater emergent wetland, seasonal wetland, or terrestrial habitat types might be more suitable in this area than managed wetlands and not require active management.

## Appendix 1: Habitat type suitability by geomorphic zone for Physical Suitability module

Habitat type	Geomorphic zone (SEI)	Elevation zone (Delta P <sub>lan</sub> )	Flag type	Flag class (simple)	Habitat type & geomorphic zone	Flag description
willow riparian scrub/shrub	Tidal zone (deeply subsided)	Deeply subsided (more than 8 ft below MLLW)	Yellow	Potentially suitable, but land too low to support proposed habitat type in the event of a levee failure event	Woody riparian habitat type in a subsided zone	Potentially suitable, but there are important complicating factors to consider. Woody riparian habitat types can be sustained in subsided zones, but would rapidly transition to open water habitat in the event of a levee failure event, making this habitat type vulnerable in this location over the long-term. Managed and non-tidal wetlands might be more suitable in this location to help halt ongoing subsidence, reduce the risk of levee failure, sequester carbon, provide habitat to waterbirds and other species, and potentially enable the restoration of tidal freshwater emergent wetlands in the future.
willow riparian scrub/shrub	Tidal zone (minimally subsided)	Shallowly subsided (up to 8 feet below MLLW)	Yellow	Potentially suitable, but land too low to support proposed habitat type in the event of a levee failure event	Woody riparian habitat type in a subsided zone	Potentially suitable, but there are important complicating factors to consider. Woody riparian habitat types can be sustained in subsided zones, but would rapidly transition to open water habitat in the event of a levee failure event, making this habitat type vulnerable in this location over the long-term. Managed and non-tidal wetlands might be more suitable in this location to help halt ongoing subsidence, reduce the risk of levee failure, sequester carbon, provide habitat to waterbirds and other species, and potentially enable the restoration of tidal freshwater emergent wetlands in the future.
willow riparian scrub/shrub	Tidal zone (intertidal)	Intertidal (between MLLW and MHHW)	Yellow	Consider alternative habitat type: tidal freshwater emergent wetland	Woody riparian habitat type in intertidal zone	Potentially suitable, but there are important complicating factors to consider. If land in the intertidal zone is hydrologically connected to the channel network, it is likely to naturally support tidal freshwater emergent wetland, not woody riparian habitat types. Hydrologically connected tidal freshwater emergent wetlands might be more suitable in this location, particularly given the relatively limited extent of the intertidal zone (where tidal freshwater emergent wetland restoration is feasible).
willow riparian scrub/shrub	Tidal-terrestrial zone	Sea level rise projection (0 to +10 ft MHHW)	Green	Land potentially suitable for proposed habitat type	Woody riparian habitat type in tidal-terrestrial zone	Potentially suitable. Note that fully functional woody riparian habitat types in the Delta should generally be hydrologically connected to fluvially-influenced channels. If that is not feasible, other seasonal wetland or terrestrial habitat types might be more suitable in this location.
willow riparian scrub/shrub	Terrestrial zone	Floodplain (more than 10 feet MHHW)	Green	Land potentially suitable for proposed habitat type	Woody riparian habitat type in terrestrial zone	Potentially suitable. Notes that fully functional woody riparian habitat types in the Delta should generally be hydrologically connected to fluvially-influenced channels. If that is not feasible, other seasonal wetland or terrestrial habitat types might be more suitable in this location.
valley foothill riparian	Tidal zone (deeply subsided)	Deeply subsided (more than 8 ft below MLLW)	Yellow	Potentially suitable, but land too low to support proposed habitat type in the event of a levee failure event	Woody riparian habitat type in a subsided zone	Potentially suitable, but there are important complicating factors to consider. Woody riparian habitat types can be sustained in subsided zones, but would rapidly transition to open water habitat in the event of a levee failure event, making this habitat type vulnerable in this location over the long-term. Managed and non-tidal wetlands might be more suitable in this location to help halt ongoing subsidence, reduce the risk of levee failure, sequester carbon, provide habitat to waterbirds and other species, and potentially enable the restoration of tidal freshwater emergent wetlands in the future.
valley foothill riparian	Tidal zone (minimally subsided)	Shallowly subsided (up to 8 feet below MLLW)	Yellow	Potentially suitable, but land too low to support proposed habitat type in the event of a levee failure event	Woody riparian habitat type in a subsided zone	Potentially suitable, but there are important complicating factors to consider. Woody riparian habitat types can be sustained in subsided zones, but would rapidly transition to open water habitat in the event of a levee failure event, making this habitat type vulnerable in this location over the long-term. Managed and non-tidal wetlands might be more suitable in this location to help halt ongoing subsidence, reduce the risk of levee failure, sequester carbon, provide habitat to waterbirds and other species, and potentially enable the restoration of tidal freshwater emergent wetlands in the future.
valley foothill riparian	Tidal zone (intertidal)	Intertidal (between MLLW and MHHW)	Yellow	Consider alternative habitat type: tidal freshwater emergent wetland	Woody riparian habitat type in intertidal zone	Potentially suitable, but there are important complicating factors to consider. If land in the intertidal zone is hydrologically connected to the channel network, it is likely to naturally support tidal freshwater emergent wetland, not woody riparian habitat types. Hydrologically connected tidal freshwater emergent wetlands might be more suitable in this location, particularly given the relatively limited extent of the intertidal zone (where tidal freshwater emergent wetland restoration is feasible).
valley foothill riparian	Tidal-terrestrial zone	Sea level rise projection (0 to +10 ft MHHW)	Green	Land potentially suitable for proposed habitat type	Woody riparian habitat type in tidal-terrestrial zone	Potentially suitable. Note that fully functional woody riparian habitat types in the Delta should generally be hydrologically connected to fluvially-influenced channels. If that is not feasible, other seasonal wetland or terrestrial habitat types might be more suitable in this location.
valley foothill riparian	Terrestrial zone	Floodplain (more than 10 feet MHHW)	Green	Land potentially suitable for proposed habitat type	Woody riparian habitat type in terrestrial zone	Potentially suitable. Note that fully functional woody riparian habitat types in the Delta should generally be hydrologically connected to fluvially-influenced channels. If that is not feasible, other seasonal wetland or terrestrial habitat types might be more suitable in this location.
willow thicket	Tidal zone (deeply subsided)	Deeply subsided (more than 8 ft below MLLW)	Yellow	Potentially suitable, but land too low to support proposed habitat type in the event of a levee failure event	Woody riparian habitat type in a subsided zone	Potentially suitable, but there are important complicating factors to consider. Woody riparian habitat types can be sustained in subsided zones, but would rapidly transition to open water habitat in the event of a levee failure event, making this habitat type vulnerable in this location over the long-term. Managed and non-tidal wetlands might be more suitable in this location to help halt ongoing subsidence, reduce the risk of levee failure, sequester carbon, provide habitat to waterbirds and other species, and potentially enable the restoration of tidal freshwater emergent wetlands in the future.
willow thicket	Tidal zone (minimally subsided)	Shallowly subsided (up to 8 feet below MLLW)	Yellow	Potentially suitable, but land too low to support proposed habitat type in the event of a levee failure event	Woody riparian habitat type in a subsided zone	Potentially suitable, but there are important complicating factors to consider. Woody riparian habitat types can be sustained in subsided zones, but would rapidly transition to open water habitat in the event of a levee failure event, making this habitat type vulnerable in this location over the long-term. Managed and non-tidal wetlands might be more suitable in this location to help halt ongoing subsidence, reduce the risk of levee failure, sequester carbon, provide habitat to waterbirds and other species, and potentially enable the restoration of tidal freshwater emergent wetlands in the future.
willow thicket	Tidal zone (intertidal)	Intertidal (between MLLW and MHHW)	Yellow	Consider alternative habitat type: tidal freshwater emergent wetland	Woody riparian habitat type in intertidal zone	Potentially suitable, but there are important complicating factors to consider. If land in the intertidal zone is hydrologically connected to the channel network, it is likely to naturally support tidal freshwater emergent wetland, not woody riparian habitat types. Hydrologically connected tidal freshwater emergent wetlands might be more suitable in this location, particularly given the relatively limited extent of the intertidal zone (where tidal freshwater emergent wetland restoration is feasible).
willow thicket	Tidal-terrestrial zone	Sea level rise projection (0 to +10 ft MHHW)	Green	Land potentially suitable for proposed habitat type	Woody riparian habitat type in tidal-terrestrial zone	Potentially suitable. Note that fully functional woody riparian habitat types in the Delta should generally be hydrologically connected to fluvially-influenced channels. If that is not feasible, other seasonal wetland or terrestrial habitat types might be more suitable in this location.
willow thicket	Terrestrial zone	Floodplain (more than 10 feet MHHW)	Green	Land potentially suitable for proposed habitat type	Woody riparian habitat type in terrestrial zone	Potentially suitable. Note that fully functional woody riparian habitat types in the Delta should generally be hydrologically connected to fluvially-influenced channels. If that is not feasible, other seasonal wetland or terrestrial habitat types might be more suitable in this location.

Appendix 1: Habitat type suitability by geomorphic zone for Physical Suitability module

Habitat type	Geomorphic zone (SEI)	Elevation zone (Delta P <sub>lan</sub> )	Flag type	Flag class (simple)	Habitat type & geomorphic zone	Flag description
vernal pool complex	Tidal zone (deeply subsided)	Deeply subsided (more than 8 ft below MLLW)	Yellow	Potentially suitable, but land too low to support proposed habitat type in the event of a levee failure event	Seasonal wetland habitat type in a subsided zone	Potentially suitable, but there are important complicating factors to consider. Seasonal wetlands habitat types (like wet meadow/seasonal wetland, vernal pool complex, and alkali seasonal wetland complex) could conceivably be created in subsided zones, but would rapidly transition to open water habitat in the event of a levee failure event, making this habitat type vulnerable in this location over the long-term. Additionally, seasonal wetlands require particular physical processes and edaphic/hydrologic conditions (e.g. hardpan development and a perched groundwater table for vernal pool complexes) that generally do not currently exist in the subsided zones of the Delta and would be difficult and cost-prohibitive to restore. These habitat types are more suitable in the tidal-terrestrial and terrestrial zones. Managed and non-tidal wetlands might be more suitable in this location to help halt ongoing subsidence, reduce the risk of levee failure, sequester carbon, provide habitat to waterbirds and other species, and potentially enable the restoration of tidal freshwater emergent wetlands in the future. [1]
vernal pool complex	Tidal zone (minimally subsided)	Shallowly subsided (up to 8 feet below MLLW)	Yellow	Potentially suitable, but land too low to support proposed habitat type in the event of a levee failure event	Seasonal wetland habitat type in a subsided zone	Potentially suitable, but there are important complicating factors to consider. Seasonal wetlands habitat types (like wet meadow/seasonal wetland, vernal pool complex, and alkali seasonal wetland complex) could conceivably be created in subsided zones, but would rapidly transition to open water habitat in the event of a levee failure event, making this habitat type vulnerable in this location over the long-term. Additionally, seasonal wetlands require particular physical processes and edaphic/hydrologic conditions (e.g. hardpan development and a perched groundwater table for vernal pool complexes) that generally do not currently exist in the subsided zones of the Delta and would be difficult and cost-prohibitive to restore. These habitat types are more suitable in the tidal-terrestrial and terrestrial zones. Managed and non-tidal wetlands might be more suitable in this location to help halt ongoing subsidence, reduce the risk of levee failure, sequester carbon, provide habitat to waterbirds and other species, and potentially enable the restoration of tidal freshwater emergent wetlands in the future. [2]
vernal pool complex	Tidal zone (intertidal)	Intertidal (between MLLW and MHHW)	Yellow	Consider alternative habitat type: tidal freshwater emergent wetland	Seasonal wetland habitat type in intertidal zone	Potentially suitable, but there are important complicating factors to consider. Seasonal wetlands habitat types (like wet meadow/seasonal wetland, vernal pool complex, and alkali seasonal wetland complex) could conceivably be created in the intertidal zone, but would be expected to transition to tidal freshwater emergent wetland if hydrologically connected to the Delta's channel network (such as in the event of a levee failure event), making seasonal wetlands vulnerable in this location over the long-term. Additionally, seasonal wetlands require particular physical processes and edaphic/hydrologic conditions (e.g. hardpan development and a perched groundwater table for vernal pool complexes) that generally do not currently exist in the intertidal zone of the Delta and would likely be difficult to restore. Seasonal wetland habitat types are generally more suitable in the tidal-terrestrial and terrestrial zones. Hydrologically connected tidal freshwater emergent wetlands might be more suitable in this location, particularly given the relatively limited extent of the intertidal zone (where tidal freshwater emergent wetland restoration is feasible).
vernal pool complex	Tidal-terrestrial zone	Sea level rise projection (0 to +10 ft MHHW)	Green	Land potentially suitable for proposed habitat type	Seasonal wetland habitat type in tidal-terrestrial zone	Potentially suitable. Seasonal wetland habitat types (like wet meadow/seasonal wetland, vernal pool complex, and alkali seasonal wetland) are suitable in the tidal-terrestrial and terrestrial zones, where they were historically located, and where it is likely most feasible to restore prerequisite hydrologic, geomorphic, and biologic processes needed to sustain seasonal wetlands. Note that seasonal wetlands in the tidal-terrestrial transition zone would be expected to transition to tidal freshwater emergent wetlands over the long-term as sea-levels rise. Managers should generally plan for and accommodate this transition by removing barriers to tidal flows and ensuring ample terrestrial habitat will remain in areas above the tidal-terrestrial transition zone.
vernal pool complex	Terrestrial zone	Floodplain (more than 10 feet MHHW)	Green	Land potentially suitable for proposed habitat type	Seasonal wetland habitat type in terrestrial zone	Potentially suitable. Seasonal wetland habitat types (like wet meadow/seasonal wetland, vernal pool complex, and alkali seasonal wetland) are suitable in the tidal-terrestrial and terrestrial zones, where they were historically located, and where it is likely most feasible to restore prerequisite hydrologic, geomorphic, and biologic processes needed to sustain seasonal wetlands.
wet meadow/seasonal wetland	Tidal zone (deeply subsided)	Deeply subsided (more than 8 ft below MLLW)	Yellow	Potentially suitable, but land too low to support proposed habitat type in the event of a levee failure event	Seasonal wetland habitat type in a subsided zone	Potentially suitable, but there are important complicating factors to consider. Seasonal wetlands habitat types (like wet meadow/seasonal wetland, vernal pool complex, and alkali seasonal wetland complex) could conceivably be created in subsided zones, but would rapidly transition to open water habitat in the event of a levee failure event, making this habitat type vulnerable in this location over the long-term. Additionally, seasonal wetlands require particular physical processes and edaphic/hydrologic conditions (e.g. hardpan development and a perched groundwater table for vernal pool complexes) that generally do not currently exist in the subsided zones of the Delta and would be difficult and cost-prohibitive to restore. These habitat types are more suitable in the tidal-terrestrial and terrestrial zones. Managed and non-tidal wetlands might be more suitable in this location to help halt ongoing subsidence, reduce the risk of levee failure, sequester carbon, provide habitat to waterbirds and other species, and potentially enable the restoration of tidal freshwater emergent wetlands in the future. [3]
wet meadow/seasonal wetland	Tidal zone (minimally subsided)	Shallowly subsided (up to 8 feet below MLLW)	Yellow	Potentially suitable, but land too low to support proposed habitat type in the event of a levee failure event	Seasonal wetland habitat type in a subsided zone	Potentially suitable, but there are important complicating factors to consider. Seasonal wetlands habitat types (like wet meadow/seasonal wetland, vernal pool complex, and alkali seasonal wetland complex) could conceivably be created in subsided zones, but would rapidly transition to open water habitat in the event of a levee failure event, making this habitat type vulnerable in this location over the long-term. Additionally, seasonal wetlands require particular physical processes and edaphic/hydrologic conditions (e.g. hardpan development and a perched groundwater table for vernal pool complexes) that generally do not currently exist in the subsided zones of the Delta and would be difficult and cost-prohibitive to restore. These habitat types are more suitable in the tidal-terrestrial and terrestrial zones. Managed and non-tidal wetlands might be more suitable in this location to help halt ongoing subsidence, reduce the risk of levee failure, sequester carbon, provide habitat to waterbirds and other species, and potentially enable the restoration of tidal freshwater emergent wetlands in the future. [4]
wet meadow/seasonal wetland	Tidal zone (intertidal)	Intertidal (between MLLW and MHHW)	Yellow	Consider alternative habitat type: tidal freshwater emergent wetland	Seasonal wetland habitat type in intertidal zone	Potentially suitable, but there are important complicating factors to consider. Seasonal wetlands habitat types (like wet meadow/seasonal wetland, vernal pool complex, and alkali seasonal wetland complex) could conceivably be created in the intertidal zone, but would be expected to transition to tidal freshwater emergent wetland if hydrologically connected to the Delta's channel network (such as in the event of a levee failure event), making seasonal wetlands vulnerable in this location over the long-term. Additionally, seasonal wetlands require particular physical processes and edaphic/hydrologic conditions (e.g. hardpan development and a perched groundwater table for vernal pool complexes) that generally do not currently exist in the intertidal zone of the Delta and would likely be difficult to restore. Seasonal wetland habitat types are generally more suitable in the tidal-terrestrial and terrestrial zones. Hydrologically connected tidal freshwater emergent wetlands might be more suitable in this location, particularly given the relatively limited extent of the intertidal zone (where tidal freshwater emergent wetland restoration is feasible).
wet meadow/seasonal wetland	Tidal-terrestrial zone	Sea level rise projection (0 to +10 ft MHHW)	Green	Land potentially suitable for proposed habitat type	Seasonal wetland habitat type in tidal-terrestrial zone	Potentially suitable. Seasonal wetland habitat types (like wet meadow/seasonal wetland, vernal pool complex, and alkali seasonal wetland) are suitable in the tidal-terrestrial and terrestrial zones, where they were historically located, and where it is likely most feasible to restore prerequisite hydrologic, geomorphic, and biologic processes needed to sustain seasonal wetlands. Note that seasonal wetlands in the tidal-terrestrial transition zone would be expected to transition to tidal freshwater emergent wetlands over the long-term as sea-levels rise. Managers should generally plan for and accommodate this transition by removing barriers to tidal flows and ensuring ample terrestrial habitat will remain in areas above the tidal-terrestrial transition zone.
wet meadow/seasonal wetland	Terrestrial zone	Floodplain (more than 10 feet MHHW)	Green	Land potentially suitable for proposed habitat type	Seasonal wetland habitat type in terrestrial zone	Potentially suitable. Seasonal wetland habitat types (like wet meadow/seasonal wetland, vernal pool complex, and alkali seasonal wetland) are suitable in the tidal-terrestrial and terrestrial zones, where they were historically located, and where it is likely most feasible to restore prerequisite hydrologic, geomorphic, and biologic processes needed to sustain seasonal wetlands.

## Appendix 1: Habitat type suitability by geomorphic zone for Physical Suitability module

Habitat type	Geomorphic zone (SEED)	Elevation zone (Delta P <sub>Lan</sub> )	Flag type	Flag class (simple)	Habitat type & geomorphic zone	Flag description
stabilized interior dune vegetation	Terrestrial zone	Deeply subsided (more than 8 ft below MLLW)	Yellow	Potentially suitable, but land too low to support proposed habitat type in the event of a levee failure event	Terrestrial habitat type in a subsided zone	Potentially suitable, but there are important complicating factors to consider. Terrestrial habitat types (like grassland, oak woodland/savanna, and stabilized interior dune vegetation) could conceivably be created in subsided zones, but would rapidly transition to open water habitat in the event of a levee failure event, making this habitat type vulnerable in this location over the long-term. Managed and non-tidal wetlands might be more suitable in this location to help halt ongoing subsidence, reduce the risk of levee failure, sequester carbon, provide habitat to waterbirds and other species, and potentially enable the restoration of tidal freshwater emergent wetlands in the future. [5]
stabilized interior dune vegetation	Terrestrial zone	Shallowly subsided (up to 8 feet below MLLW)	Yellow	Potentially suitable, but land too low to support proposed habitat type in the event of a levee failure event	Terrestrial habitat type in a subsided zone	Potentially suitable, but there are important complicating factors to consider. Terrestrial habitat types (like grassland, oak woodland/savanna, and stabilized interior dune vegetation) could conceivably be created in subsided zones, but would rapidly transition to open water habitat in the event of a levee failure event, making this habitat type vulnerable in this location over the long-term. Managed and non-tidal wetlands might be more suitable in this location to help halt ongoing subsidence, reduce the risk of levee failure, sequester carbon, provide habitat to waterbirds and other species, and potentially enable the restoration of tidal freshwater emergent wetlands in the future.
stabilized interior dune vegetation	Terrestrial zone	Intertidal (between MLLW and MHHW)	Yellow	Consider alternative habitat type: tidal freshwater emergent wetland	Terrestrial habitat type in intertidal zone	Potentially suitable, but there are important complicating factors to consider. Terrestrial habitat types (like grassland, oak woodland/savanna, and stabilized interior dune vegetation) could conceivably be created in the intertidal zone, but would be expected to transition to tidal freshwater emergent wetland if hydrologically connected to the Delta's channel network (such as in the event of a levee failure event), making terrestrial habitat types vulnerable in this location over the long-term. Terrestrial habitat types are generally more suitable in the tidal-terrestrial and terrestrial zones. Hydrologically connected tidal freshwater emergent wetlands might be more suitable in this location, especially given the relatively limited extent of the intertidal zone (where tidal freshwater emergent wetland restoration is feasible).
stabilized interior dune vegetation	Terrestrial zone	Sea level rise projection (0 to +10 ft MHHW)	Green	Land potentially suitable for proposed habitat type	Terrestrial habitat type in tidal-terrestrial zone	Potentially suitable. Terrestrial habitat types (like grassland, oak woodland/savanna, and stabilized interior dune vegetation) are suitable in the tidal-terrestrial and terrestrial zones, where they were historically located, and where it is likely most feasible to restore prerequisite hydrologic, geomorphic, and biologic processes needed to sustain terrestrial habitat types. Note that terrestrial habitat types in the tidal-terrestrial transition zone would be expected to transition to tidal freshwater emergent wetlands over the long-term as sea-levels rise. Managers should generally plan for and accommodate this transition by removing barriers to tidal flows and ensuring ample terrestrial habitat will remain in areas above the tidal-terrestrial transition zone.
stabilized interior dune vegetation	Terrestrial zone	Floodplain (more than 10 feet MHHW)	Green	Land potentially suitable for proposed habitat type	Terrestrial habitat type in terrestrial zone	Potentially suitable. Terrestrial habitat types (like grassland, oak woodland/savanna, and stabilized interior dune vegetation) are suitable in the tidal-terrestrial and terrestrial zones, where they were historically located, and where it is likely most feasible to restore prerequisite hydrologic, geomorphic, and biologic processes needed to sustain terrestrial habitat types.
alkali seasonal wetland complex	Tidal zone (deeply subsided)	Deeply subsided (more than 8 ft below MLLW)	Yellow	Potentially suitable, but land too low to support proposed habitat type in the event of a levee failure event	Seasonal wetland habitat type in a subsided zone	Potentially suitable, but there are important complicating factors to consider. Seasonal wetlands habitat types (like wet meadow/seasonal wetland, vernal pool complex, and alkali seasonal wetland complex) could conceivably be created in subsided zones, but would rapidly transition to open water habitat in the event of a levee failure event, making this habitat type vulnerable in this location over the long-term. Additionally, seasonal wetlands require particular physical processes and edaphic/hydrologic conditions (e.g. hardpan development and a perched groundwater table for vernal pool complexes) that generally do not currently exist in the subsided zones of the Delta and would be difficult and cost-prohibitive to restore. These habitat types are more suitable in the tidal-terrestrial and terrestrial zones. Managed and non-tidal wetlands might be more suitable in this location to help halt ongoing subsidence, reduce the risk of levee failure, sequester carbon, provide habitat to waterbirds and other species, and potentially enable the restoration of tidal freshwater emergent wetlands in the future. [6]
alkali seasonal wetland complex	Tidal zone (minimally subsided)	Shallowly subsided (up to 8 feet below MLLW)	Yellow	Potentially suitable, but land too low to support proposed habitat type in the event of a levee failure event	Seasonal wetland habitat type in a subsided zone	Potentially suitable, but there are important complicating factors to consider. Seasonal wetlands habitat types (like wet meadow/seasonal wetland, vernal pool complex, and alkali seasonal wetland complex) could conceivably be created in subsided zones, but would rapidly transition to open water habitat in the event of a levee failure event, making this habitat type vulnerable in this location over the long-term. Additionally, seasonal wetlands require particular physical processes and edaphic/hydrologic conditions (e.g. hardpan development and a perched groundwater table for vernal pool complexes) that generally do not currently exist in the subsided zones of the Delta and would be difficult and cost-prohibitive to restore. These habitat types are more suitable in the tidal-terrestrial and terrestrial zones. Managed and non-tidal wetlands might be more suitable in this location to help halt ongoing subsidence, reduce the risk of levee failure, sequester carbon, provide habitat to waterbirds and other species, and potentially enable the restoration of tidal freshwater emergent wetlands in the future.
alkali seasonal wetland complex	Tidal zone (intertidal)	Intertidal (between MLLW and MHHW)	Yellow	Consider alternative habitat type: tidal freshwater emergent wetland	Seasonal wetland habitat type in intertidal zone	Potentially suitable, but there are important complicating factors to consider. Seasonal wetlands habitat types (like wet meadow/seasonal wetland, vernal pool complex, and alkali seasonal wetland complex) could conceivably be created in the intertidal zone, but would be expected to transition to tidal freshwater emergent wetland if hydrologically connected to the Delta's channel network (such as in the event of a levee failure event), making seasonal wetlands vulnerable in this location over the long-term. Additionally, seasonal wetlands require particular physical processes and edaphic/hydrologic conditions (e.g. hardpan development and a perched groundwater table for vernal pool complexes) that generally do not currently exist in the intertidal zone of the Delta and would likely be difficult and costly to restore. These habitat types are generally more suitable in the tidal-terrestrial and terrestrial zones. Hydrologically connected tidal freshwater emergent wetlands might be more suitable in this location, particularly given the relatively limited extent of the intertidal zone (where tidal freshwater emergent wetland restoration is feasible).
alkali seasonal wetland complex	Tidal-terrestrial zone	Sea level rise projection (0 to +10 ft MHHW)	Green	Land potentially suitable for proposed habitat type	Seasonal wetland habitat type in tidal-terrestrial zone	Potentially suitable. Seasonal wetland habitat types (like wet meadow/seasonal wetland, vernal pool complex, and alkali seasonal wetland complex) are suitable in the tidal-terrestrial and terrestrial zones, where they were historically located, and where it is likely most feasible to restore prerequisite hydrologic, geomorphic, and biologic processes needed to sustain seasonal wetlands. Note that seasonal wetlands in the tidal-terrestrial transition zone would be expected to transition to tidal freshwater emergent wetlands over the long-term as sea-levels rise. Managers should generally plan for and accommodate this transition by removing barriers to tidal flows and ensuring ample terrestrial habitat will remain in areas above the tidal-terrestrial transition zone.
alkali seasonal wetland complex	Terrestrial zone	Floodplain (more than 10 feet MHHW)	Green	Land potentially suitable for proposed habitat type	Seasonal wetland habitat type in terrestrial zone	Potentially suitable. Seasonal wetland habitat types (like wet meadow/seasonal wetland, vernal pool complex, and alkali seasonal wetland complex) are suitable in the tidal-terrestrial and terrestrial zones, where they were historically located, and where it is likely most feasible to restore prerequisite hydrologic, geomorphic, and biologic processes needed to sustain seasonal wetlands.
grassland	Tidal zone (deeply subsided)	Deeply subsided (more than 8 ft below MLLW)	Yellow	Potentially suitable, but land too low to support proposed habitat type in the event of a levee failure event	Terrestrial habitat type in a subsided zone	Potentially suitable, but there are important complicating factors to consider. Terrestrial habitat types (like grassland, oak woodland/savanna, and stabilized interior dune vegetation) could conceivably be created in subsided zones, but would rapidly transition to open water habitat in the event of a levee failure event, making this habitat type vulnerable in this location over the long-term. Managed and non-tidal wetlands might be more suitable in this location to help halt ongoing subsidence, reduce the risk of levee failure, sequester carbon, provide habitat to waterbirds and other species, and potentially enable the restoration of tidal freshwater emergent wetlands in the future. [7]

## Appendix 1: Habitat type suitability by geomorphic zone for Physical Suitability module

Habitat type	Geomorphic zone (SEI)	Elevation zone (Delta P/Lan)	Flag type	Flag class (simple)	Habitat type & geomorphic zone	Flag description
grassland	Tidal zone (minimally subsided)	Shallowly subsided (up to 8 feet below MLLW)	Yellow	Potentially suitable, but land too low to support proposed habitat type in the event of a levee failure event	Terrestrial habitat type in a subsided zone	Potentially suitable, but there are important complicating factors to consider. Terrestrial habitat types (like grassland, oak woodland/savanna, and stabilized interior dune vegetation) could conceivably be created in subsided zones, but would rapidly transition to open water habitat in the event of a levee failure event, making this habitat type vulnerable in this location over the long-term. Managed and non-tidal wetlands might be more suitable in this location to help halt ongoing subsidence, reduce the risk of levee failure, sequester carbon, provide habitat to waterbirds and other species, and potentially enable the restoration of tidal freshwater emergent wetlands in the future.
grassland	Tidal zone (intertidal)	Intertidal (between MLLW and MHHW)	Yellow	Consider alternative habitat type: tidal freshwater emergent wetland	Terrestrial habitat type in intertidal zone	Potentially suitable, but there are important complicating factors to consider. Terrestrial habitat types (like grassland, oak woodland/savanna, and emergent wetland) hydrologically connected to the Delta's channel network (such as in the event of a levee failure event), making terrestrial habitat types vulnerable in this location over the long-term. Terrestrial habitat types are generally more suitable in the tidal-terrestrial and terrestrial zones. Hydrologically connected tidal freshwater emergent wetlands might be more suitable in this location, especially given the relatively limited extent of the intertidal zone (where tidal freshwater emergent wetland restoration is feasible).
grassland	Tidal-terrestrial zone	Sea level rise projection (0 to +10 ft MHHW)	Green	Land potentially suitable for proposed habitat type	Terrestrial habitat type in tidal-terrestrial zone	Potentially suitable. Terrestrial habitat types (like grassland, oak woodland/savanna, and stabilized interior dune vegetation) are suitable in the tidal-terrestrial and terrestrial zones, where they were historically located, and where it is likely most feasible to restore prerequisite hydrologic, geomorphic, and biologic processes needed to sustain terrestrial habitat types. Note that terrestrial habitat types in the tidal-terrestrial transition zone would be expected to transition to tidal freshwater emergent wetlands over the long-term as sea-levels rise. Managers should generally plan for and accommodate this transition by removing barriers to tidal flows and ensuring ample terrestrial habitat will remain in areas above the terrestrial transition zone.
grassland	Terrestrial zone	Floodplain (more than 10 feet MHHW)	Green	Land potentially suitable for proposed habitat type	Terrestrial habitat type in terrestrial zone	Potentially suitable. Terrestrial habitat types (like grassland, oak woodland/savanna, and stabilized interior dune vegetation) are suitable in the tidal-terrestrial and terrestrial zones, where they were historically located, and where it is likely most feasible to restore prerequisite hydrologic, geomorphic, and biologic processes needed to sustain terrestrial habitat types.
oak woodland/savanna	Tidal zone (deeply subsided)	Deeply subsided (more than 8 ft below MLLW)	Yellow	Potentially suitable, but land too low to support proposed habitat type in the event of a levee failure event	Terrestrial habitat type in a subsided zone	Potentially suitable, but there are important complicating factors to consider. Terrestrial habitat types (like grassland, oak woodland/savanna, and stabilized interior dune vegetation) could conceivably be created in subsided zones, but would rapidly transition to open water habitat in the event of a levee failure event, making this habitat type vulnerable in this location over the long-term. Managed and non-tidal wetlands might be more suitable in this location to help halt ongoing subsidence, reduce the risk of levee failure, sequester carbon, provide habitat to waterbirds and other species, and potentially enable the restoration of tidal freshwater emergent wetlands in the future. [8]
oak woodland/savanna	Tidal zone (minimally subsided)	Shallowly subsided (up to 8 feet below MLLW)	Yellow	Potentially suitable, but land too low to support proposed habitat type in the event of a levee failure event	Terrestrial habitat type in a subsided zone	Potentially suitable, but there are important complicating factors to consider. Terrestrial habitat types (like grassland, oak woodland/savanna, and stabilized interior dune vegetation) could conceivably be created in subsided zones, but would rapidly transition to open water habitat in the event of a levee failure event, making this habitat type vulnerable in this location over the long-term. Managed and non-tidal wetlands might be more suitable in this location to help halt ongoing subsidence, reduce the risk of levee failure, sequester carbon, provide habitat to waterbirds and other species, and potentially enable the restoration of tidal freshwater emergent wetlands in the future.
oak woodland/savanna	Tidal zone (intertidal)	Intertidal (between MLLW and MHHW)	Yellow	Consider alternative habitat type: tidal freshwater emergent wetland	Terrestrial habitat type in intertidal zone	Potentially suitable, but there are important complicating factors to consider. Terrestrial habitat types (like grassland, oak woodland/savanna, and stabilized interior dune vegetation) could conceivably be created in the intertidal zone, but would be expected to transition to tidal freshwater emergent wetland types vulnerable in this location over the long-term. Terrestrial habitat types are generally more suitable in the tidal-terrestrial and terrestrial zones. Hydrologically connected tidal freshwater emergent wetlands might be more suitable in this location, especially given the relatively limited extent of the intertidal zone (where tidal freshwater emergent wetland restoration is feasible).
oak woodland/savanna	Tidal-terrestrial zone	Sea level rise projection (0 to +10 ft MHHW)	Green	Land potentially suitable for proposed habitat type	Terrestrial habitat type in tidal-terrestrial zone	Potentially suitable. Terrestrial habitat types (like grassland, oak woodland/savanna, and stabilized interior dune vegetation) are suitable in the tidal-terrestrial and terrestrial zones, where they were historically located, and where it is likely most feasible to restore prerequisite hydrologic, geomorphic, and biologic processes needed to sustain terrestrial habitat types. Note that terrestrial habitat types in the tidal-terrestrial transition zone would be expected to transition to tidal freshwater emergent wetlands over the long-term as sea-levels rise. Managers should generally plan for and accommodate this transition by removing barriers to tidal flows and ensuring ample terrestrial habitat will remain in areas above the tidal-terrestrial transition zone.
oak woodland/savanna	Terrestrial zone	Floodplain (more than 10 feet MHHW)	Green	Land potentially suitable for proposed habitat type	Terrestrial habitat type in terrestrial zone	Potentially suitable. Terrestrial habitat types (like grassland, oak woodland/savanna, and stabilized interior dune vegetation) are suitable in the tidal-terrestrial and terrestrial zones, where they were historically located, and where it is likely most feasible to restore prerequisite hydrologic, geomorphic, and biologic processes needed to sustain terrestrial habitat types.
open water	Tidal zone (deeply subsided)	Deeply subsided (more than 8 ft below MLLW)	Green	Land potentially suitable for proposed habitat type	Open water in a subsided zone	Potentially suitable. Specific types of hydrologically connected open water suitable in the intertidal zone include tidal channels and tidal ponds or lakes (including "flooded islands"). Note that multiple factors, including the degree of subsidence, local turbidity, and resulting flows will influence the ecological characteristics of any newly flooded islands and the resulting value to native aquatic species (Durand 2017). In hydrologically disconnected areas (e.g. on subsided islands protected by levees), suitable open water types include non-tidal ponds.
open water	Tidal zone (minimally subsided)	Shallowly subsided (up to 8 feet below MLLW)	Green	Land potentially suitable for proposed habitat type	Open water in a subsided zone	Potentially suitable. Specific types of hydrologically connected open water suitable in the intertidal zone include tidal channels and tidal ponds or lakes (including "flooded islands"). Note that multiple factors, including the degree of subsidence, local turbidity, and resulting flows will influence the ecological characteristics of any newly flooded islands and the resulting value to native aquatic species (Durand 2017). In hydrologically disconnected areas (e.g. on subsided islands protected by levees), suitable open water types include non-tidal ponds.
open water	Tidal zone (intertidal)	Intertidal (between MLLW and MHHW)	Green	Land potentially suitable for proposed habitat type	Open water in intertidal zone	Potentially suitable. Specific types of open water suitable in the intertidal zone include tidal channels and tidal ponds or lakes.
open water	Tidal-terrestrial zone	Sea level rise projection (0 to +10 ft MHHW)	Green	Land potentially suitable for proposed habitat type	Open water in tidal-terrestrial zone	Potentially suitable. Specific types of open water suitable in the tidal-terrestrial zone include tidal and fluvial channels, tidal and nontidal perennial pond or lakes, and tidal and nontidal intermittent pond or lakes.
open water	Terrestrial zone	Floodplain (more than 10 feet MHHW)	Green	Land potentially suitable for proposed habitat type	Open water in terrestrial zone	Potentially suitable. Specific types of open water suitable in the terrestrial zone include fluvial channels, nontidal perennial pond or lakes, and nontidal intermittent pond or lakes.
urban/barren	Tidal zone (deeply subsided)	Deeply subsided (more than 8 ft below MLLW)	Yellow	Potentially suitable, but land too low to support proposed habitat type in the event of a levee failure event	Urban area in a subsided zone	Zones must be protected from flooding and sea-level rise with levees and other flood control infrastructure. This tool does not evaluate the suitability of urban development in any particular location beyond noting the flood risk inherent in locating urban development in these zones. Urban development is subject to myriad local, county, and state regulations, including Delta Plan policies requiring new commercial, residential, and industrial development in the Delta to be located wisely.

## Appendix 1: Habitat type suitability by geomorphic zone for Physical Suitability module

Habitat type	Geomorphic zone (SEI)	Elevation zone (Delta P/Lan)	Flag type	Flag class (simple)	Habitat type & geomorphic zone	Flag description
urban/barren	Tidal zone (minimally subsided)	Shallowly subsided (up to 8 feet below MLLW)	Yellow	Potentially suitable, but land too low to support proposed habitat type in the event of a levee failure event	Urban area in a subsided zone	Potentially suitable, but there are important complicating factors to consider. Urban areas located in the subsided, intertidal, and tidal-terrestrial zones must be protected from flooding and sea-level rise with levees and other flood control infrastructure. This tool does not evaluate the suitability of urban development in any particular location beyond noting the flood risk inherent in locating urban development in these zones. Urban development is subject to myriad local, county, and state regulations, including Delta Plan policies requiring new commercial, residential, and industrial development in the Delta to be located wisely.
urban/barren	Tidal zone (intertidal)	Intertidal (between MLLW and MHHW)	Yellow	Potentially suitable, but land too low to support proposed habitat type in the event of a levee failure event	Urban area in intertidal zone	Potentially suitable, but there are important complicating factors to consider. Urban areas located in the subsided, intertidal, and tidal-terrestrial zones must be protected from flooding and sea-level rise with levees and other flood control infrastructure. This tool does not evaluate the suitability of urban development in any particular location beyond noting the flood risk inherent in locating urban development in these zones. Urban development is subject to myriad local, county, and state regulations, including Delta Plan policies requiring new commercial, residential, and industrial development in the Delta to be located wisely.
urban/barren	Tidal-terrestrial zone	Sea level rise projection (0 to +10 ft MHHW)	Yellow	Potentially suitable, but proposed anthropogenic habitat type will need to be protected from sea-level rise over the long term	Urban area in tidal-terrestrial zone	Potentially suitable, but there are important complicating factors to consider. Urban areas located in the subsided, intertidal, and tidal-terrestrial zones must be protected from flooding and sea-level rise with levees and other flood control infrastructure. This tool does not evaluate the suitability of urban development in any particular location beyond noting the flood risk inherent in locating urban development in these zones. Urban development is subject to myriad local, county, and state regulations, including Delta Plan policies requiring new commercial, residential, and industrial development in the Delta to be located wisely.
urban/barren	Terrestrial zone	Floodplain (more than 10 feet MHHW)	Green	Land potentially suitable for proposed habitat type	Urban area in terrestrial zone	Potentially suitable. Urban development is subject to myriad local, county, and state regulations, including Delta Plan policies requiring new commercial, residential, and industrial development in the Delta to be located wisely. There are a variety of ways to increase support for native wildlife in and around urban areas, including urban greening and native plantings, low-impact development, beneficial reuse of wastewater, and construction of water-treatment wetlands.
agriculture/non-native/ruderal	Tidal zone (deeply subsided)	Deeply subsided (more than 8 ft below MLLW)	Yellow	Potentially suitable, but land too low to support proposed habitat type in the event of a levee failure event	Agriculture in a subsided zone	Potentially suitable, but there are important complicating factors to consider. Note that agriculture located in the subsided, intertidal, and tidal-terrestrial zones must be protected from flooding and sea-level rise with levees and other flood control infrastructure. Certain crop types, including rice, can help reduce the rate of ongoing subsidence and thereby limit future increases in levee instability and flood risk, while also providing some benefits to native wildlife. Working landscapes – agricultural lands managed to support biodiversity and provide habitat resources–will play an important role in achieving ecosystem goals in the Delta. There are opportunities for agricultural lands in all zones to incorporate wildlife-friendly agriculture practices, including seasonally flooding fields; modifying levees to support marsh or woody riparian channel margin habitat (Davenport et al. 2016); integrating perennial managed wetlands into the agricultural matrix to provide habitat, reverse subsidence, and generate revenue through the carbon market (e.g., Deverel et al. 2014; American Carbon Registry 2017); and implementing other best management practices/techniques (e.g., agroforestry and diversified farming) to improve habitat and connectivity for wildlife (Kremen and Merenlender 2018).
agriculture/non-native/ruderal	Tidal zone (minimally subsided)	Shallowly subsided (up to 8 feet below MLLW)	Yellow	Potentially suitable, but land too low to support proposed habitat type in the event of a levee failure event	Agriculture in a subsided zone	Potentially suitable, but there are important complicating factors to consider. Note that agriculture located in the subsided, intertidal, and tidal-terrestrial zones must be protected from flooding and sea-level rise with levees and other flood control infrastructure. Certain crop types, including rice, can help reduce the rate of ongoing subsidence and thereby limit future increases in levee instability and flood risk, while also providing some benefits to native wildlife. Working landscapes – agricultural lands managed to support biodiversity and provide habitat resources–will play an important role in achieving ecosystem goals in the Delta. There are opportunities for agricultural lands in all zones to incorporate wildlife-friendly agriculture practices, including seasonally flooding fields; modifying levees to support marsh or woody riparian channel margin habitat (Davenport et al. 2016); integrating perennial managed wetlands into the agricultural matrix to provide habitat, reverse subsidence, and generate revenue through the carbon market (e.g., Deverel et al. 2014; American Carbon Registry 2017); and implementing other best management practices/techniques (e.g., agroforestry and diversified farming) to improve habitat and connectivity for wildlife (Kremen and Merenlender 2018).
agriculture/non-native/ruderal	Tidal zone (intertidal)	Intertidal (between MLLW and MHHW)	Yellow	Potentially suitable, but land too low to support proposed habitat type in the event of a levee failure event	Agriculture in intertidal zone	Potentially suitable, but there are important complicating factors to consider. Note that agriculture located in the subsided, intertidal, and tidal-terrestrial zones must be protected from flooding and sea-level rise with levees and other flood control infrastructure. Certain crop types, including rice, can help reduce the rate of ongoing subsidence and thereby limit future increases in levee instability and flood risk, while also providing some benefits to native wildlife. Working landscapes – agricultural lands managed to support biodiversity and provide habitat resources–will play an important role in achieving ecosystem goals in the Delta. There are opportunities for agricultural lands in all zones to incorporate wildlife-friendly agriculture practices, including seasonally flooding fields; modifying levees to support marsh or woody riparian channel margin habitat (Davenport et al. 2016); integrating perennial managed wetlands into the agricultural matrix to provide habitat, reverse subsidence, and generate revenue through the carbon market (e.g., Deverel et al. 2014; American Carbon Registry 2017); and implementing other best management practices/techniques (e.g., agroforestry and diversified farming) to improve habitat and connectivity for wildlife (Kremen and Merenlender 2018).
agriculture/non-native/ruderal	Tidal-terrestrial zone	Sea level rise projection (0 to +10 ft MHHW)	Yellow	Potentially suitable, but proposed anthropogenic habitat type will need to be protected from sea-level rise over the long term	Agriculture in tidal-terrestrial zone	Potentially suitable, but there are important complicating factors to consider. Note that agriculture located in the subsided, intertidal, and tidal-terrestrial zones must be protected from flooding and sea-level rise with levees and other flood control infrastructure. Certain crop types, including rice, can help reduce the rate of ongoing subsidence and thereby limit future increases in levee instability and flood risk, while also providing some benefits to native wildlife. Working landscapes – agricultural lands managed to support biodiversity and provide habitat resources–will play an important role in achieving ecosystem goals in the Delta. There are opportunities for agricultural lands in all zones to incorporate wildlife-friendly agriculture practices, including seasonally flooding fields; modifying levees to support marsh or woody riparian channel margin habitat (Davenport et al. 2016); integrating perennial managed wetlands into the agricultural matrix to provide habitat, reverse subsidence, and generate revenue through the carbon market (e.g., Deverel et al. 2014; American Carbon Registry 2017); and implementing other best management practices/techniques (e.g., agroforestry and diversified farming) to improve habitat and connectivity for wildlife (Kremen and Merenlender 2018).
agriculture/non-native/ruderal	Terrestrial zone	Floodplain (more than 10 feet MHHW)	Green	Land potentially suitable for proposed habitat type	Agriculture in terrestrial zone	Potentially suitable. Working landscapes – agricultural lands managed to support biodiversity and provide habitat resources–will play an important role in achieving ecosystem goals in the Delta. There are opportunities for agricultural lands in all zones to incorporate wildlife-friendly agriculture practices, including seasonally flooding fields; modifying levees to support marsh or woody riparian channel margin habitat (Davenport et al. 2016); integrating perennial managed wetlands into the agricultural matrix to provide habitat and generate revenue through the carbon market (e.g., Deverel et al. 2014; American Carbon Registry 2017); and implementing other best management practices/techniques (e.g., agroforestry and diversified farming) to improve habitat and connectivity for wildlife (Kremen and Merenlender 2018).