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Delta Habitat Opportunities - Assessing Risks with Climate Change

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Abstract

The California Delta is a key component of the largest estuary on the west coast. It is also a key component for the water supply system serving much of California. Both the Delta environment and the water supply system are in crisis and are at high risk. The area is dynamic. Land use change is active on the periphery of the Delta. Sea level rise and expected changes in precipitation patterns increase the uncertainty of what habitat conditions will be over time. Of interest are existing terrestrial and aquatic habitats and potential areas or corridors that may have conditions in the future that resemble those most valued now. One of the goals is identifying areas that could potentially provide a rich mix of habitat types through the range of daily, seasonal, and annual cycles. ArcGIS provides a variety of spatial analysis and spatial statistics tools for modeling terrestrial habitats for this area. This should assist in attempting to reduce risks for both systems.

A large array of data is available to model characteristics considered suitable for habitat restoration activities in and near the Delta. Major portions of the California Delta were tidal and fresh water marshland prior to development in the late 1800's. These areas are now largely agricultural lands. some of which are now deeply subsided and are well below current sea level. By the end of this century sea level is expected to rise over 1 meter in the Delta area. Future restoration of aquatic and wetland environments are expected to focus on areas in or near the Delta that can accommodate sea level rise. Major factors of interest for habitat restoration are:

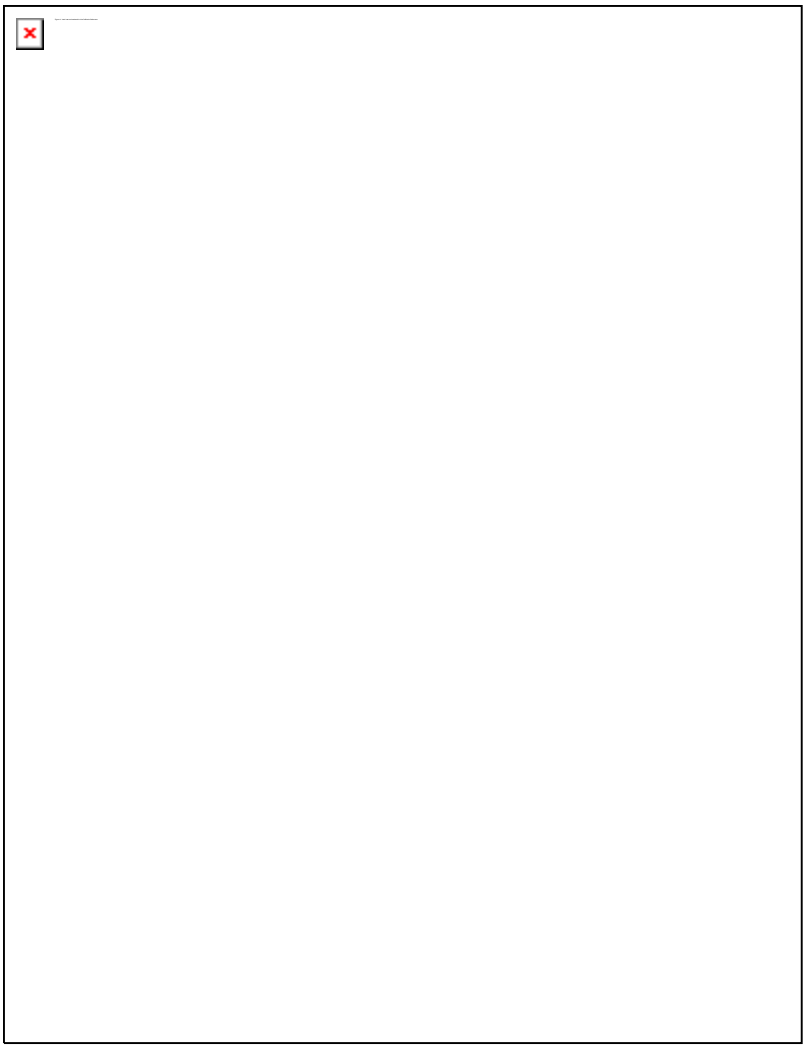
- Lands or soils suitable for wetland habitat
- Surface elevations that are are above -1 meter MSL and within the expected tidal range for that location
- Areas above mean high water that can accommodate sea level rise
- Areas that can provide a mix of open water, wetland, and upland habitats over time within the expected tidal influence for that location.
- Areas with land uses that can tolerate inundation
- Areas that are not now or likely to become urbanized

Introduction

The California Delta and Suisun Marsh area are major components of San Francisco Bay Estuary, the largest estuary on the U.S. pacific coast. The Delta and adjacent Suisun Marsh are constrained to one outlet at Carquinez Strait by coastal mountains. Instead of the migration of fluvial and tidal sediments seaward to the bay, tidal and fluvial sediments historically were stratified upstream as sea levels rise and fall (Atwater, 1982). The Delta has formed at the confluence of the San Joaquin and Sacramento rivers. These river systems carry flows from the watersheds of the Central Valley and are key components in the water supply system for the State.

Delta as Habitat

Wetlands in Suisun Marsh and the Delta represent about 10 percent of the existing wetland areas in California. Suisun Marsh is largely managed wetlands and comprises the major share of existing wetlands. The Delta area is now largely in agriculture. Complexes of wetland and riparian systems that were present prior to agricultural development exist only as fragmented remnants. There are approximately 13,000 hectares (23,000 acres) of wetlands and 6,000 hectares (14,000 acres) of riparian habitat in the Delta area. Over 202,000 hectares (500,000 acres) of Delta lands are in agricultural production. Urbanization of lands in the Delta is generally occurring on the periphery. Figure 1 shows major land use categories within the Delta and remaining areas of wetland or riparian habitat. Agriculture and urban areas are based on 2007 mapping by the California Department of Water Resources. Wetland and riparian areas are based on detailed vegetation mapping by the California Department of Fish and Game done between 2002 and 2005.



Delta as Water Supply

Water passing through the Delta is a source of water for a majority of the State's population and provides irrigation water for over 1.0 million hectares (2.5 million acres). The water system consists of the main channels of the Sacramento and San Joaquin Rivers and a complex network of sloughs. It is a key component of Federal and State water projects. Pumps at the southern end of the Delta conduct water into the California Aqueduct and Delta-Mendota Canal from the northern Central Valley, mainly to agriculture in the San Joaquin Valley, and to urban southern California. These pumps have been periodically shut down due to potential conflicts with Delta smelt and other species.

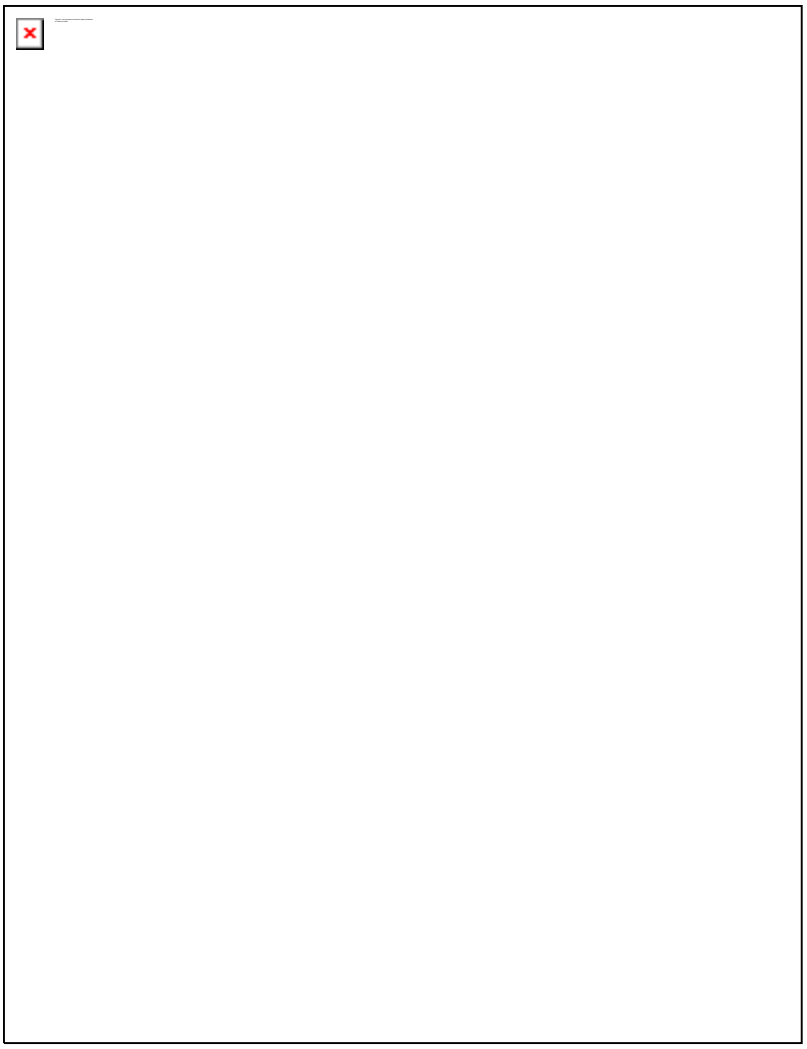
At the end of 2006, the Governor of the State of California appointed a Blue Ribbon Task Force to study and develop a strategic vision for the Delta. This task force issued the vision statement for the Delta in 2007 followed by a Delta Vision Strategic Plan in 2008. The major recommendation of the task force is: ***The Delta ecosystem and a reliable water supply for California are the primary, co-equal goals for sustainable management of the Delta.***

Levees and Subsidence

Levees define the water supply system and the land-water interface of “islands” and tracts. These islands would be more properly called polders, in that but for the levees, they would be below sea level or flood stage. Natural levees along major stream channels have served as the basis for man-made levees constructed to reclaim tidal and non tidal wetlands as farmland since the late 1800's. There are over 1,600 kilometers (1000 miles) of levees at the present time (URS Corp., 2007). Drainage and conversion of the organic peat and muck soils to agricultural production have led to significant subsidence. Some areas of the Delta are now well below current mean sea level (MSL).

Many of the levees were constructed from local materials on site. Since 1900, there have been 166 recorded levee failures (URS Corp, 2007). Only portions of this levee system near the cities of Stockton, West Sacramento, and Sacramento are considered adequate for flood protection. The Delta is in close proximity to major active faults in Northern California. It is expected that a severe seismic event would lead to catastrophic collapse of many levees in this system. Sea level rise expected from climate change is expected to place an increasing amount of stress on an already risky levee system. Failure of key levees or a catastrophic collapse threatens the operation of key water supply systems for the state.

Levees limit the linkage of aquatic species from open water environments to the remaining wetland environments in the Delta area. They restrict flows to some remaining wetland habitats on the interior of islands. The lack of stability in the levee system and the threat of sea level rise places existing wetlands or restoration of wetland areas in deeply subsided portions of the Delta at risk.

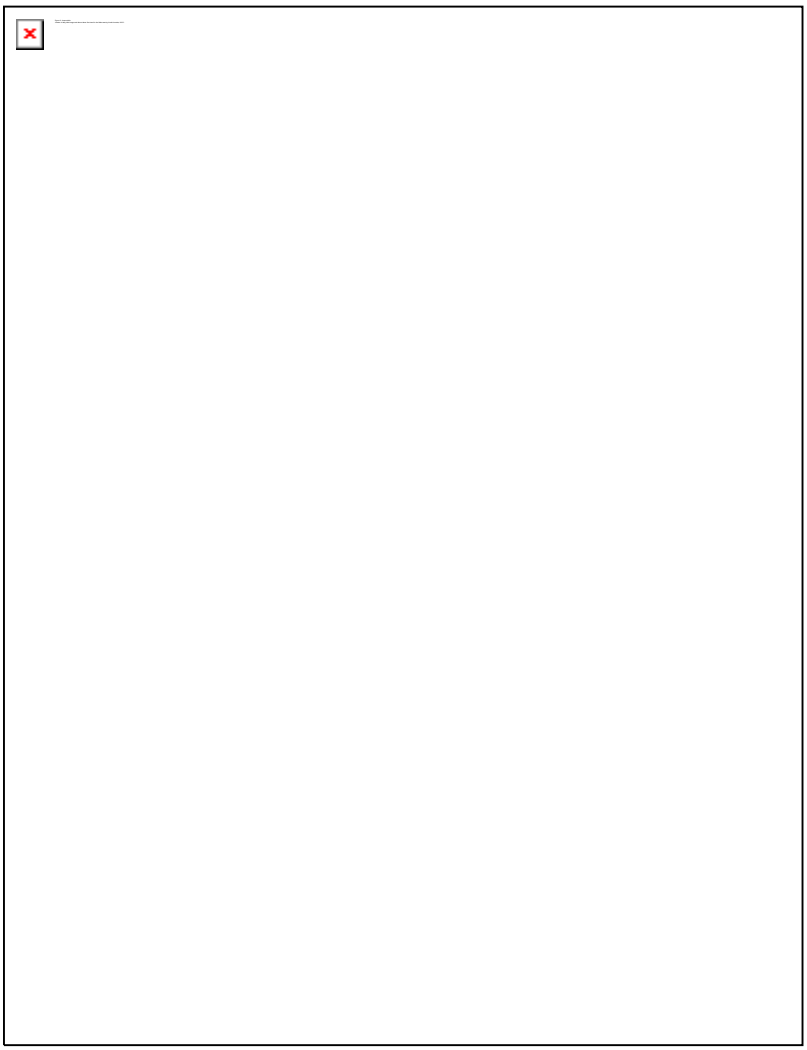


Sea Level Rise and Habitat

Wetlands in the Delta had largely developed in the area of tidal influence. The general tidal range for this area is currently within about 0.75 to 1.5 meters. Typically the soils are wet with a water table at or near the soil surface for extended periods. They may be flooded but with water depths generally less than 2 meters. The average elevation for existing saline and fresh water wetlands in the Delta area is about 1 to 2 meters above mean sea level (MSL). The average minimum range is very close to current mean sea level with the average maximum elevations at 2 to nearly 3 meters MSL. However, there is considerable variation in elevations for wetland areas on deeply subsided portions of Delta as well as wetlands that have developed along the periphery of the Delta.

The Governor of the State of California was asked by the Task Force to direct state agencies to plan critical facilities for a sea level rise of approximately 1.4 meters (55 inches) by 2100 (Blue Ribbon Task Force, 2008). The National Research Council will render a refined target. There are a variety of estimates on both the rate and amount of sea level rise. Several analyses have been underway concerning fluctuations in the daily and monthly tidal range with variations in sea level rise for San Francisco Bay and the Delta area. Noah Knowles, USGS, has evaluated the

additional land area affected by a 1 meter rise in sea level considering daily and monthly tidal ranges (Blue Ribbon Task Force, 2007). These areas are shown in Figure 3. They represent additional areas above mean sea level that could be affected by daily tidal ranges up to 1 meter MSL with levee failures.



Both changes in sea level and tidal range need to be considered for the development or restoration of seasonal and permanent wetlands in the area. The Delta Vision Strategic Plan identifies the following targets for restoration.

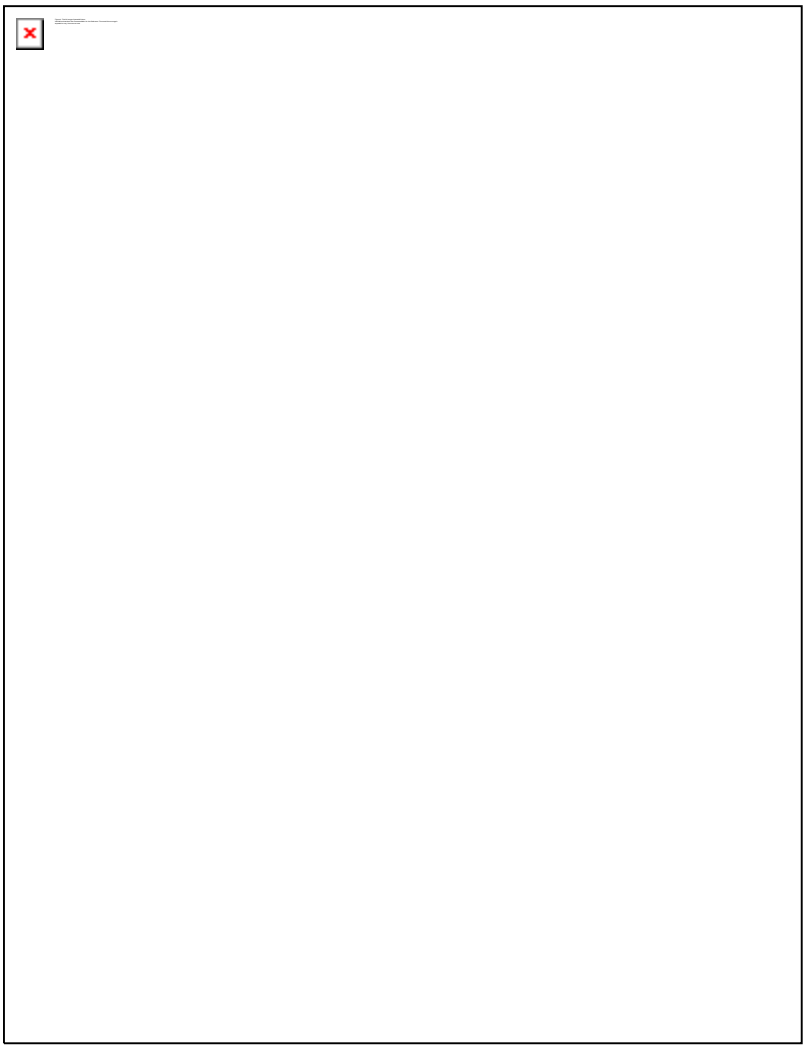
- Inter-tidal Marsh - 12,000 hectares (30,000 acres) by 2040
- Tidal open water - 18,000 hectares (45,000 acres) by 2040
- Permit increased inundation of flood plains to restore their function as an interconnected system with wetland and aquatic habitats

The plan provided key criteria for identifying potential areas for restoration of these habitats (DV strategic Plan, 2008). Tidal marsh should be within the current range of tides. The topography should accommodate changes in the tidal range due to sea level rise. The topography should be varied enough to include flood plain habitat and uplands as a complex and interconnected

system. The area should be large enough to permit the development of dendritic patterns or networks within the wetland areas. Besides providing for a complex set of habitats of wetland, floodplain, and upland, the system needs to connect to open water. This would provide opportunity for organisms to migrate between habitats on a daily, seasonal, and annual basis.

Supporting studies for the Delta Vision process by Stuart Siegel examined the issue of potential wetland restoration areas considering potential sea level rise and tidal range. In this examination, Siegel recognized that portions of the Delta would probably experience different ranges of water elevations from sea level rise and tidal influence (Siegel, 2007). He recognized differences in elevations for future inter-tidal areas (mean low/low water to mean high/high water) for different areas. These are about 0.5 meter to over 2 meters above current MSL, For a zone referred to as sea level rise accommodation, values ranged from about 1.5 to 3.5 meters above current MSL depending on the area.

Figure 4 shows the full range of future inter-tidal and sea level rise accommodation for the Delta. The actual range is expected to vary depending on the area of interest.



Modeling Potential Habitat

Of interest in identifying opportunities for aquatic and wetland restoration is recognizing areas in or adjacent to the Delta that will accommodate variations in sea level rise and tidal fluctuations. While this can be considered to be largely a topographic exercise, several other factors typically play a role for analysis. The Delta area and Suisun Marsh have a rich collection of data. Most GIS information is available via the California Spatial Library or California Digital Atlas (http://atlas.resources.ca.gov/mx/). Other information such as detailed soils information is available on other publicly accessible sites. Some information for use in evaluating areas for wetland and related habitats are:

- Elevation data which is available from multiple sources at different resolutions and extent
- Current land use and crop mapping for 2007 by California Department of Water Resources
- Detailed vegetation mapping following National standards by California Department of Fish and Game, 2006
- Levee inventory for Delta developed by URS Corporation for the California Department of Water Resources, 2007
- Detailed soil mapping by the Natural Resources Conservation Service

The key factor is elevation range to meet requirements for these habitats considering both sea level rise and the variability of tidal influence across the area. The investigator may have additional criteria of importance either generally or for a specific area. A conceptual model for raster processing was implemented in ArcGIS as tools using python scripts. These scripts manage the following:

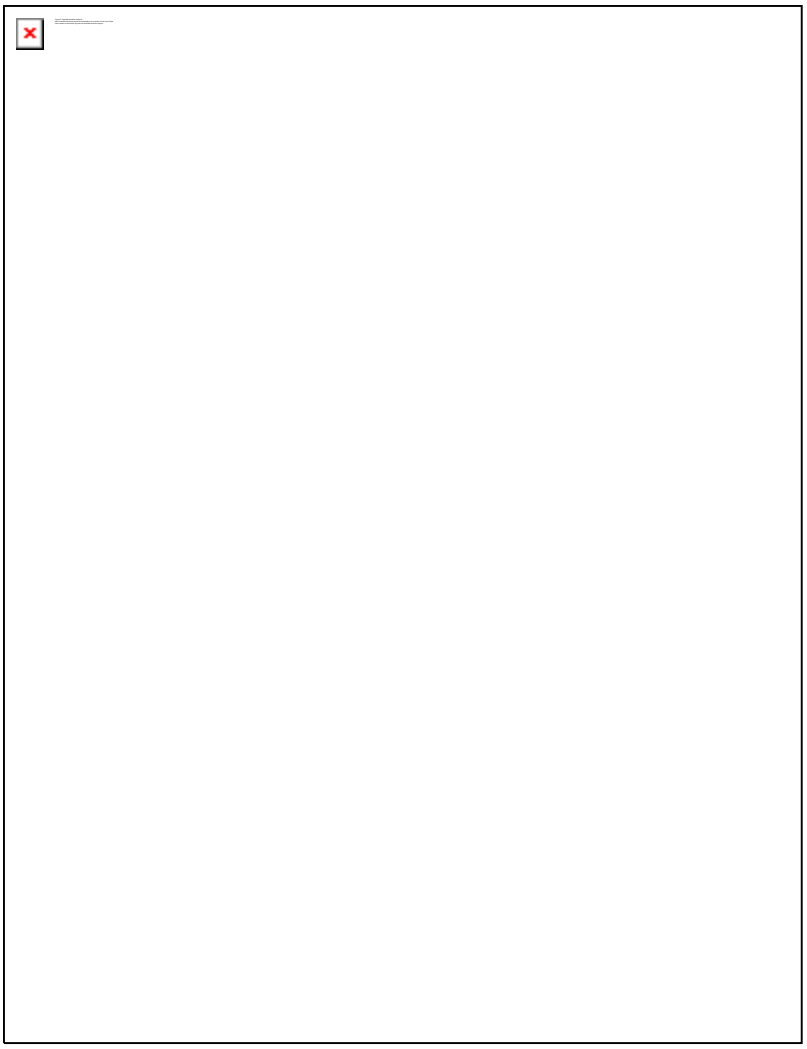
- Prepare a workspace and documentation file to store rasters derived from an elevation dataset.
- Permit the user to select the elevation source for topography
    - This defines the raster resolution or cell size
- Identifies the snap raster for derived rasters
- Permit the user to select an area of interest based on a feature class to limit the analysis
    - Defines the extent of analysis for derived rasters
- Elevation range for future inter-tidal and sea level rise accommodation can be adjusted for that area
- Permit the user to identify the elevation range of interest for the habitat type or types
    - Generates a raster based on the elevation range of interest for that area of the Delta.
- Permit the user to identify land uses that should be excluded from the analysis such as urban, orchard, vineyard, etc.
    - Defines a mask to eliminate areas of the specified land uses for derived grids

- Generate a series of rasters based on the user specified criteria including:
    - Elevation range for future inter-tidal and sea level rise accommodation
- Slope grid based on selected elevation source
- Slope rank to eliminate strongly or steeply sloping areas
- Distance from existing open water
- Distance from levees that may constrain flows between aquatic habitats and wetlands
- Weighted land uses not originally excluded
- Weighted overlay of derived rasters

Limiting analysis to an area of interest permits the user to adjust the elevation range to fit the expected variation in sea level rise and tidal influence for that area. The documentation file captures information on the parameters set for an analysis. Where multiple runs are done for an area of interest, the documentation files can be reviewed to identify the parameters set by the user. This can be particularly useful for:

- Analysis of an area with different sources for elevation
- Variations in the expected range of future inter-tidal or sea level rise accommodation elevations
- Elimination of different land use categories for the analysis of an area

The elevation range and other parameters can then be adjusted as needed for an area or a scenario. Figure 5 shows a portion of the north Delta. For this scenario, the future inter-tidal zone is expected to be from about 0.90 meters to 2.13 meters MSL. The elevation range for sea level rise accommodation is 2.14 meters to 3.65 meters MSL. For the scenario, land uses of Urban, Orchard, and Vineyard were excluded. This allows the user to focus on parameters of interest for a particular area.

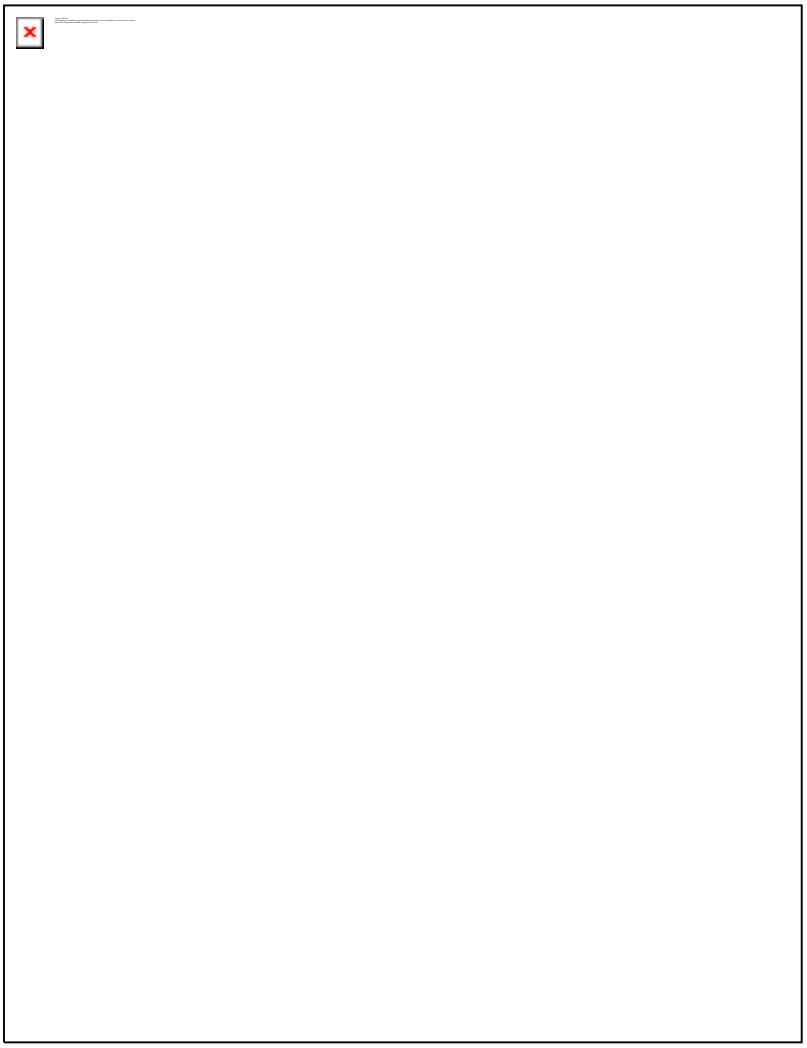


The derived rasters can then be carried forward into other analysis such as ranking distance from existing water ways, proximity to levees or slope of the elevation surface. They are also available for further modeling and analysis such as the weighted sum or weighted overlay.

Important characteristics for successful development of a mix of aquatic and wetland habitats include level to nearly level surfaces large enough to provide areas for interconnected habitats over daily, seasonal, and yearly patterns. Levees can hinder that connection between aquatic and wetland habitat. They can also identify areas where modifications can be made to levees to assist in development of those habitats.

The rasters can be displayed with other information such as soils identified as hydric. Hydric soils are soils which have formed under saturated conditions from flooding or ponding for a sufficient time during the year to develop anaerobic conditions and which exhibit those conditions in the soil profile. Figure 6 shows the same area of the north Delta with weighted and ranked values based on surface slope displayed with detailed mapping of hydric soils. The soil map units displayed were placed into 3 groups. The dominant group displayed is comprised of map units composed of over 50 percent soils recognized as hydric. The second group contains map units with 11 to 50 percent hydric soils. The third group of soil map units contain 1 to 10

percent soils recognized as hydric. They represent only a small portion of the area displayed in this map and are largely along stream channels of mixed alluvium. For this portion of the Delta, most of the elevation range for expected inter-tidal and sea level rise accommodation falls within the group of dominantly hydric soils. What is interesting in this figure is that the dominant hydric soils group extends well beyond the expected elevation range for sea level rise.



Summary

Sea level rise is of major concern for identifying areas for restoration of aquatic and wetland habitat in the Delta area. Much of the Delta has experienced substantial subsidence since drainage and agricultural development of wetland areas. The current levee system restricts flows between open aquatic habitats and wetland areas. Planning for habitat restoration in the Delta area has identified the need to have a complex mixture of interconnected aquatic, wetland and upland habitats. This area of habitats should be adaptable to changes in sea level and tidal patterns. ArcGIS provides a rich environment and tools for modeling topography based on elevation data with other data of interest. In this application, a set of tools based on Python scripts were developed to:

- Allow the user to select the appropriate elevation and bathymetric data
- Identify the elevation range of interest considering changes in sea level or the tidal range
- Limit the analysis to a portion of the Delta area
- Exclude land use types that are considered unsuitable for habitat restoration

These tools generate a series of rasters that can be further used in analysis or display with other data. A documentation file is written identifying the parameters set and the generated data. This permits the user to review and evaluate multiple scenarios for that area.

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