# Wetland Processes

**Wetlands provide many societal benefits:** food and habitat for fish and wildlife, including threatened and endangered species; water quality improvement; flood storage; shoreline erosion control; economically beneficial natural products for human use; and opportunities for recreation, education, and research.

## Formation and Structure

Marshlands occur where ocean meets land in flat areas and transitions from water (aquatic) habitat to land (terrestrial) habitat. Small changes in elevation and water movement with tides creates zones of transition between the land and ocean. Marshes evolve over time with earth plate (tectonic) movement, erosion, and sea level changes. Tidally influenced marshland like the Petaluma Marsh have dendritic pattern of ditches which look like branches of an oak tree with vegetation shifting dramatically within inches of elevation change and described by habitat zones. Size of tidal shifts, flow rates, and salt content all have a tremendous influence on survivability in these transition zones, so vegetation appears in narrow bands along the waterway which create habitat niches for a variety of animal species.

**Vegetation** traps particles that drop out of water, called sediments, mostly small soil particles and organic matter, and that builds soil around the plants. Cordgrasses (*Spartina spp.*) and Bulrush/Tule (*Schoenoplectus spp.*) are major species that do this at the water edges. In the higher marsh, two dominant plant species, Pickleweed (Salicornia virginica) and Saltgrass (Distichlis spicata), are stress tolerant species that can maintain their productivity under adverse conditions irrespective of local sedimentation deposition. The value of vegetation adapted to variable and elevated soil salinity is to substantially contribute to soil and organic matter building up in marshes.

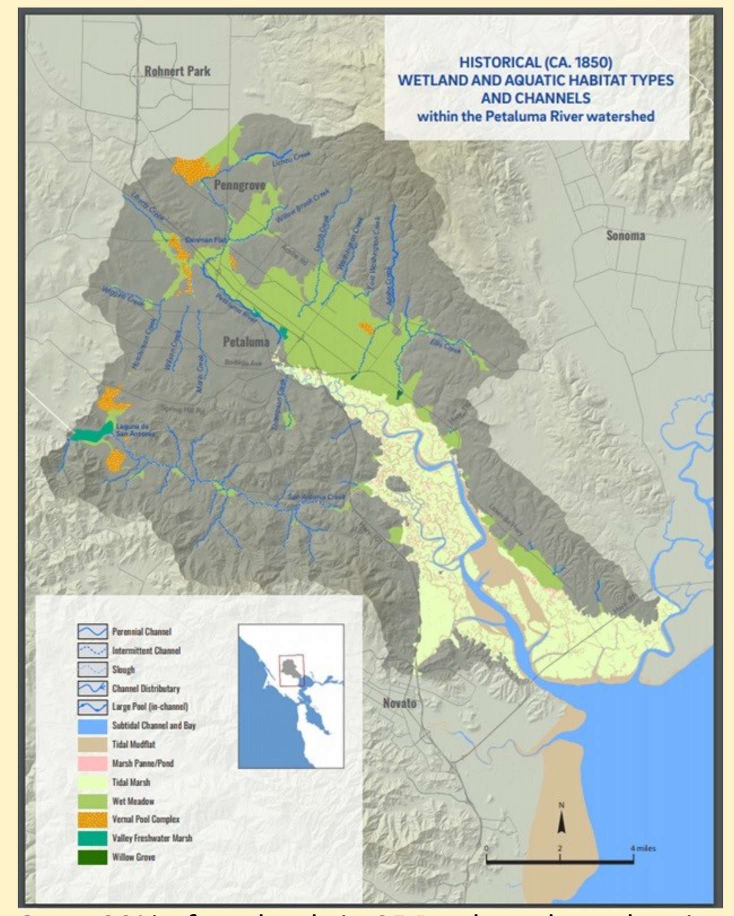
## Salinity

Water in an estuary, where water from rivers mix with ocean water, contains variable amount of dissolved salt. The salinity gradient generally increases from the input source of an estuary, usually a stream or river, to the output source, the sea or ocean. Salinity is measured as parts per thousand (ppt) of solids in liquid (1% = 10 ppt). The salinity of the ocean is generally around 35 ppt (3.5%). The fresh water from rivers has salinity levels of 0.5 ppt or less. Within the estuary, salinity levels are referred to as oligohaline (0.5-5 ppt), mesohaline (5-18 ppt), or polyhaline (18 to 30 ppt). Near the connection with the open sea, estuary waters may be euhaline, where salinity levels are the same as the ocean at more than 30 ppt (3%).

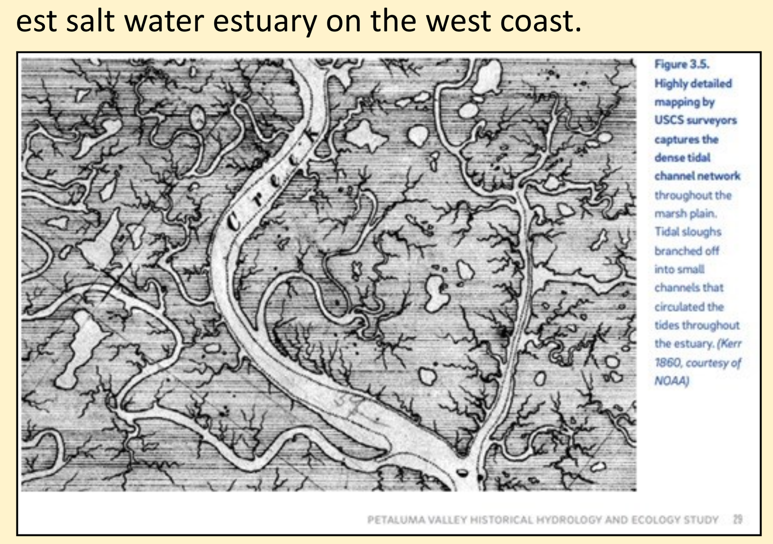
Our **Petaluma River is a tidal slough** with water salinity ranging from 0.5 to 2% making our Petaluma Marsh an oligohaline estuary. The salinity of an estuary can vary variable and dependent on the amount of freshwater flowing in, tides, elevation, physical location, and evaporation. Estuaries have a water balance that is either positive (freshwater inputs exceed evaporation), neutral (there is a balance between freshwater inflows and evaporation), or negative (freshwater inflows are less than the amount of evaporation). Seasonally, our Petaluma Marsh decreases in salinity in the winter months with increased rainfall and cooler temperatures and increases in salinity in the summer with decreased freshwater inflows and increased evaporation.

**Salinity affects soil and water chemistry** in estuaries, most notably the amount of dissolved oxygen. Solubility is the amount of oxygen that can dissolve in water, which decreases as salinity increases. Solubility is important because animals and smaller organisms have salinity ranges that they can tolerate before they experience stress. Some estuarine species such as fish can adapt to changes in oxygen levels by practicing avoidance techniques. Other organisms such as mollusks, oysters, and mud dwelling organisms cannot travel large distances. Salinity levels outside of their tolerance ranges cause negative effects including increased stress and decreased reproduction and survival rates.

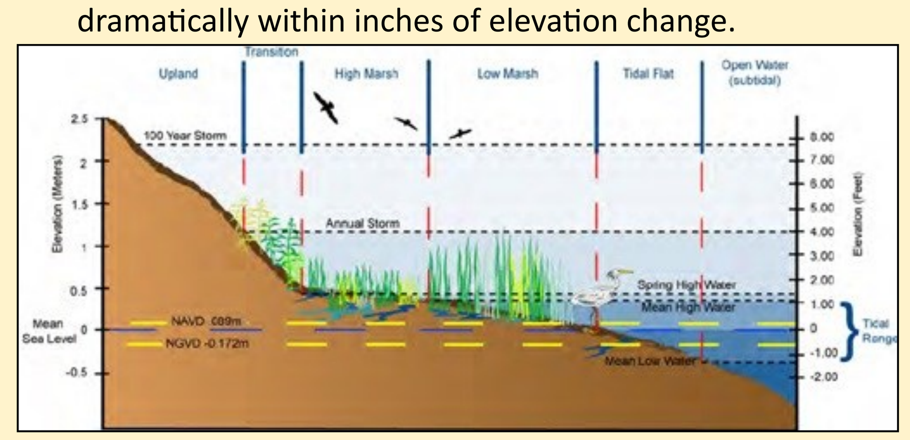
**Organic matter** such as bits of plants and animals, animal waste, decomposed bodies, tiny animals, and microbes are dissolved and suspended in water and attach to soil and sediments and thereby carried into the marsh. Decaying plants and animals in the marsh also contribute larger organic particulate. Detritus is all the non-living organic matter and the associated microbial community. Carbon is the chemical element that forms the structural chains of all chemical compounds used by living beings. The marsh food web which uses detritus as the starting food source, turns over more carbon than rainforests making saltwater marshes highly biologically active and productive ecosystems. The complex relationships between the living (biotic) and abiotic (nonliving) systems including water and sediment flows, vegetation, and the detritus food web have evolved over millennia, so the salt marsh ecosystem is robust, adapting to changes, and capable of surviving eventful impacts.




Over 80% of wetlands in SF Bay have been lost in last 150 years. Even though Petaluma lost much of it to suburban development on the east side and agricultural diking at the river mouth, we have the largest salt water estuary on the west coast.

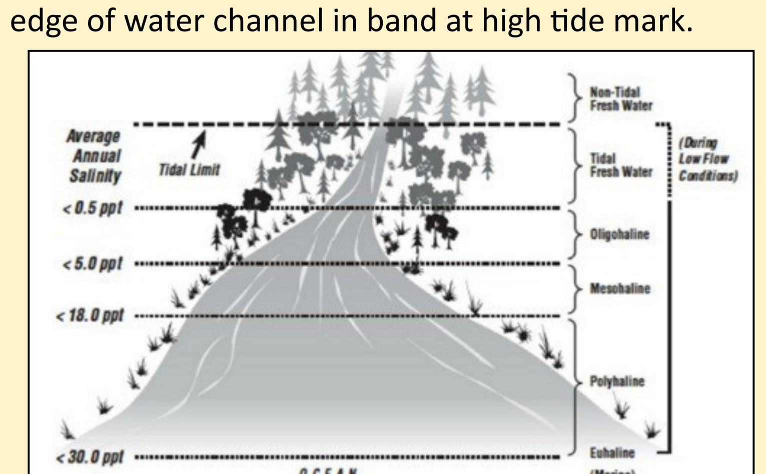


Marsh channels have dendritic pattern which look like branches of an oak tree. Vegetation and habitat shifts dramatically within inches of elevation change.




This diagram of a tidal marsh transition zones shows how vegetation shifts with tidal flow and elevation.

Image of California Cordgrass, ***Sporobolus foliosus***, at edge of water channel in band at high tide mark.




Salt concentration decreases upstream so plants and animals also shift.

## Sediments

Sediments are small particles from natural sources of eroded rocks, soil, and organic (living and dead) sources but also human sources like road debris, trash, plastics, industrial waste, and wastewater that are carried by moving water and can settle out or be trapped and become part of the marsh system. Processes governing movement of water and sediments in a marsh are very complex. Sediments are added and removed by tides, rain, erosion, trapping by vegetation, and amount of living matter (biomass).

Sediments flow up the Petaluma River and wetlands from ocean tides through the SF and San Pablo Bays. In addition, the Sacramento and San Joaquin Rivers transport large volumes of sediment through the Sacramento-San Joaquin Delta to San Pablo Bay, particularly in the rainy season, which can then enter the mouth of the Petaluma River and flow up with the tides. Tidal inflow and outflow, twice every 25 hours, constantly moves sediments up and down river, making the river water "muddy", reducing sunlight penetration. Some sediment contains the mineral apatite with phosphorus which can increase algal blooms or contain mercury from past mining operations which is toxic to many living things.

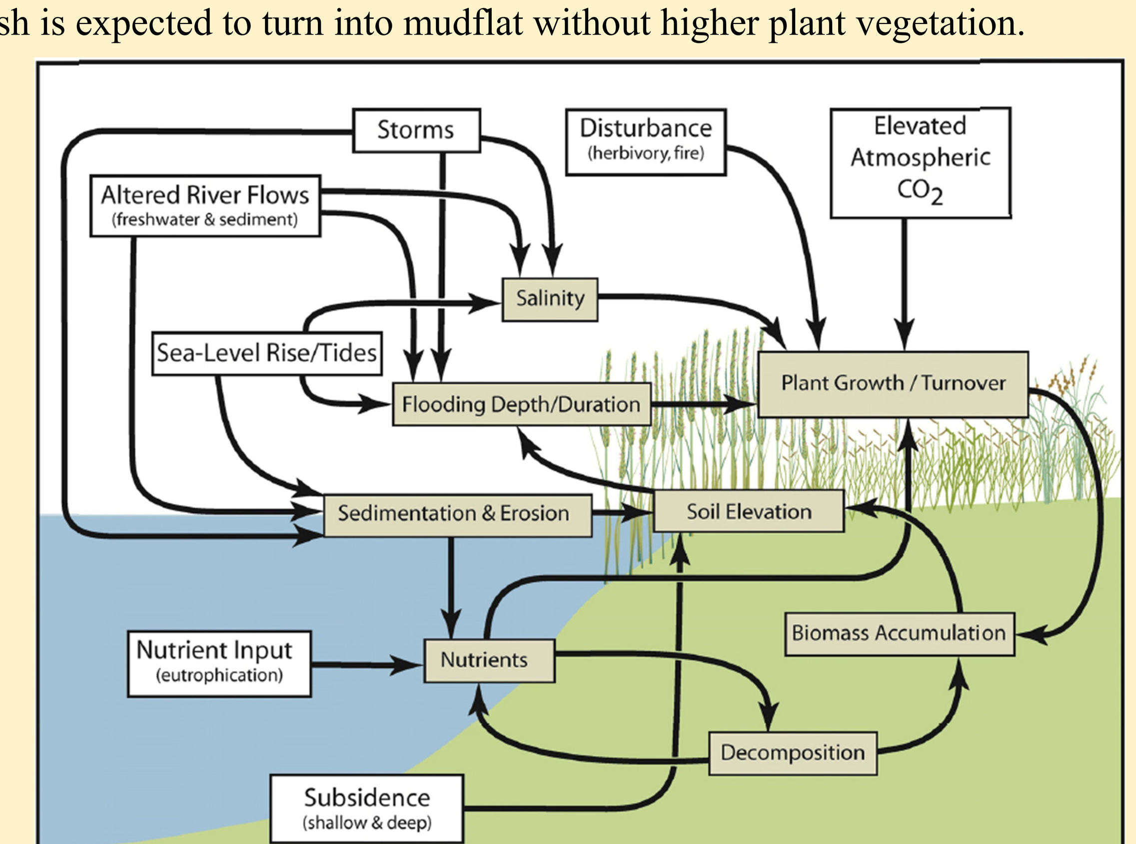
Sediments flow down in the watershed from soil erosion and landslides, intensive agricultural land use, construction and land development, urban runoff through storm sewers, and intentional waste disposal. Best practices in agriculture and regulated land use in urban and industrial areas can reduce the potential for erosion and pollution.

**Soil erosion** is a natural process. Erosion can be chronic and/or episodic. Chronic erosion is constant and occurs during significant rainfall. Episodic erosion occurs occasionally, and sediment often moves in a big pulse, such as during a storm event or series of storm events. Landslides are an example of episodic erosion.

The Petaluma River watershed is composed of a highly erodible rock type, especially in the eastside hills, which has the potential to generate large volumes of sediment. When detached soil and rock particles (sediment) from erosion enters a water system, it settles out (sedimentation) depending on water flow and location — at a tunnel carrying a stream or open drain under a road or railroad (culvert), in a stream channel, in a pond or reservoir, or in an estuary. While some sediment is needed to bring nutrients and building materials to aquatic ecosystems, too much sediment causes problems and impacts flooding and water quality. Sedimentation can reduce the capacity of watercourses to hold storm water flows, thereby increasing flooding.

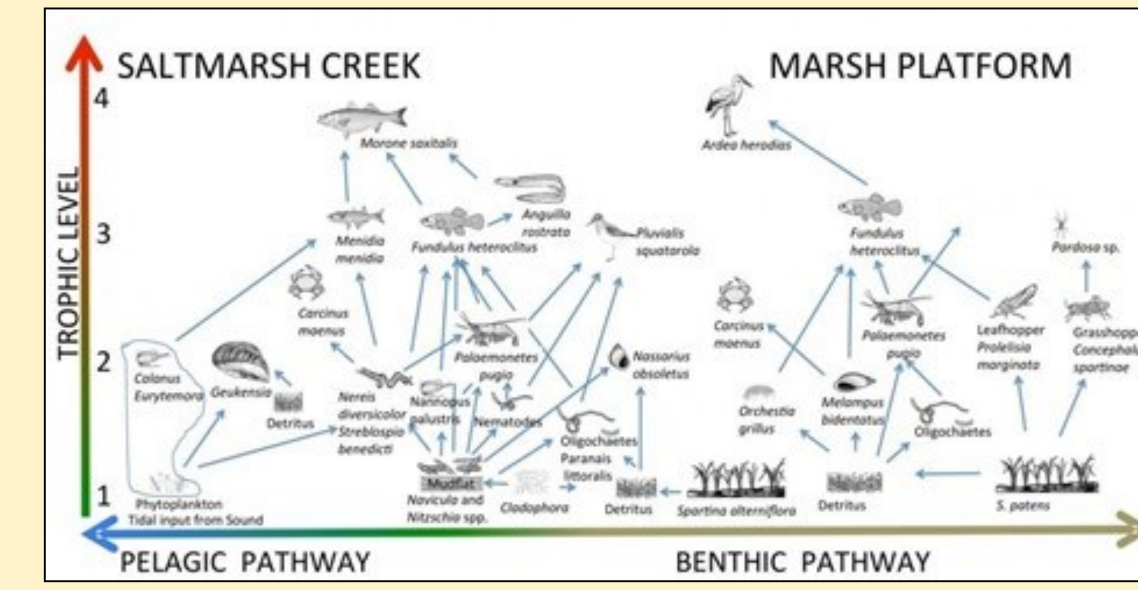
Fine soil particles fill in wetlands and cement stream bottoms into uniform surfaces that no longer provide nooks and crannies to shelter young fish and the aquatic animals they eat causing a decline of salmon and steelhead trout. Sediments can also contain toxic chemicals and plastic bits that look like food, another major cause of the decline of many animal species in streams, marshes, and the ocean.

These sources of sediments significantly increase the total amount delivered to the water channel network affecting both navigation and water-carrying capacity. Total accumulation also depends on sea level changes so expanding oceans from increased temperature and ice melting will bring in more sediment, raising the entire marsh over the next 50 years by at least one foot. However, water rise of over two feet drowning most vegetation, so much of our marsh is expected to turn into mudflat without higher plant vegetation.



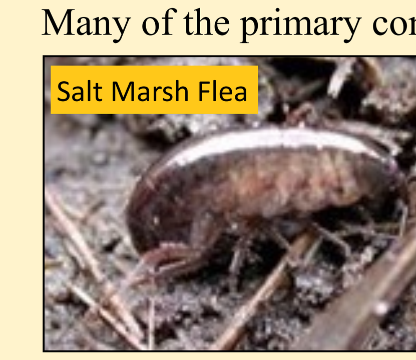

This is a conceptual model of a tidal salt marsh with substantial tidal inputs of mineral sediment. These are also feedback loops that interacts with the food web. Complexity creates a more robust, sustainable environment for all.

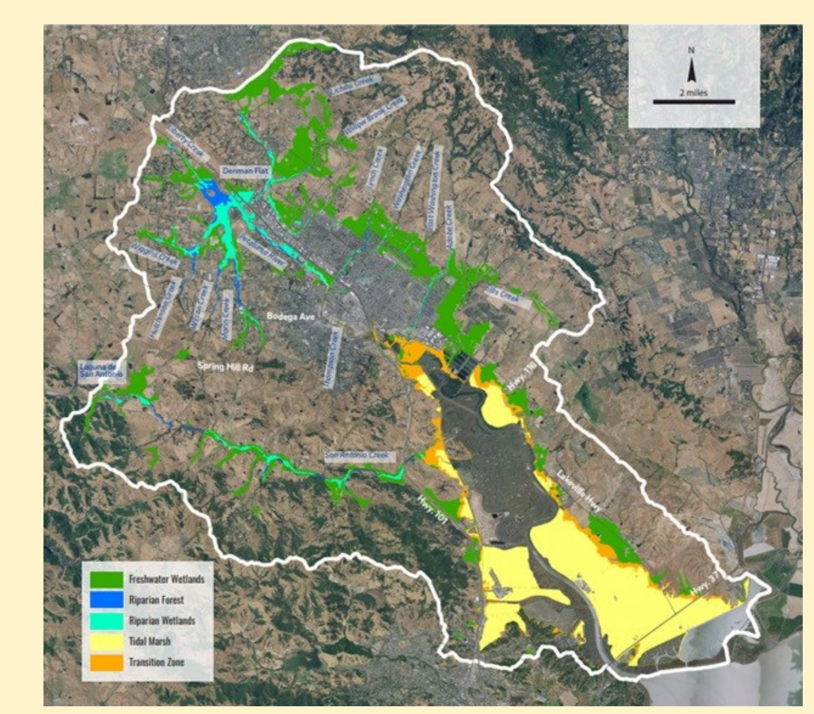
Food webs interact with water (pelagic) and soil (benthic) systems, salt concentration, elevation, and vegetation creating complex biodiversity.




The **food web** on the marsh, like the marsh itself, is part aquatic and part terrestrial. One section of the food web is like other terrestrial systems and primary producers are rooted, vascular plants such as grasses, small broadleaf plants, sedges, and rushes and sedges. Trophic level starts at the simplest food source at the bottom and then each level above consumes the level below until the largest animals are at the top of the food chain and highest trophic level. Each trophic level retains about 10% of the energy in biomass and uses 90% for daily living. The Pelagic Pathway leads to water-based life forms and Benthic Pathway leads to bottom dwellers and soil substrate. Feedback mechanism is a loop system in which the system responds to perturbation either in the same direction (positive feedback) or in the opposite direction (negative feedback). These food web relationships involve feedback systems that influence sediment deposition, soil formation, and marshland elevation so that even with the large volume of movement, overall changes over a long time are slow.

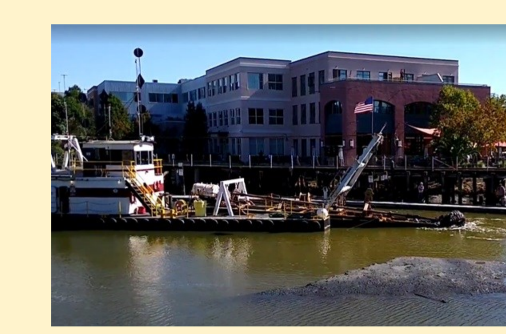
Many of the primary consumers on the marsh are invertebrate herbivores, for example snails, crabs, and grasshoppers, which eat plants. Because of slow decomposition in the low oxygen (anaerobic) soils, detritus becomes the lowest trophic level in another section of the marsh food web. Detritivores, such as Salt Marsh Fleas, the most abundant taxa on the marsh, depend on the litter produced by the marsh plants. Many of these herbivores and detritivores become prey for fish at high tide, when flooding water provides access to the marsh surface. At low tide, they are fed upon by birds and small mammals.



The colored areas in our watershed are opportunities for creating nature based solutions to save and enhance our wetlands.

Dredger working in Turning Basin.



## Dredging

Dredging is the removal of built-up sediments in the river channel to protect against flooding of our downtown area while permitting more robust river traffic. Digging deeper and wider channels and straightening the curves to improve riverboat traffic changes the natural system. Nature will fill in any sediment we remove from the bottom of the channel to bring it back to its historical natural balance.

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