

## **Physical Features**

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The Santa Cruz Mountains divide San Mateo County into two sections. This range of mountains extends northward from Santa Cruz County about 85 miles to the Golden Gate. The coastal section of San Mateo County, found west of those mountains, contains small fertile valleys and beaches.

This area has not always appeared as it does now. Over the eons of time, many geologic forces have worked to shape the landscape, including seismic activity, sea level changes, sand movement, and sedimentation. These forces are still at work today. In the grand scale of geologic time, however, the changes that might appear in our lifetimes are minuscule. On page 7 of this section, you will find a geologic time scale, a handy reference for discussion of the area's geologic history.

When interpreting the physical environment to visitors, don't simply relate statistics about geological features; try to tie this information to other aspects of the site. Make it interesting for your listener, for example: "You are at the overlap of the Pacific Plate and the North American Plate. We are moving at the rate of 4.5 feet every million years. This spot on the coast was once off Monterey. In 15 million years it may be up near Point Reyes." Perhaps you could tell your visitors that the sand they are walking on today will be part of the beach at Santa Cruz in only a few years.

The *Natural History of Año Nuevo* discusses our coastal geologic history in some detail. This section highlights these geologic features, and discusses the Pescadero Marsh, as well. Most of this material is quoted from the 1985 Project Report by Dr. Robert R. Curry, UC Santa Cruz; the 1975 report "The Natural Resources of Pescadero Marsh and Environs," by Department of Fish and Game Biologist Bruce Elliot; Frank S. Viollis' master thesis "The Evolution of Pescadero Marsh;" and various geology texts. These are all available for your review at the Pescadero office.

## **Forces at Work**

### **Tectonic Geology**

Plate tectonics is a branch of geology concerned with seismic activity and continental movement. It is based on the theory that the earth's surface comprises a small number of large, semi-rigid sections that float across the earth's mantle (the layer of the earth between the crust and the core), with seismic activity and volcanism occurring primarily at the junction of these sections.

At least six major plates are recognized—the Indian, Pacific, Antarctic, American, African, and Eurasian plates. The plates may include both continental and oceanic areas. For example, the American plate embraces North and South America and Greenland, as well as the western Atlantic Ocean. By contrast, the Pacific plate is restricted to the oceanic area. The northeastern side of the Pacific plate, along the western United States, is defined by the San Andreas fault. The Pacific plate moves generally northwestward and jostles the American plate in the process.

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Map of the major tectonic plates of the world, from the United States Geological Survey, <http://pubs.usgs.gov/gip/earthq3/what.html>

A *fault* is a break in the continuity of a rock formation, caused by a shifting or dislodging of the earth's crust, in which adjacent surfaces are differentially displaced parallel to the plane of fracture. An *earthquake* is a series of elastic waves in the earth's crust, caused by sudden relaxation of strains accumulated along geologic faults and by volcanic action, which results in movements of the earth's surface.

### Seismic Activity

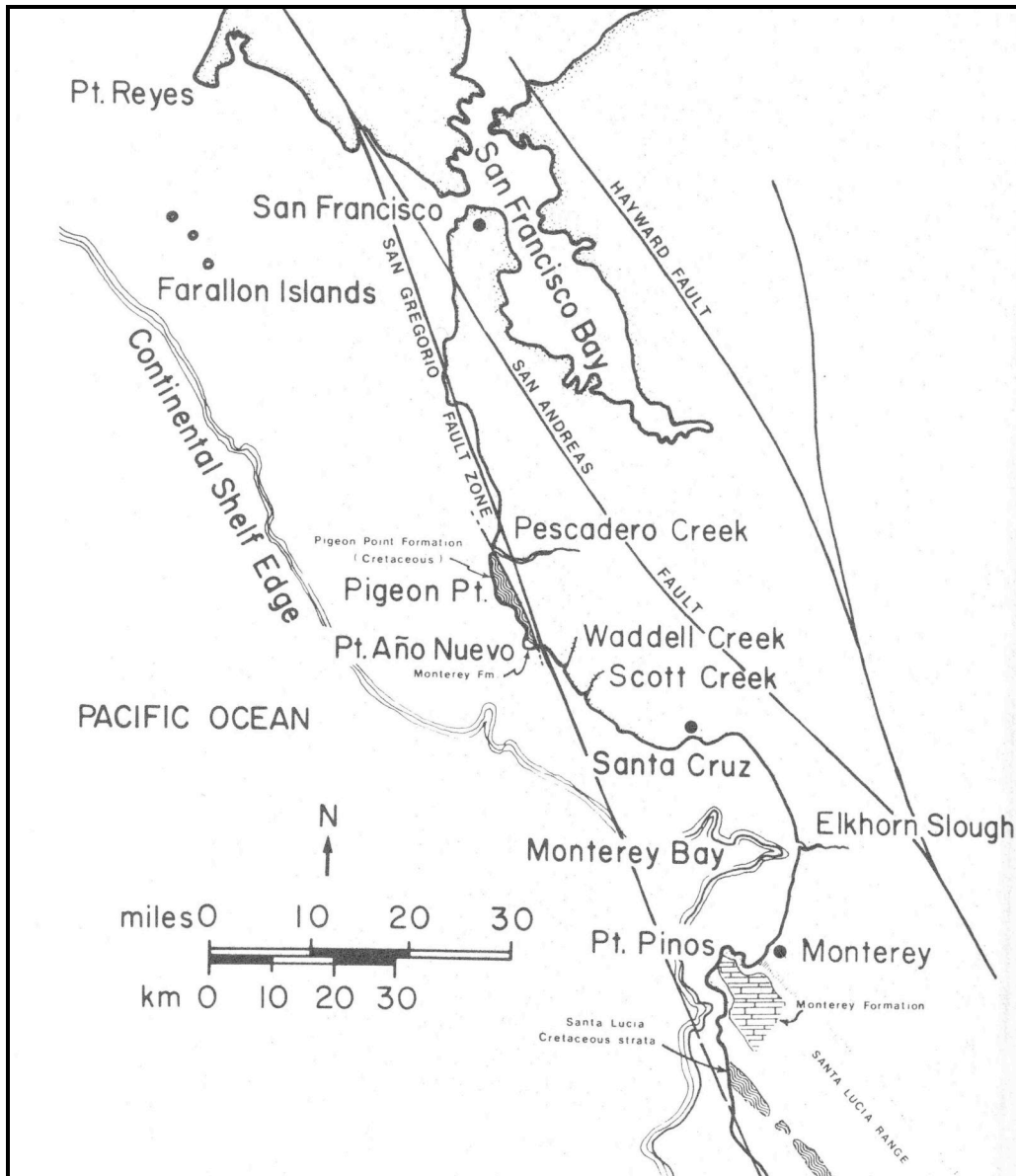
Since the mission days of the early 1800s, earthquakes of varying severity have been a part of this region's written history. Geological evidence indicates that the earth shook here long before the local Indians arrived.

The most active region is the San Andreas fault zone, which passes through the Santa Cruz Mountains, marked near Half Moon Bay by the Crystal Springs Reservoir. The San Andreas fault has had a lateral displacement of 350 miles since the Jurassic period (190 million years ago). Evidence suggests that the granite rocks of Montara Mountain and the Point Reyes Peninsula were once part of the ancestral southern Sierra Nevada. The effects of this magnitude of movement can be seen in the folds and faults on either side of the San Andreas.

Seismic activity is not confined to just this fault zone, however, for the entire California coastal area west of the San Andreas is active. Several active faults run almost parallel with the coast. The Seal Cove-San Gregorio-Palo Colorado fault zone runs along the coast, mostly offshore, from Stinson Beach to the southern end of Monterey Bay, and perhaps beyond, covering a distance of at least 100 miles. The San Gregorio fault is approximately one mile east of Pescadero Beach. It lies between one and two miles offshore from Half Moon Bay State Beach. It comes back onshore and runs along the base of the hill at Pillar Point near the runways of the

Half Moon Bay airport, and it passes through Montara and Gray Whale beaches before going back offshore. North of Bolinas in Marin County, it may join the San Andreas fault.

From Monterey southward, it is not clear whether the San Gregorio fault connects with another fault, the Hosgri fault. (The Hosgri fault zone has been the center of considerable controversy because of the possible danger posed to the Diablo Canyon Nuclear Reactor.) If these faults are connected, the San Gregorio-Hosgri fault zone is second only to the San Andreas in size.



The map depicts San Gregorio fault and other major local faults. (From *The Natural History of Año Nuevo*, edited by Burney J. Le Boeuf and Stephanie Kaza, Pacific Grove: The Boxwood Press, 1981.

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Paralleling the San Andreas fault approximately 13 miles to the west, the San Gregorio fault is considered to be an active fault. Recent work indicates that some faulting has occurred during the last 11,000 years, although this is not a certainty. Some other faults in the area include:

- ◆ The **Pilarcitos fault** runs parallel to Pilarcitos Creek through Pilarcitos Valley along Highway 92.
- ◆ The **Coastways fault** lies to the east of the town of Pescadero.
- ◆ The **Frijoles fault** enters the sea just south of the Pescadero Creek mouth.
- ◆ The **Butano fault** runs north of Pescadero from the San Andreas to the San Gregorio fault zone, crossing the Pescadero and San Gregorio Creeks along the way.

An average of five to ten earthquakes are felt each year in the area from Half Moon Bay to Monterey. Most of the shocks are of Richter magnitude 2.0 to 4.0, although larger ones have been recorded, particularly to the south in the Watsonville-Moss Landing area.

The San Francisco earthquake of April 18, 1906, an estimated 8.3 on the Richter scale, was the most destructive earthquake on the coastal area in recent time. An engineering party on their way south noticed fissures in the soil at San Gregorio from a few inches to 15 feet in width from which a little sand and water was being ejected (Santa Cruz Sentinel, April 18, 1906). Several miles east of San Gregorio a creek was dammed up by a slide.

In the town of Pescadero the shock was heavy; nearly all of the brick chimneys fell, and cracks were visible in the streets.

At Pigeon Point, the brick lighthouse showed cracking around the inside of its base. At Bolsa Point, just north of Pigeon Point, a concrete pipe, 24 inches in diameter and six inches thick embedded in clay, was cracked by the shock.

In the town of Half Moon Bay, buildings were badly damaged; some old frame houses and the brick bank building were flattened. The grading for the Ocean Shore Railroad had just been completed along Devil's Slide when the earthquake struck. It wiped out much of the work that had been done and sent construction equipment into the ocean. The work was redone, but the financial hit was a major factor in the eventual demise of the railroad.

The October 17, 1989 Loma Prieta earthquake, which rocked the Bay Area at 7.1, was centered in the Santa Cruz Mountains. Aside from minor structural damage and loss of personal possessions, residents of the coastside were quite fortunate compared to others. One interesting result from the earthquake, however, was a change in the water level in springs and creeks. Some water levels rose while some springs dried up.

## **Sea Level Changes**

In addition to seismic activity, another major geologic factor in altering the region's landscape has been changing sea levels. Sea level rise is a universal worldwide feature affecting all coastal areas. For example, Frank Viollis noted in "The Evolution of Pescadero Marsh," "Pescadero Valley looked considerably different 15,000 years ago, and Pescadero Marsh did not exist. Still, the rivers that flowed through the valley and out to sea, probably originated at or near the same headwaters as Pescadero and Butano Creeks do today. However, they met the ocean some 15 miles west of the present shoreline."

The sea level at that time was nearly 330 feet lower than the present level. This was due to vast amounts of water locked up during the Ice Age in giant sheets of ice covering almost all of

Canada and large parts of Northern United States, Europe, and Asia. The Ice Age, or Pleistocene, consisted of four periods, during which there were major glacial advances that were then followed by retreats and a return to climates that sometimes were even warmer than that of the present. During the maximum advance of the glaciers, about 27% of the earth's present land areas were probably buried by ice.

For the last several thousand years, melting glaciers have been raising the sea level, and modern records of sea levels indicate that the sea is still rising. The rate of the rise, however, has declined. During the period of maximum ice melting—from over 10,000 years ago to about 8,000 years ago—the sea level rose on the order of one meter every 60 years. Then it slowed over a 12,000-year period to rise at an average rate of only one meter per 600 years for the last 6,000 years.

As the rate of sea level rise decreased, however, drowned valleys were exposed, and the shore interface gradually shifted westward. Today, after 7,000 years of slower sea level rise, the land has again outpaced the sea. For example, up to 50 vertical feet of land that was once below sea level has been exhumed at Pescadero Marsh. This corresponds to the area of the southern and eastern lands along the two creeks, where the watercourses are today incised at least 50 feet back down to the old mid-glacial forested valley bottoms.

The rapid net uplift of the land, which would tend to shift the beach boundary westward and steeper seaward sediment transport gradients, may tend to be compensated for, to some unknown degree, by rapidly rising sea level. This action is particularly significant for areas such as Pescadero Marsh which, as a result of the sea level rises, may have its life as a saltwater marsh and estuary prolonged. (It is interesting, however, that in particular the south end of Pescadero Beach is rising, and probably moving north, relative to the marsh/lagoon system. This tends to raise the marsh outlet above sea level, virtually defeating tidal exchange, and further decreases seaward gradients for the lower reaches of the sediment-laden streams. In other words, the geologic processes now at work tend to dam the tidal inlet.)

Additional evidence of the rising continental landmass can be found in the coastal terraces. Along the shoreline, waves loaded with abrasive sand are eating away at the soft sea cliffs. The surf action tends to cut into the headlands at a right angle, creating a flat, wave-cut bench. With tectonic uplift, these benches or terraces are pushed high and dry. In many parts of California, the shore has a step-like appearance from the different terraces that have been created by different sea levels.

## **Sand Movement**

The effects of beach movement can be seen in daily and seasonal fluctuations of beach formations, such as the Pescadero sand dunes. Beach sediment in San Mateo County is derived from both cliff erosion and from the small coastal streams and rivers draining the Santa Cruz Mountains. The movement of sand in general is the result of several different processes.

## **Seasonal onshore and offshore movement**

Waves are the most significant force operating on a beach, and waves, in turn, are dependent upon the winds that generate them. Severe wave action generally results in steeply sloping beaches of coarse sand, whereas gentle wave action or reduced wave height produces broad, flat areas of fine sand and mud. In winter, extreme tides and storms create large, powerful waves that carry most of the sand away, depositing it offshore as sandbars. These shorter winter beaches

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leave steep beach cliffs exposed and vulnerable to violent storm waves. The smaller waves of summer tend to wash the sand back and restore the beach to its former level. Severe erosion, however, may not be reversible.

Highly erosive winter wave conditions can have major impacts on a beach. For example, the Pescadero beach was very wide in 1928. In the winter of 1939-40, however, there were three destructive storms with deep-water waves of 20-25 feet. These were followed by four very destructive southwesterly storms in the 1940-41 winter, which closed Highway 1, eroded large areas of beaches and other coastline, and flooded some homes in Half Moon Bay. After its erosion from 1939 to 1941, Pescadero beach apparently became progressively wider through the 1950s, 60s, and 70s. Storms in 1978 and 1980 diminished the beach volume somewhat, and the storms of January 1982 significantly reduced its overall width.

The seasonal movement of sand is a factor in the formation and breaking of the beach bars at the mouths of creeks, such as Pilarcitos and Frenchman's Creeks, and San Gregorio, Pomponio, and Pescadero Creeks. When a lagoon is closed by the bar, runoff and wave overwash are impounded in the lagoon. The lagoon breaks through the bar at times of high lagoon levels and, upon occasion, high runoff.

### **Littoral drift**

Longshore sediment transport is a type of sand movement caused by the littoral current. This current is established when waves move toward the shoreline at an oblique angle. Littoral current is a predominant characteristic along most of the California coast because the prevailing wave direction for much of the state is at an angle to the shoreline. The sand that is lifted by breaking waves is carried in the direction of the littoral current until a natural feature such as a headland or an artificial structure, such as a breakwater, stops it. The net movement is generally from northwest to southeast.

The total volume of sand in the littoral drift is very large. The volume of sand moving past a given point in San Mateo County can vary from 100,000 to 300,000 cubic yards per year! Eventually this sediment, unless deposited on other beaches to the south, reaches the head of the Monterey Submarine Canyon at Moss Landing, where it is carried down the steep canyon and deposited on the deep ocean floor. This sand is lost forever from the littoral drift.

As a result of this sand movement and accumulation, dunes and the dune plant community have developed. They can be spectacular. Frank Viollis noted in his thesis: "The most noticeable physical feature at Pescadero State Beach is not the 500 acres of marshland, or the mouth of the creek itself, but the towering dunes which reach nearly 40 feet in height."

These dunes certainly illustrate the dynamic nature of the dune community. Prior to stabilization by introduced vegetation and Highway 1, the dunes were actively modified by northwesterly winds. An 1854 topographic map shows the dune field and its fronting beach as wrapping eastward at its southern end, into the estuary. This is precisely what would be expected today, if the dunes were not stabilized by vegetation and highway surfacing, and if the tidal volume moving into the lagoon were sufficiently large to transport sand there by longshore drift.

Most significantly, the 1854 map reveals the topographic low spot at the extreme north end of the dune field, where seasonal overwashing charged the back-beach lagoon system behind the dunes. In 1854 at least, the area immediately east of the dune field was a periodically replenished salt-water lagoon. The North Pond saltwater overflow may have been cut off as early as 1927 or

1928 and certainly by the time of state highway construction in 1939. North Pond now has no inlet or outlet and is dependent on rainfall and runoff from the surrounding hillsides.

## Geological Formations

ERAS	PERIODS		BEGINNING	ANIMALS	GEOLOGIC FORMATION
<b>Cenozoic</b>	Quaternary	Recent (Holocene)	15,000 years ago	Mammals	Alluvial deposits
	Quaternary	Pleistocene (Ice Age)	1,500,000 years ago		Marine terraces
	Tertiary	Pliocene	15,000,000 years ago		Purisima formation
	Tertiary	Miocene	30,000,000 years ago		
	Tertiary	Oligocene	40,000,000 years ago		Mindego basalt
	Tertiary	Eocene	50,000,000 years ago		
	Tertiary	Paleocene	60,000,000 years ago		
<b>Mesozoic</b>	Cretaceous		12,000,000 years ago		Pigeon Point formation
	Jurassic		160,000,000 years ago	Reptiles and Ammonites	
	Triassic		180,000,000 years ago		
<b>Paleozoic</b>	Permian		225,000,000 years ago		
	Pennsylvanian	(Carboniferous)	270,000,000 years ago	Amphibians	
	Mississippian	(Carboniferous)	300,000,000 years ago	Age of Fishes	
	Devonian		345,000,000 years ago	Invertebrates	
	Silurian		375,000,000 years ago	Invertebrates	
	Ordovician		435,000,000 years ago	Invertebrates	
	Cambrian		540,000,000 years ago	Invertebrates	
<b>Proterozoic</b>	Keweenaw	Precambrian	1,000,000,000 years ago	Indirect Evidence of Life	
	Huronian	Precambrian			
<b>Archeozoic</b>	Timiskaming	Precambrian	3,350,000,000 years ago		
	Keewatin	Precambrian	5,000,000,000 years ago		

**Pigeon Point Formation:** These rocks, between 65 and 80 million years old, are exposed along the coast from Cascade Creek in the south to near Pescadero in the north. The formation was deposited within a large trough that existed during the Cretaceous Period along what is now the California coast. The sediments originated from a large landmass to the west (called Cascadia) and a rather low mountain range to the east. In certain areas the Pigeon Point formation is 8,500 feet or more thick.

**Mindego Basalt and related volcanic rock:** These volcanic rocks are probably submarine in origin and can be found along the coast immediately south of Pescadero Creek.

**Purisima Formation:** This formation, which can be found in many areas along the San Mateo coast, was deposited as the sea encroached on the land approximately 5 to 10 million years ago.

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The Purisima Formation consists largely of fine-grained sandstone, siltstone, and mudstone. It is a major source of Tertiary fossils, including a variety of marine clams, snails, and foraminifers.

**Marine Terrace Deposits:** The encroaching sea deposited marine sediments approximately 500,000 to 1 million years ago. Sediments are primarily composed of sand and gravel up to 45 inches thick in some places. The bluffs along the coast reveal the relationships between these slightly tilted Pleistocene deposits and the underlying material.

**Alluvial Deposits:** Holocene alluvium originated from the erosive forces of water and includes sand, silt, and gravel. The alluvium is found along streams and their outlets. At Half Moon Bay State Beach, the only geologic units exposed are alluvial deposits of various ages and the beach sands.

## ***Features of Pescadero Marsh***

### **Sedimentation**

The wetlands system depends primarily upon Pescadero and Butano Creeks for its supply of fresh water, while Honsinger and Bradley Creeks and surrounding hillsides are secondary contributors. Both primary sources are perennial streams, although there is very little flow during the late summers of extremely dry years. 90% of Pescadero Creek's annual flow occurs from December through April. Peak discharge typically occurs in January and February during heavy rains, when the soil is saturated from previous storms.

Stream flow tends to respond rapidly to precipitation, due probably to basin shape and storm orientation relative to the basin, steep slopes, relatively impermeable underlying soils, land uses, and well developed drainage pattern. Correspondingly, these streams carry large quantities of sediment. The work by Dr. Curry suggests that sediment influx, as well as land reclamation for agricultural purposes, contributed strongly to the reduction in tidal areas.

The sediment influxes were primarily episodic and associated with major storms and periods of watershed manipulation. Based upon a sediment record that has only been outlined from 1955 to the present, it is reasonable to assume that significant sediment influx occurred in the period from the late 1850's through 1890, when major runoff floods coincided with initial logging. Then the storms of 1940, 1956, 1958, and 1973 set the stage for the very long-duration floods of 1982 to carry the bulk of the sediment to the marsh that we see within the top six feet of silt to coarse sand.

Butano Creek appears to be the major contributor of sediment in the marsh. Pescadero Creek has a sufficient gradient in its lower course to carry the bulk of its load to the beach to nourish the beach and sand dunes. Butano, on the other hand, has such a low gradient in the lower three miles of the stream course that it cannot transport its load to the sea. Most of Butano's sediment is trapped in the lowlands and is not discharged to the beach.

### **A Sequential Evolution of Pescadero Marsh**

As a result of the past and current geological forces at work, Pescadero Marsh came into being. The sequence of those events over the past two million years up to historic times, when man's activities became another force, is summarized as follows by Frank Viollis:

- ◆ Fault movement of the past two million years, along with the removal of ancient sandstones and siltstones by stream erosion, have created the present valley at Pescadero.
- ◆ During the last interglacial low stand of sea (15,000 years ago), base level was some 330 feet below its present position. Streams flowed through the lower Pescadero Creek Valley, but the valley was graded and more V-shaped, as stream energy adjusted to a lower base level. The fluvial waters entered the ocean some 15 miles west of the present shoreline. Pescadero Marsh and the alluvial flood plain did not exist.
- ◆ Worldwide melting of continental and alpine glaciers during the past 15,000 years has raised the level of the sea to its present position. However, the rate of sea level rise during the past 15,000 years has not been constant, and it wasn't until 6,500 years ago that the oceanic waters invaded the depression at the present site of Pescadero Marsh.
- ◆ During the period which followed, an estuary was formed as the sea extended into the valley. Stream energy decreased as the base level approached its present level about 5,000 years ago. Then sediment began to accumulate in the lower Pescadero Valley.
- ◆ During the next two thousand years sediment continued to be deposited, raising the elevation of the valley floor. Mud flats were probably extensive, as were the drainage channels that meandered across them.
- ◆ The agents of water, wind, and animals (chiefly birds) transported seeds from distant points. These seeds established the pioneer plants that constituted the first marshes. The pioneer plants, once established, further trapped sediment, raising the level of the flats and young marshes. New habitats were created providing a more diverse group of plants and animals.
- ◆ Sediment continued to reach the lower Pescadero Valley from both fluvial and littoral sources. Sand, eroded from sea cliffs north of Pescadero, accumulated within a relatively deep water estuary.
- ◆ About 4,000 years ago the accumulation of sand at the mouth of the creek formed the base of the dunes, which led to the formation of the present-day sand spit. Streams probably meandered across the sand and out to sea, before the main stream channel was confined to its present path. Marshes formed east of the present confluence and estuarine circulation allowed for a marine fauna typical of a small coastal estuary.
- ◆ During the past 3,000 years, sediment has continued to accumulate at the site of the marsh. However, the rate of sediment build-up in the marsh probably increased due to the development of a sand spit at the mouth and the subsequent reduction in flushing action.
- ◆ Marsh growth was extending westward along with the accumulation of sediment. The actual rate of sedimentation varied from day to day and year to year. Floods quickly added a large quantity of sediment to the marsh, bringing upland debris. During dry periods, little sediment was added to the marsh (other than wind-blown sand) and the evolution slowed.

It was probably during this period that Indians inhabited the area and human impact on the marsh began—an impact that has been particularly significant beginning in the 20th century.

## **Management of Pescadero Marsh**

The Department of Parks and Recreation seeks to manage the Pescadero Marsh Natural Preserve to protect and maintain the most natural environment as possible, considering the past and present modifications to the marsh and its water sources.

A major impact of siltation in the lagoon and stream channels, besides increased flooding along Butano Creek, is the reduction of the tidal volume going in and out of the marsh on a daily basis. More tidal volume and natural water circulation through the marsh means more sediment carried from the lagoon and channels. This principle was integral in planning for the first State Park-funded restoration of the marsh. In 1990, a team of hydrologists and biologists created a plan describing alternatives for restoration, such as the removal or breaching of interior levees not needed for flood control. In 1993 and 1997, the first projects from the plan were constructed.

The ambitious plan called for the removal of portions of numerous levees, to allow the return of tidal circulation to areas cut off from the sea. One element of the plan was to connect north pond more directly to the lagoon, to allow tidal fluctuation when the lagoon is open to the ocean. Migrating shorebirds now use the mudflat habitat at low tides. The original plan called for installing culverts to regulate flows into north pond and north marsh. By 2005, these culverts had failed. New research is needed to design the appropriate system to maintain the tidal connection, and meet habitat needs for the variety of aquatic and terrestrial species that depend on this system.

## **Ocean Dynamics**

The waters along the San Mateo coast are often more treacherous than people realize. Described below are a few of the hazards that make this stretch of shore particularly dangerous.

### **Cold Water**

The water along the San Mateo coast usually ranges from 50 to 55 degrees. Most people notice the effects of the cold within about 20 minutes and swimmers are liable to get numb quickly. Once numbness sets in, it is easy to stay in too long, because the body no longer feels cold. The cold not only saps your energy, which you will need if you find yourself in trouble, but can lower your core temperature to the point of getting hypothermia.

Severe hypothermia is deadly. If the victim is no longer shivering and appears to have an altered mental status (they appear drunk, combative, or just “out of it”), they need gentle treatment and immediate medical attention.

Note that the surfers, who plan on staying in for a while, wear full wetsuits, often including hoods and booties.

### **Rip Currents**

As breaking waves push water ashore, this water is returned back to sea along rip currents. Rip currents are short, narrow currents that flow straight out to sea from the surf zone. Once the water moves past the surf zone, the narrow rip current quickly dies out. They are quite common along the state beaches, with several usually visible from any one spot.

Because rip currents are moving water from the beach and surf zone out to sea, they are often discolored with sediment and foamier than surrounding water. The opposing flow may cause

incoming waves to break farther out. You may be able to identify long-shore feeder currents (currents between the beach and surf) moving parallel to the shore and then turning at a right angle away from shore as the water channels into the rip current.

Also erroneously called a rip tide or undertow, rip currents can pose a danger to beachgoers, especially if they don't wear wetsuits. Getting caught in a rip current can be a frightening experience, but it is important not to panic. Remember that the current is moving straight out from the beach. People commonly exhaust themselves trying to swim against this current straight back to shore. Because rip currents are narrow, the best way out is to swim parallel to the shore until you are out of the rip, then swim back in with the help of the waves. Even if you can't seem to get out of the rip, remember it won't last much farther than the surf zone. You may observe surfers intentionally using the rip currents as an efficient way to get offshore.

The following information on rip currents is offered by the United States Lifesaving Association at <http://www.usla.org/ripcurrents/ripcurrents.asp>.

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## Why Rip Currents Form

As waves travel from deep to shallow water, they break near the shoreline. When waves break strongly in some locations and weakly in others, this can cause circulation cells, which are seen as rip currents: narrow, fast-moving belts of water traveling offshore.

## Why Rip Currents are Dangerous

Rip currents are the leading surf hazard for all beachgoers. They are particularly dangerous for weak or non-swimmers. Rip current speeds are typically 1-2 feet per second. However, speeds as high as 8 feet per second have been measured. This is faster than an Olympic swimmer can sprint! Thus, rip currents can sweep even the strongest swimmer out to sea.

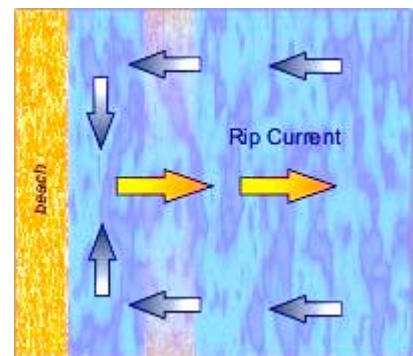
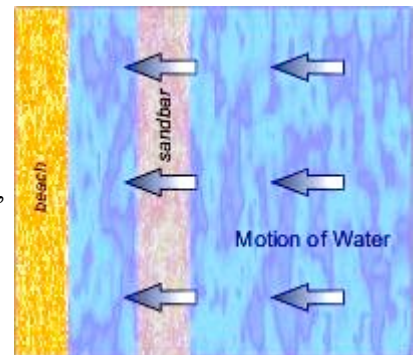
Over 100 drownings due to rip currents occur every year in the United States. More than 80% of water rescues on surf beaches are due to rip currents.

## When Rip Currents Form

Rip currents can be found on many surf beaches every day. Under most tide and sea conditions the speeds are relatively slow. However, under certain wave, tide, and beach profile conditions the speeds can quickly increase to become dangerous to anyone entering the surf. The strength and speed of a rip current will likely increase as wave height and wave period increase. They are most likely to be dangerous during high surf conditions as the wave height and wave period increase.

## Where Rip Currents Form

Rip currents most typically form at low spots or breaks in sandbars, and also near structures such as groins, jetties and piers. Rip currents can be very narrow or extend in widths to hundreds of yards. The seaward pull of rip currents varies: sometimes the rip current ends just beyond the line of breaking waves, but sometimes rip currents continue to push hundreds of yards offshore.



<http://www.usla.org/images/ripcurrent2.jpg>

Diagrams courtesy of the NWS Southern Region Headquarters

## How to Identify Rip Currents—Look for any of these clues:

- ◆ a channel of churning, choppy water
- ◆ an area having a notable difference in water color
- ◆ a line of foam, seaweed, or debris moving steadily seaward
- ◆ a break in the incoming wave pattern

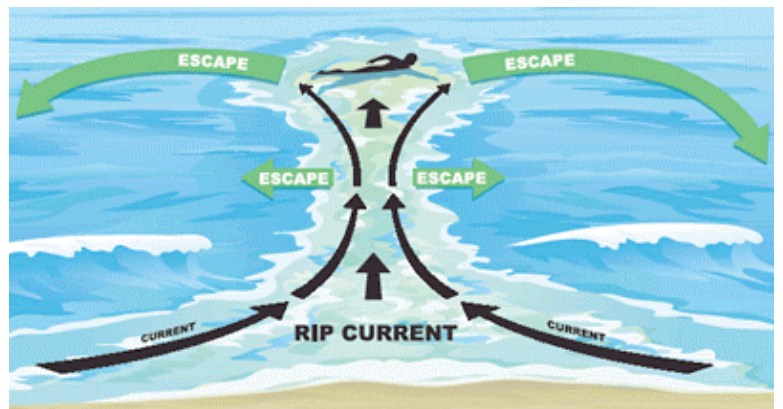
None, one, or more of the above clues may indicate the presence of rip currents. Rip currents are often not readily or easily identifiable to the average beachgoer. For your safety, be aware of this major surf zone hazard. Polarized sunglasses make it easier to see the rip current clues provided above.



Photo courtesy of the U.S. Army Corps of Engineers Field Research Facility at Duck, NC.

## How to Avoid and Survive Rip Currents

- ◆ Never swim alone.
- ◆ Be cautious at all times, especially when swimming at unguarded beaches. If in doubt, don't go out!
- ◆ Whenever possible, swim at a lifeguard protected beach.
- ◆ Obey all instructions and orders from lifeguards.
- ◆ If caught in a rip current, remain calm to conserve energy and think clearly.
- ◆ Don't fight the current. Swim out of the current in a direction following the shoreline. When out of the current, swim towards shore.
- ◆ If you are unable to swim out of the rip current, float or calmly tread water. When out of the current, swim towards shore.
- ◆ If you are still unable to reach shore, draw attention to yourself: face the shore, wave your arms, and yell for help.
- ◆ If you see someone in trouble, get help from a lifeguard. If a lifeguard is not available, have someone call 9-1-1. Throw the rip current victim something that floats and yell instructions on how to escape. Remember, many people drown while trying to save someone **else from a rip current.**



## **Rogue Waves**

Waves are not all of uniform size. They generally come in sets, with smaller waves alternating with larger ones. Often people get lulled into a false sense of security by a set of small waves, and venture farther out into the water. The next set of larger waves may be an unpleasant surprise. Because of the unpredictable nature of waves, it's never a good idea to turn your back on the ocean.

## **Steep Beaches**

The steep beaches along the San Mateo coast create several hazards. With just a small step or two, you can suddenly be in much deeper water. This can make it much easier to get soaked or pulled off your feet when the next big wave comes in. The steepness of the beaches causes the water draining back from a wave to move very quickly and forcefully, again pulling people off their feet easily. Children, of course, are more affected by these hazards than taller and stronger adults.

## **Mavericks**

Mavericks is a world-class surfing spot just off the coast of Pillar Point. Situated over a reef just outside of Sail Rock, Mavericks only breaks in certain conditions. If a storm is moving just right, large swells from the north or west move through a deep-water canyon to the west of Mavericks, then funnel toward the main bowl at Mavericks. That bowl starts at more than 70 feet deep, but in less than a quarter of a mile, the ocean floor channels to a shelf of the reef that is only 18 feet deep. When this reef abruptly stops a powerful ocean-going wave, it has nowhere to go but up. Dedicated surfers monitor buoy reports and meteorological data on the Internet to predict when (and how hard) Mavericks will break. A major surf contest is usually held every winter, with top surfers coming from all over the world on 24-hours' notice. With wave faces that can reach more than 50 feet, only the world's best surfers are invited. Mavericks can be particularly dangerous because it does not wash onto a beach, but onto a mass of jagged rocks. Great white sharks are also known to patrol the area.