

**Table 7. Instrumental Data
for the May 22, 1960 Tsunami**

Location	Max. Amplitude/Feet
California:	
San Diego	2.3
La Jolla	1.7
Wilson Cove, San Clemente Island	2.1
Alamita Bay	2.0
Long Beach	2.9
Terminal Island	3.1
San Pedro	1.5
Los Angeles/Berth 60	2.5
Santa Monica	4.6
Port Hueneme	4.4
Monterey	4.1
San Francisco	1.5
Alameda	1.0
Crescent City	5.5
Oregon:	
Astoria	0.5
Washington:	
Neah Bay	1.2
Friday Harbor	0.3
Echo Bay	trace

The *San Diego Tribune* (May 24, 1960, p. 1) reports that surges during the night caused a 100-ton derrick barge to ram a concrete piling supporting the South Ingraham Street bridge in Mission Bay Park. A 35-foot section of the 70 foot piling was broken off requiring a month and \$3,000 to repair. The barge had been employed in cleaning up the damage in Quivira Basin caused by the earlier surges.

The *San Diego Union* (May 24, 1960, p. 1) reports waves eight feet above normal at 8:55 P.M. (high tide).

At 4:20 A.M. on the 24th, surges tore out more sections of the Harbor Department's docks on Shelter Island. One 100 foot section was turned

over with the pontoons on top. Three 50 foot lengths were half turned over. Damage was estimated at \$6,000.

At the Navy Electronics Laboratory docks the stern of the 87 foot Navy yawl *Saluda* was lashed against the small boat dock causing minor damage to the yacht and pier.

A 22-foot cabin cruiser was sunk near Dana Landing about 8:00 P.M. on the 23rd. The hull was punctured as the owner attempted to pull it aboard his trailer.

A crowd gathered on Shelter Island to watch the swirling whirlpools and see the damage caused by the currents. Police were needed to break up a traffic jam during the night.

The *San Pedro News Pilot* (May 26, 1960, p. 9) reported that a large shoal in front of the Harbor Master's headquarters was washed away, deepening the area by eight to twenty feet and saving a ordered dredging operation.

1963, October 13, 05:17 GMT. A magnitude 8.1 earthquake in the South Kuril Islands, Russia, produced a four-meter wave locally. It was reported observed at Crescent City's Citizens Dock where it rose and fell 2.1 feet (range) in three minutes at 8:22 A.M. Successive waves of 1.5 feet, 2.3 feet, 3.3 feet, and 1.9 feet were measured up to 9:40 A.M.

The stern mooring of one fishing boat was torn loose (*Del Norte Triplicate*, October 17, 1963, p. 1). The *San Diego Union* reported a 0.2 foot wave recorded at Scripps but otherwise the wave was not observed there. It was also well recorded at Avila. (See Figure 124.) Validity 4.

1964, March 28, 03:36 GMT. A massive magnitude 8.4 earthquake originated in Prince William Sound, Alaska, giving rise to a major tectonic tsunami affecting the entire Pacific Ocean Basin and also causing more than a dozen local landslide tsunamis in the epicentral area. They caused \$84 million in damage in Alaska

and 107 deaths. Run-up heights exceeded 200 feet. Due to the orientation of the generating zone the largest waves outside of Alaska were directed toward the United States and Canadian west coasts causing much more damage to the west coast, particularly at Crescent City, than all previous tsunamis combined and exceeding \$17 million. There were 16 fatalities and a fatal heart attack and a fatal accident which may have been related to the tsunami. (Refer to Figures 125 through 140 for marigrams, pages 199–205) Validity 4.

WASHINGTON

Summary: Two people were injured and two more suffered heart attacks. Damage to bridges and roads was at least \$80,000. One fishing boat was wrecked. Several skiffs and fishing nets were lost (\$4,000). At least 16 homes were damaged including three destroyed. Nine trailers were damaged and three cars were lost. One mile of sea bulkhead was lost.

Friday Harbor. Recorded instrumentally with an amplitude of 1.15 feet.

Neah Bay. Recorded instrumentally with an amplitude of 2.35 feet. Considerable amounts of driftwood was deposited on the beach at Cape Flattery Lighthouse (Darling, April 22, 1964).

La Push. The second and highest wave occurred at 11:55 P.M. and was reported as 5.3 feet above predicted tide at the Patterson and Butts Dock. It was a gradual rise of the water and not a bore. Several boats and a floating dock broke loose from their moorings. The channel to the Coast Guard boat house may have decreased in depth. The first wave arrived at 11:25 as a three-foot rise. (Hogan et al., 1964) The Coast Guard at Quillayute River reported a maximum height of 7 feet (Darling, April 21, 1964).

Hoh River Mouth. The second and largest wave occurred at 00:10 A.M. on the 28th and was 1.7

feet above the predicted tide. No damage was reported. The amplitude was estimated by using the tsunami debris line and the predicted tide level (Hogan et al., 1964).

A grandmother in Seattle heard of the possible tsunami and called her daughter who was vacationing with her daughter, Patty (age 11), at Kalaloch Beach, Jefferson County. The daughter and an eleven-year old boy were camping on the beach. The mother reached them five to ten minutes before the wave. The boy went immediately to higher ground but the girl wanted to get her sleeping bag and pup tent. The mother grabbed the girl and headed for higher ground also as she could hear the water and logs coming. They reached a tree at the base of the 40-foot scrub covered embankment when the wave struck. The water reached their knees. After the wave receded, they attempted to climb higher. The second wave still reached to their ankles although they were five feet higher. All escaped without injury (*Seattle Daily Times*, March 30, 1964, p. 2).

Seattle. Earthquake waves generated seiches on Lake Union which caused minor damage to the gangway of the U.S. Coast and Geodetic Survey (USCGS) ship *Patton* and snapped mooring lines on the USCGS ship *Lester Jones*. Minor damage was also done to several pleasure craft, house boats and floats that broke their moorings. This earthquake phenomena was observed as far as the east coast and gulf coast of the United States and is not related to the tsunami. The tsunami was recorded with an amplitude of 0.4 feet at Seattle (Spaeth and Berkman, 1972).

Belfair. Tides were about three feet higher than normal at Belfair and the southern end of the Hood Canal. The water went over the highway at Beard's Corner and there was a lot of brush and trees floating in the canal (*Seattle Daily Times*, March 28, 1964, p. 1, 2).

Taholah. A wave of amplitude of 2.4 feet was reported to have occurred at 00:50 A.M. at the Indian village of Taholah at the mouth of the

Quinault River. Several fishing skiffs and fishnets valued at \$1,000 were lost (Hogan et al., 1964). Four Tacoma men camping at Point Grenville south of Taholah were chased from their tents by the waves. One man was hospitalized for shock and their car and camping equipment were damaged (*Seattle Daily Times*, March 28, 1964, p. 2).

Wreck Creek (near Point Grenville). An amplitude of 14.9 feet was estimated at the highway bridge along the exposed ocean beach where \$500 in damage occurred. The fill material at the bridge approach was eroded and debris was deposited on the bridge deck and nearby highway (Hogan et al., 1964).

Moclips. The second and highest wave occurred at 1:30 A.M. and was 11.1 foot high on the exposed beach south of town. Damage was done to eight beach houses there. An estimated \$6,000 was caused to beach front houses, timber pile bulkheads, and the road. Damage to the houses was to the ocean side walls which were battered by floating logs. Houses were flooded to a depth of six inches to several feet and debris littered the yards. One house moved on its foundation (Hogan et al., 1964). Several cars were lost (Murphy, 1964).

Pacific Beach. Damage of \$12,000 was reported to buildings at Pacific Beach and an additional \$500 in damage occurred to a bridge over Joe Creek there. The amplitude of the first two waves at the Oceanographic Research Station was estimated at between 6.5 and 7.5 feet.

One medium-sized dwelling with four occupants, the Smiths and grandchildren, was lifted off its foundation, moved 40-feet to the northwest and partly torn apart. A second building was damaged and flooded, yards were eroded and covered with heavy debris.

The second wave was the highest. It was deflected by the south bank of Joe Creek and turned northwesterly inundating dwellings on the north bank. Damage to the bridge included the

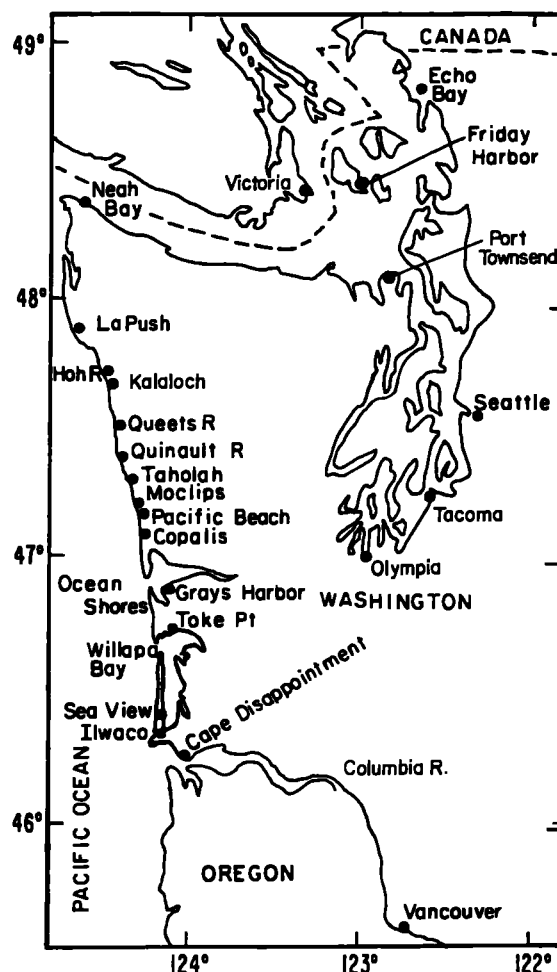


Figure 20. Location map for the State of Washington.

loss of three pilings and two 20-foot concrete spans. The wave was estimated to be eight feet high at the bridge (Hogan et al., 1964). One person at the Pacific Beach Navy Base injured his arm. Another person was reported to have suffered a broken foot but the community where the injury occurred was not identified. A private car of a member of the base personal was lost on the beach as he attempted to warn campers at Point Grenville (Murphy, 1964).

Boone Creek. About \$500 in damage was done to a building at Iron Springs Resort. The foundation of one building was damaged and two

inches of water flooded the floor. Water was one foot above the floor level on the outside of the building. Heavy debris was left in the yard and low sections of the road near Boone Creek. The water was one to two feet above the road level at the Boone Creek culvert. A section of the road shoulder six feet wide, eight feet high, and 80 feet long was washed out and heavy debris was deposited causing \$400 in damage (Hogan et al., 1964). About 75 guests were stranded at Iron Springs Resort by the bridge failures at Joe Creek to the north and on the Copalis River to the south. There was no warning (*Aberdeen Daily World*, March 31, 1964, p. 1).

Copalis. The first wave arrived about 11:30 P.M. Trailers were overturned and a car was washed into the Copalis River. The driver, Al Smith, was rescued but the deputy sheriff's car was washed over by the waves. Mr. Smith was attempting to reach his children at Pacific Beach (see above). The second wave arrived at 1:05 A.M., when two cars were lost. Two heart attacks were reported but the location of the victims is uncertain. Both survived. A third wave at 3:05 A.M. hit the sea wall hard, badly damaging about one mile of it. Two homes were wrecked, one beyond salvage and three others damaged by being moved from their foundations. The beach had been closed to clam diggers earlier due to the stranding of a barge there. Otherwise this beach would have a favorite camping area. Logs and driftwood had been left half a mile inland (Murphy, 1964).

The State Highway 109 bridge over the Copalis River consisted of a 4-piling timber bent and two timber spans near the center of the bridge. The height was estimated at six feet at the bridge. Mr. Leonard Hulbert, 50, stopped on the Copalis Bridge to watch the logs pile up against the footing. The bridge collapsed plunging him and the car into the river. He forced open the door against the current and escaped. His leg was pinned by the door, but he was able to pull loose. An area resort owner said the water swept nearly half a mile beyond its normal tide line

carrying some trailers more than 100 feet. Damage to the bridges at Joe Creek, Boone Creek, and the Copalis River was estimated at \$75,000, and \$5,000 additional damage occurred there due to shoulder erosion and debris. These damage figures did not include the cost of building the detours around the damaged bridges (Hogan et al., 1964).

Grays Harbor Ocean Shores (0.75 miles south of Oyhut). A 9.7-foot wave was reported for the exposed ocean beach at the Central Motel office at the west end of Chance a la Mer Street at 11:32 P.M. Debris was deposited in the streets and on the beach (Hogan et al., 1964). A ranger at Ocean City pulled a woman immobilized by fear out of the surf (*Daily Olympian*, March 30, 1964, p. 1).

Aberdeen. Seiches set up by the earthquake waves caused 5,000 gallons of water to spill from the reservoir washing over a five block area of Aberdeen. It washed out a gravel road and flooded the basement of one home. Four lawns were covered with gravel and a \$6,000 sunken garden was damaged. A sun deck and other gardens were damaged. These were not tsunami effects (Murphy, 1964).

Three log rafts at Saginaw Shingle Company on the Chekalis River broke loose and were recaptured without further damage (*Aberdeen Daily World*, March 31, 1964, p. 2). The Boat Club mooring area located about ten miles upstream from the bay was apparently silted up. Boats were left high and dry on the mud even at a plus tide. The Boat Club is located just south of the South Montesano bridges (Murphy, 1964).

On a beach north of Aberdeen, a woman was awakened by the rocking of her trailer. She stepped out into waist deep water. On reaching higher ground she needed hospitalization for a rapid heart beat. "We were up to our waist one minute and tumbling head over heels the next," she said. Four trailers were toppled at Redfield Trailer Camp after their occupants had fled. Some autos were reportedly overturned on the

sand (*Daily Olympian*, March 30, 1904, p. 1). About 250 guests were evacuated at 11:30 P.M. at Ocean Shores at the suggestion of the Navy Hydrographic Station at Pacific Beach. Water ran up the access road and into the motel office and units to a depth of about two feet. It receded without doing significant damage (*Seattle Daily Times*, March 28, 1964, p. 1 and 2).

Westport. A fishing boat was wrecked and there was debris on the beaches (Murphy, 1964).

Willapa Bay. The Bone River bridge about eleven miles south of South Bend was damaged when an oyster plant building was swept against it (*Ilwaco Tribune*, April 3, 1964, p. 1). Losses to the oyster beds in Gray's Harbor and Willapa Bay were estimated at \$900,000 over the several years needed for recovery (Thorsen (1988) quoting *The Aberdeen Daily World*, April 30, 1964). Unestimated losses also resulted from loss of tourism.

Sea View. A maximum wave amplitude of 12.5 feet was reported but no damage was observed (Hogan et al., 1964).

Ilwaco. A four to five-foot wave was reported at a dock south of Eides Warehouse, Ilwaco, which caused minor damage (Hogan et al., 1964). The *Ilwaco Tribune* (April 3, 1964, p. 1) and *Chinook Observer* (April 3, 1964, p. 1) report that a man and woman were going beach combing after hearing of the tsunami alert. As they crossed Holman Creek in their jeep, a wave stopped the motor. They jumped free but the jeep rolled over.

Four youths were camping at Beards Hollow when the first wave hit at 11:35 P.M. filling their old car. The car was shoved 60 feet. There was an undetermined amount of damage to the oyster beds. Particularly hard hit was Stony Point where oysters were washed up on the beach and new seed oysters were swept out to sea. Damage may have reached \$100,000 to \$200,000. The channel was deepened but no

other damage was reported. No warning was received until a few minutes before the waves arrived.

Cape Disappointment. The U.S. Coast Guard Station at Cape Disappointment on the north shore of the mouth of the Columbia River reported a 5.7 foot wave at its boat moorage and fueling dock at 11:35 P.M. No damage occurred.

Columbia River. The tsunami was recorded at Astoria, Oregon, 14 miles from the river mouth with an amplitude of about 15 inches. At the Beaver tide gage 41 miles upriver the amplitude was about seven inches and at Vancouver, Washington, the amplitude was about two inches (Wilson and Tørum, 1968).

OREGON

Summary: Four children were drowned and one woman suffered a fatal heart attack. Bridges, houses, trailers, cars, motel units and sea walls were destroyed at communities along the length of the coast. Damage estimates are uncertain but appear to be between \$750,000 and \$1,000,000. Most of the communities did not receive any warning.

Astoria. A wave was recorded with an amplitude of 1.3 feet.

Point Adams. The Coast Guard reported a first arrival at 23:55 and a maximum height of 5.5 feet with the second wave (Darling, April 21, 1964).

Warrington. The waves did damage to a large area along the Warrington waterfront. Residents had been alerted. Log rafts were torn loose and broken up at the Warrington mill. An estimated \$20,000 in damage was done to the mill docks and rafts. Two boats were floating attached to large logs but were rescued. The Skipanon River was at the highest level ever known.

Sunset Beach area was not damaged (*Seaside Signal*, April 2, 1964, p. 11).

Gearhart. One home next to the Necanicum Creek at Fourteenth Street was heavily flooded. The residents awoke to find water ankle deep. The water filled the room halfway to the ceiling, leaving one to three inches of sand on the floor. A grand piano was full of water. A small cabin was left in the middle of the road 100 feet from its former site. Logs were thrown on the yard of a home on Thirteenth Street, and fill dirt around the water main washed away (*Seaside Signal*, April 2, 1964).

Seaside. Waves which followed the Necanicum River and Neawanna Creek caused \$276,000 in damage (\$235,000 to private property). The Fourth Avenue bridge was destroyed, a motel and several downtown business between First Avenue and Broadway were damaged and the Avenue C bridge was closed. At the north end of the harbor ten to twelve houses and four trailers were damaged, and the railroad trestle over the Neawanna Creek was destroyed (Spaeth and Berkman, 1967). It is notable that here as in several other places on the Oregon Coast the damage occurred well away from the coast.

A wall of water ten feet high raced up the Necanicum River damaging the Twelfth Avenue bridge, knocking out the condemned Fourth Avenue Bridge, passed the Broadway bridge without damaging it, knocked in the railing of the Avenue A bridge and severely damaged the Avenue G bridge. It took out a new rock wall facing the Necanicum Boulevard embankment. With the water came tons of dirt, logs, tree

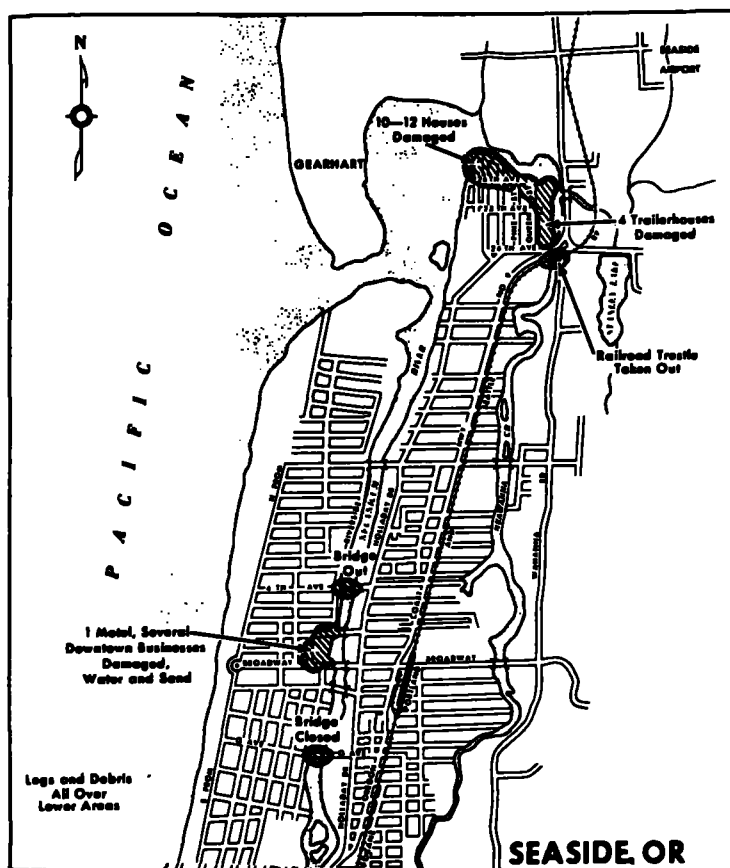


Figure 21. Location map for Seaside, Oregon, showing major damage from the March 28, 1964 tsunami. (Spaeth and Berkman, 1976)

stumps, and marine life. Broadway was flooded. The water reached as far as the golf course leaving it strewn with small debris. Damage to the city property was estimated at \$46,000.

Mrs. Mary Eva Deis, 50, died of a heart attack when the wave struck her home (*Seattle Daily Tribune*, March 30, 1964, p. 2). The Venice Trailer Court was hard hit. Automobiles in the city parking lot were swept into the river (*Olympian*, March 28, 1964, p. 2).

The heaviest damage occurred along the Neawanna Creek. Homes along the creek were flooded far up Bear Valley. The area from the creek bank to Queen, Pine, and Oregon Streets and 35th Avenue were severely damaged with no homes in that area escaping damage. The

residents did not get an advanced warning and some awoke to find water under their beds (*Seaside Signal*, April 2, 1964, p. 1).

Cannon Beach. A bridge and motel unit moved about 2,000 feet inland causing \$150,000 in private and \$50,000 in damage to city property. The water penetrated Elk Creek washing out the old Highway 101 bridge and damaged the new bridge (Spaeth and Berkman, 1967). No warning had been issued. The first wave struck at 11:34 P.M. and swept the 200 foot long Elk Creek bridge a quarter mile upstream past the Sea Ranch stable. One of the houses of the Buoys and Gulls Motel was also swept away into a swamp. The other cottage and home at the motel were twisted from their foundations and flooded.

Water forced open doors and broke windows at the Bell Harbor Motel leaving a log in one unit, ruined furniture, and left salt and silt deposits. The water reached the height of the kitchen sinks, and some mattresses and portable TV sets were swept away.

The store at Driftwood Trailer Camp and one summer home were damaged. Some houses were knocked from their foundations. Several other houses were flooded to a depth of three or four feet. A family car was washed 75 feet away into a small creek. Several families escaped by wading in water up to two feet deep. A family asleep at the trailer camp was awakened by the lurching of the trailer and found the floor flooded. They waded out but their car was swept away.

A sewer line attached to the bridge and power lines were severed to the north shore of Elk Creek. The Sea Ranch lost three bridges to a pasture and some large objects smashed the barn wall and cracked the concrete flooring. The house was flooded. Logs also punched a hole through a beach front rental.

The water poured down the street carrying logs, debris, and sand everywhere between the

buildings and littering the street. Several sections of sea walls were washed away (*Seaside Signal*, April 2, 1964, p. 1).

"At Cannon Resort utility poles were knocked down and a two-story dwelling swept into Elk Creek" (*Seattle Daily Tribune*, March 28, p. 2).

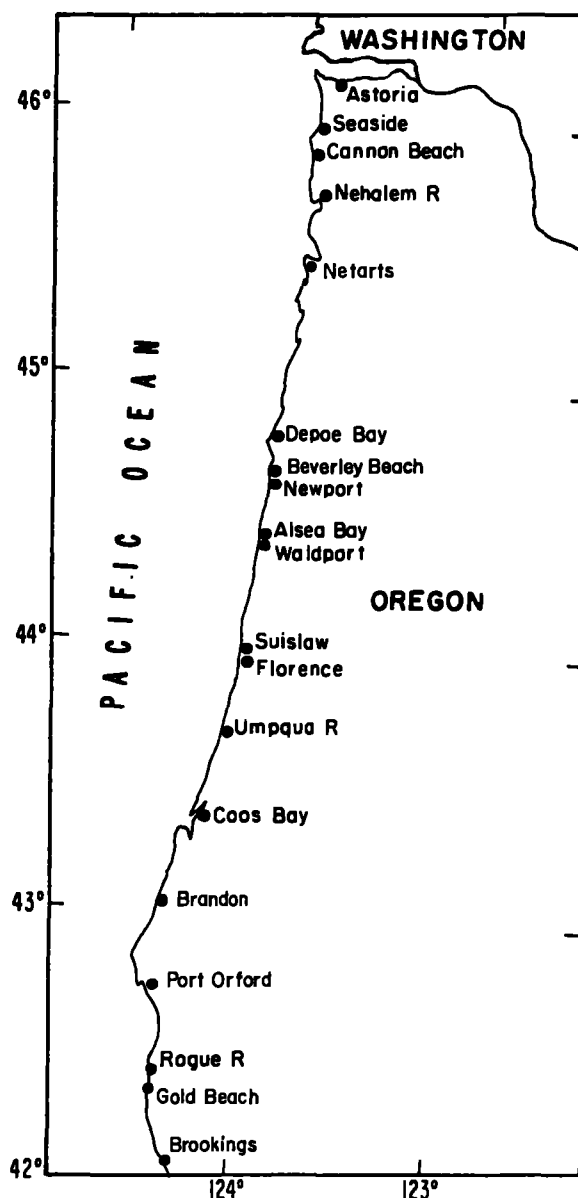


Figure 22. Location map for the State of Oregon.

Nehalem River. Water was 10–11.5 feet in height (Spaeth and Berkman, 1967).

Tillanook Bay. The Coast Guard reported a maximum height of three feet and first arrival at 23:45 (Darling, April 21, 1964).

Depoe Bay. Five thousand dollars in damage was done. The wave appears to have been about 10–11.5 feet high (Wilson and Tørum, 1968).

Newport. The McKinzie family from Tacoma was camping at Beverly Beach State Park, located between Newport and Depoe Bay. Mrs. McKinzie was a Red Cross Senior Life Saver and the children—ages three, six, seven, and eight—could swim. As they slept on the beach, a wave swept over them without warning. The first wave was small, and Mr. and Mrs. McKinzie gathered up the soaked children. Mrs. McKinzie was holding two of the children's hands when the second wave hit and battered them with logs and debris. She was knocked unconscious and found 400 yards from the camp. Mr. McKinzie climbed a cliff for help. The adults were able to reach an air pocket about one foot below the roof of their driftwood lean-to but all four of the children were lost. Only one body was recovered. The adult McKinzie's were treated for shock. The family dog was also lost. (Story compiled from: *San Diego Union*, March 24, 1964; *Seattle Daily Tribune*, March 28, 1964, p. 2; and, *Aberdeen Daily World*, March 31, 1964.)

A log hit the retaining wall in the bay at Newport breaking off six feet at the end. Driftwood and logs were scattered over the highway near Waldport and Beaver Creek. About \$6,000 in property damage was reported by Spaeth and Berkman (1967) and the waves were apparently about ten to 11.5 feet high at Yaquina Bay.

Waldport–Alsea Bay Area. \$145,000 in damage was reported for the port facilities and another \$15,000 in damage was done to private property (Spaeth and Berkman, 1967). Damage was

evident in photographs of a picnic area at Ona State Park and to a small pier on Waldport Bay. (Schatz, 1965, figs. 1 and 2) The city docks were washed out to sea and the channel filled with sand. A lumber bridge drifted from the dock and onto the beach. A motel south of Waldport had driftwood in five of its units and a log in one. The grounds were littered with about two feet of driftwood (*Newport News*, April 2, 1964, p. 1). The Waldport dock held two restaurants and many boats; nothing survived but a few crumpled planks. Two motels at Yachats were damaged by water (*Newport Graphic-Review*). This report of two motels damaged probably includes the one given above.

Florence. \$50,000 in damage was done. Waves reached heights of twelve feet (Spaeth and Berkman, 1967). The initial wave was about eight feet above mean high water at the Coast Guard station near the mouth of the Suislaw River and was only slightly dissipated when it reached Florence on the South Slough and surrounding tidal flats at the river mouth (Schatz et al., 1964).

The first wave noticed at the Coast Guard station was about midnight when the water appeared to act erratically. An eight foot wave at 12:25 A.M. knocked out floating stalls and a 24 x 60 foot floating dock and broke loose a pile driver. A float house on the Suislaw River was broken loose as well as an undetermined number of skiffs and small boats along the bank.

The next large wave at ten to eleven feet arrived at 1:22 A.M. and came up the river as a series of white capped waves, each succeeding wave higher than the other. It washed out a major portion of the bulkhead at Bay Bridge Marina. It knocked over pilings, tore apart the boat house, broke, and smashed and twisted the loading ramp into an unrecognizable shape. A new fueling station was ripped apart. Damage there was estimated at \$30,000.

A third large wave only three feet over normal high tide arrived at 2:15 A.M.

Between the first and second wave it seemed almost possible to walk across the river which was choked by trees, logs, lumber, etc. Prior to the second wave, the water drained out so fast that logs were shooting down the river like water-borne arrows.

The second wave came in with a roaring sound knocking out power lines on the west side of Florence. The commercial boats bobbed like corks but were securely tied down (*Florence Suislaw News*, April 2, 1964, p. 1).

House trailers at the Bay Bridge Marina were pushed from their parking stalls and smashed together. Houses along Second Street had their yards covered with roots, logs, pilings, and other flotsam. Bay and Juniper Streets were also littered.



Figure 23. Boat owner and fireman flee the second and largest wave at Florence, Oregon. Photo published by permission of the *Suislaw News*.

Umpqua River (Reedsport).

Waves reached 11 feet in height (Darling, April 21, 1964) and caused \$5,000 in damage but was negligible at Reedsport, ten miles from the river mouth (Spaeth and Berkman, 1967). Two drag boats were broken loose from their moorings at Winchester Bay's Salmon Harbor. The bait stand also broke loose. The Salmon Harbor manager tried to evacuate his family and trailer but their car was swamped (*Coos Bay The World*, March 28, 1964).

"The tidal current hit Winchester Bay area at approximately 11:45 P.M. on March 27, 1964. The tidal current entered the small boat basin with great speed due to the fact that the boat basin is protected on one side by a break water, and a boat must enter and leave through a small opening at one (end) of the basin. This attributed most of the damage to the harbor due to the fact that the water poured through the

opening with great speed (of) approximately 20 to 30 Kts.

"During the first surge of water into the harbor the tide rose to a plus 14' at which time most of the damage was done in the harbor. The second tidal current entered the harbor at 1:00 A.M. at this time the tide rose to a plus 11' and took 30 minutes to return to normal. The third surge hit at 2:00 A.M. and rose to a high of 11½' at this time part of the breakwater slid into the harbor. The fourth surge hit at approximately 2:45 A.M. and the tide rose to a high of 7'.

"The tidal currents continued through the night occurring approximately every half hour and were reduced in height and speed gradually until late in the morning around eleven o'clock. The only real damage other than a few fishing boats breaking their moorings was the breakwater slide

at 2:00 A.M." (Letter of April 13, 1964, from Douglas A. Pearce, Officer in Charge, U.S. Coast Guard Umpqua River Lifeboat Station, to John Darling, Corps of Engineers, U.S. Army).

Coos Bay. The first wave at 23:40 reached 9 feet (Darling, April 21, 1964) and caused \$20,000 in damage (Spaeth and Berkman, 1967). It was negligible by the time it reached Pony Point about seven miles up the channel having been dissipated as it traveled over the large mud flats (Schatz et al., 1964). The wave arrived shortly before midnight. The maximum range was 14 feet. Damage was done by the first two waves and the sucking action of the surge. Charleston Hanson's Landing and the Charleston small boat basin took the brunt of the damage. Hansen's large charter boat was torn from its mooring, flipped over and sunk. The boat was salvaged but damage to the boat and floating dock was estimated at \$21,500. In the small boat basin several boats were torn from their moorings. Nineteen pilings were damaged, four 40 foot floats, six pontoons (4 x 4 x 12 feet) and ten fenders were ripped out. Damage here was estimated at about \$17,000. A fishing boat was tipped over and sank north of the bridge.

At funnel-shaped Sunset Beach, debris and sand were swept across the road and up into the picnic and camping areas. Picnic tables and benches were tossed about and two bridges were ripped out. Three skin divers camped at the north end of the beach escaped but their car was almost covered by the water. A panel delivery truck was carried 100 feet from the parking area, ending with its front end on a picnic table. A woman sleeping inside was uninjured. A new jeep about 100 feet from the ocean near the top of the sea wall was picked up, rolled and destroyed by big logs crashing into it.

At Empire, the biggest waves reached the edge of the highway and eroded fill and damaged outflow pipes at a new sewage plant (*North Bend News*, April 2, 1964, p. 1).

At Sunset Beach water marks were left eight feet

high on the rock wall and rest rooms were filled waist deep with water.

Parts of the stiff boom at the south end of the basin was torn loose. A wing of the Charleston draw bridge was damaged and a navigation light was destroyed.

North Bend. No damage was incurred at North Bend.

Brandon. Negligible damage (Spaeth and Berkman, 1967). Wave appears to have reached 10-11.5 feet. The first wave struck at 11:40 P.M. and rose four feet above normal high tide. It caused little damage except to break free a 100-log boom at Moore Mill and Lumber Company on the Coquille River and to destroy numerous piles. Most of the logs were recovered on the beach. One man in a small boat had a harrowing experience among the crashing logs but escaped unharmed. Fifteen piles were broken and 25 additional pilings were pulled up and floated away. Most of the logs ended up on the beach along a three mile stretch from Table Rock to Crooked Creek. The wave came over the bank along Front Street leaving much debris behind but not flooding any of the buildings. An outboard motor boat moored to a floating dock at Randolph on the Coquille River was carried several miles down stream to the Bullards bridge (*Brandon Western World*, April 2, 1964, p. 1).

Port Orford. Negligible damage (Spaeth and Berkman, 1967).

Rogue River (Gold Beach). There was \$3,000 in damage (Spaeth and Berkman, 1967). Damaged were several small boats and docks, especially on the Wedderburn side. No damage reported at Port Orford (*Humboldt Standard*, March 30, 1964, p. 17). Damage was estimated at \$30,000 to \$40,000 according to the sheriff. The first wave arrived at 11:43 P.M. and major surges continued for three to four hours. The heaviest damage occurred at the Rogue River Boat Service. About 400 feet of floating dock was

torn apart and scattered along the river. There was no warning except a mention on television. Every piling was broken. The dock was salvaged but expensive to repair. Parts were found 2.5 miles upriver at Elephant Rock. Boats torn loose from the dock made circles around a large island in front of the boat service as the water ebbed and flowed. One jet boat was ruined and another small boat badly damaged. All boats had some damage. The damage here was estimated at \$3,500.

At Del Rogue a 35-foot vessel was ripped loose and suffered \$1,000 in damage. Four other boats including a new jet boat were lost along with fishing gear and another was damaged. The height was determined by a level to be 9.4 feet above the tide level (*Gold Beach Curry County Reporter*, April 2, 1964, p. 1).

Chetco River (Brookings). Negligible damage. Water rose to within a foot of the top of the dock. The south bank of the Chetco River was overflowed flooding a field. The Coast Guard motor life boat struck some rocks from the jetty while leaving to assist Crescent City. The propeller shaft was bent but the boat was able to continue its mission (*Brookings Harbor Pilot*, April 2, 1964, p. 1).

Maximum range was 11 feet, with the first arrival at 23:52 being the largest (Darling, April 21, 1964).

Winchuck River. Three homes were damaged and a half a foot of water was left in one home in the low lying farm areas on the Winchuck River. A garage extension was damaged, mud left in the house, and extensive damage was done to the yard (*Humboldt Standard*, March 30, 1964, p. 17). Damage was estimated at \$2,000 (*Brookings Harbor Pilot*, April 2, 1964, p. 1).

The *Coos Bay World* (March 28, 1964, p. 1) reports minor damage to the Winchuck bridge and five families along the river were evacuated.

CALIFORNIA

Summary: There were twelve fatalities excluding the death of a Wilmington longshoreman killed when a cable on a crane broke and dropped a loaded pallet on him. Twelve were injured in Crescent City during the early part of the disaster. Damage in California probably exceeded \$17,000,000. Crescent City was the worst affected with about \$15,000,000 of the damage occurring there. About \$1,000,000 occurred inside San Francisco bay due to currents, a major source of damage on the southern California Coast. Late arriving surges also caused one death and considerable damage. Because of its proximity and source region orientation, this event is perhaps the most damaging tsunami to be expected for northern California and can serve as a design tsunami.

Smith River. Magoon (1965) reports \$6,000 in damage to floating structures; strong currents on the river 0.3 miles above the mouth and a maximum wave height of 13.3 feet above mean lower low water level. A dock was washed away. No effects were reported for nearby Pelican State Beach.

Crescent City. The disaster at Crescent City exceeded all the combined effects in historical time from tsunamis on the United States west coast. Estimates of damage were: \$11 million (Magoon 1965); \$15 million (*Triplicate*, March 28, 1984); \$16 million (Griffin et al., 1984).

These estimates substantially increased the earlier estimate of \$7.4 million made shortly after the disaster. In Crescent City there were ten fatalities due to drowning. In the early hours of the disaster twelve people were hospitalized and twelve others were treated as outpatients. These numbers probably do not reflect the injuries sustained in the clean up. The port facilities and 29 city blocks containing 172 business, twelve house trailers, and 91 homes were damaged or destroyed. The businesses and homes on Highway 101 South were particularly hard hit

and eight of the fatalities occurred there. Twenty-one boats were sunk, due in part to their being moored at both ends. The Coast Guard cutter *Cape Carter*, a lumber tug and a few fishing boats managed to escape the harbor and ride out the waves in the open sea.

A tsunami advisory bulletin was issued at 9:30 P.M. PST by the Seismic Sea Wave Warning System in Honolulu and was followed by a warning at 10:37 P.M. These gave an expected arrival time of midnight. There was nothing special about the warning to distinguish it from the many such warnings received over the years which were mostly for harmless waves, since the system does not attempt to predict the wave heights. Low lying areas were being warned when the first wave arrived at 11:39 P.M., just after high tide.

The first rise exceeded the gage limit but was estimated to have been 14 feet above mean lower low water (MLLW) (Kent, 1964), or about nine feet above the tide level. The wave period was about 29 minutes and it flooded the lower parts of town to 2nd Street. The second wave was smaller, at six feet above tide beginning about 12:10 A.M.

Believing the worst was over as had always been the case in the past, many merchants and sightseers converged on the area having been alerted by television, radio, and friends. Officials attempted to limit access to the area by sightseers to prevent looting, but businessmen and residents were allowed to pass.

The third wave also exceeded the limits of the gage which failed altogether at this time. It was

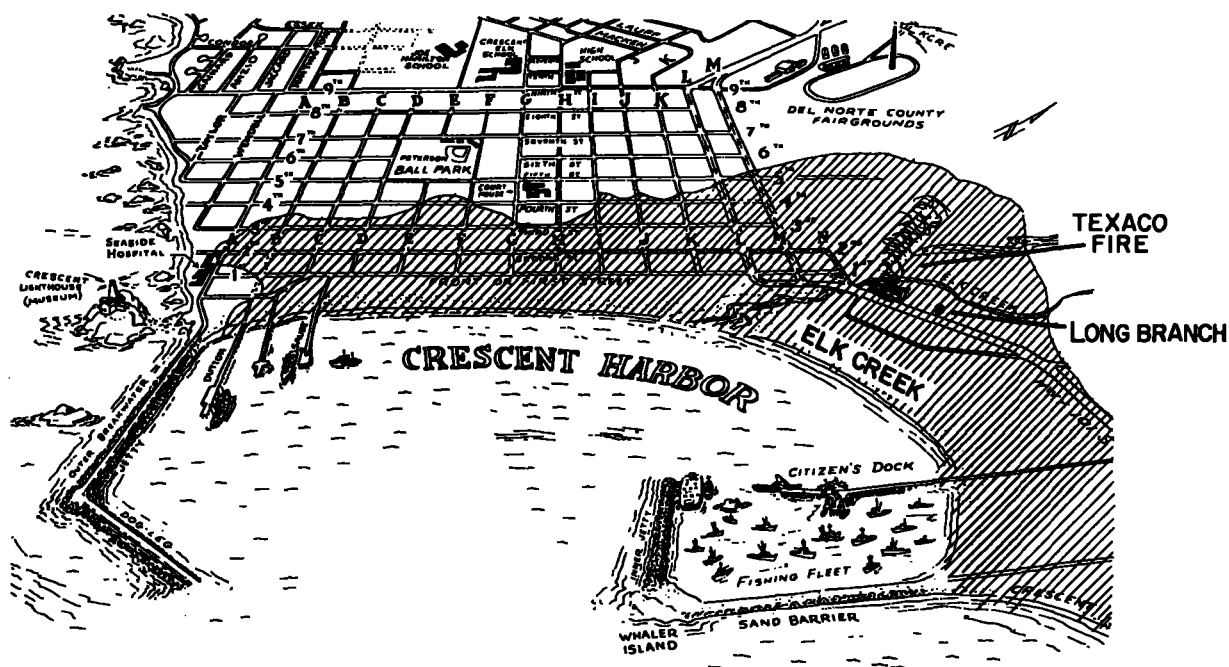


Figure 24. Inundation map for Crescent City for the March 28, 1964 tsunami. (Used by permission of Wallace Griffin, Crescent City Printing Co.)

estimated to have been sixteen feet above MLLW (Kent, 1964). It was at least a foot over Citizens Dock. A fire started at Nichols Pontiac and houses on the lower end of town floated off their foundations. The draw down after the third wave was exceptional. The curator at the Battery Point Lighthouse reported that it receded 0.75 of a mile beyond the end of the outer breakwater (Webber and Webber, 1991, p. 77). Boats were left on their sides in the mud.

Most of the damage and fatalities were caused by the fourth and largest wave beginning about 1:40 A.M. and peaking about 2:00 A.M. It reached a height of 20.78 feet above MLLW (Magoon, 1965) or about 15.7 feet above the expected tide. (It was not 28 feet as given by Magoon, 1965. Magoon added the height of the tide to the wave height rather than subtracting it.) There is some confusion in the various accounts on the timing and count of the waves. The beginning wave arrival times given here are basically from the rise above the expected tide from the tide gage record. Most popular accounts refer to times near the wave maximum. Some accounts missed the second wave, which was smaller, and treat the largest wave as the third wave.

The third and particularly the fourth waves picked up logs, cars, trucks, and other debris which acted as battering rams against buildings. One log penetrated the Post Office. The mail was sucked out but later most of it was painstakingly recovered. Fallen electrical wires posed additional hazards and at least one person was burned by contact with the wires while in the water.

Many people were at high risk: swimming for their lives; wading in deep and swift flowing water; floating on car and trailer tops; standing on furniture and on roof tops in flooded homes, motels, and places of business; and floating in moving homes and cars. Ten were drowned—a relatively small number considering the large number of people in the water or in out-of-control situations. Many people were helped to

safety by use of heavy equipment such as road graders and log loaders.

Mrs. Mabel Violette, 75, had remained at home in bed unaware of the tsunami. She awoke as the house began to jerk and heave. The roof fell, pinning her in bed. The house traveled three blocks. She was not found until 10:30 A.M. the next morning when her cries for help were heard by a passerby (Griffin et al., 1984, p. 80).

Of the ten people who drowned, five were at the Long Branch Tavern on Highway 101 South. They had been at home celebrating the 54th birthday of the owner of the Long Branch, Bill Clauson. On hearing of the tsunami they went to the tavern to empty the cash register which had gotten wet from the first wave. As everything appeared normal they continued their party.

A few minutes before the third wave, a Coast Guard car stopped and shouted a warning. Water came in the back door and everyone jumped on pieces of furniture. The floor buckled and the west wall collapsed. The lights went out. The room flooded until there was just head room to breath. The wave crested and become calm. The son, Gary, and M.D. McGuire, a patron, helped Mr. Clauson, his wife (Agatha), Joan Fields (Gary's girl friend), Juanita Edwards (an employee), her husband, Earl, and Bruce Garden (the bartender) to the roof. Gary and McGuire swam to dry land and got a boat that McGuire had. When Gary returned with the boat he rowed to the Long Branch. The water was calm (4th crest?) and all seven got into the boat to row about 75 feet. When the boat was about two or three boat lengths from dry land, the water started to recede, pulling them into Elk Creek. Bruce Garden managed to grab the Highway 101 bridge and saved himself as the boat passed underneath. Gary, a good swimmer, saved himself with difficulty but the other five perished (Griffin et al., 1984). The Long Branch was moved from its foundation almost into Elk Creek.



Figure 25. Nielsen's Hardware at 3rd and I Street, Crescent City, where water was four to six feet high. (Used by permission, Wallace Griffin, Crescent City Printing Co.) Note car intruding through the window. Damage is increased by floating projectiles such as automobiles, logs, and boats.



Figure 26. Magruder's store on 2nd Street, Crescent City, with tsunami in progress, probably the first or second wave. The second wave flooded the store to a depth of 16 inches and the third was three to four feet deep. (Used by permission, Wallace Griffin, Crescent City Printing Co.)

Three other fatalities occurred in the same area. Mrs. Wright, who lived near the Frontier Cafe, tried to escape with her three children. Her ten-month old son, William, was pulled from her arms and her three-year old daughter, Bonita, was also drowned.

Joyce London, who lived behind the Del Norte Ice Company on Highway 101, had just made a pot of coffee when her friend Lavella Hillsburg of Hammond Hill Road and her boyfriend arrived to warn them of the tsunami. The London's television was not working, and they were not aware of the danger. She, her husband, and their friends tarried to have a cup of coffee just after 1:00 A.M. and before the arrival of the largest wave. They got into their car but the wave shut it off. They tried to walk out arm-in-arm but were separated. Lavella, 49, was killed. Joyce was badly battered, with her hand, legs and seven ribs broken, and blows to the back of the head and face, requiring three months hospitalization. The men were unhurt.



Figure 27. Office and motel unit from Van's Motel block Highway 101. These structures floated from their foundations and damaged units in the next door Breaker's Motel. (Photo credit: U.S. Army)

There were two casualties in the downtown area. Adolph Arrigoni, 65, a bootblack from Italy who lived on "B" Street was found covered with debris on Third Street (Cates, 1984). James Parks, who had a combination home and shoe repair shop in a trailer on Front and Battery, was

drowned when his trailer was swept away and overturned.

Oran Magruder, 73, died of a heart attack and is sometimes mentioned as a casualty. However, he died peacefully in his sleep.

Fire started in Nichols Pontiac Automobile Agency from a shorted fuse box and soon thereafter the Union Oil and Hussy Texaco oil bulk plants tanks ignited and exploded one after the other. The fire burned for several days. Another home burned when the owner could not report it due to loss of telephone service and fire fighters could not respond in time. Floating and hissing butane tanks were a potential fire hazard.

Mr. Stockman's (operator at the Texaco station) reactions are instructive and representative of others. He reported in Griffin (1984, p. 62-63), "At 11:45 P.M. a tourist and I heard news that a tidal wave was due to hit Crescent City about midnight. I told him we have had false alarms before...I laughed at several customers that asked me if I intended to close the station and get to safety..."

"About midnight I looked down the street toward Elk Creek and water was coming down the highway...I began to get worried as the water came right to the edge of the station drive but it soon began to subside..."

He called his boss, Sonny Hussy, but since the water did not get up into the driveway he was not too concerned, thinking the worst was over. Mr. Hussy and his wife came down to check the gas tank lids. When another wave started about 1:00 A.M. they put Hussy's car on the rack. Water rose six inches deep in the station. They worried about the possibility of fire and electrical shock but calmed down when the water began to recede again.

Then the "big one" began to arrive and he raised his boss' car with them in it to the top of the service rack. The water reached eight feet inside the station and the car on top of the rack was

being moved about. Then the lights went out. Luckily they survived and escaped the station before the fire began.

The retreating waves left a huge amount of debris behind: timbers, 2.5 million board feet of lumber (Miller, 1964), perhaps 1,000 automobiles, shattered buildings, silt, and fish from the bay. Fish were found everywhere: in hanging flower baskets, rafters, desk drawers, in walls, and in large piles. Sand was not notably left behind as tsunamis have strong draw back currents which clean up such deposits. Telephone and electrical lines were destroyed. The harbor was silted up in places and needed dredging. Many of the old buildings were built of sturdy redwood timbers but floated from their foundations.

There is now a sculpture and plaque commemorating the ten killed in Crescent City and one killed at the mouth of the Klamath River mouth.



Figure 28. Cars stacked up at Harbor Motors, Second and L Street, Crescent City. Note that the lighter trunk end of the cars floated up onto the heavier motor ends. (Used by permission, Wallace Griffin, Crescent City Printing Co.)

Three additional people were listed as missing by Griffin et al. (1984), but these have now been accounted for (Griffin, personal communication, Feb. 17, 1993). *Crescent City's Dark Disaster* (Griffin et al., 1984) is a source of numerous first hand accounts of experiences during the tsunami and includes photographs of its effects. It is a useful reference for those interested in disaster responses.

Crescent City Harbor has a history of being unusually susceptible to tsunamis from all directions, more so than most other west coast communities. This characteristic has been ascribed to the effects of the Cobb Seamount, 400 miles to the northwest (Roberts and Chien, 1964) and to the shape of the coast. It is a crescent shaped embayment from Point St. George to Patrick's Point, forty miles to the south (Wilson and Tørum, 1968, p. 111, 112). The facts that the largest wave was the fourth wave and that Crescent City is affected disproportionately by waves from the south as well as the north supports the concept of a harmonic resonance of the coast shelf with a mode of the common tsunami periods between 15 and 60 minutes.

Klamath River. Sgts. Donald McClure and Stuart Harrington were fishing for eels at the mouth of the Klamath River when suddenly at about 11:30 P.M. a wall of water about twelve feet high crashed over the sand bar without warning. They and the surrounding driftwood were picked up and carried about half a mile up river. With difficulty they climbed on a large log and shed their fishing boots. A second surge again pushed them back up river. When the water began going out, they swam for the north shore near the Requa boat dock. Sgt. McClure did not make the shore and drowned. His death is generally counted with the ten from Crescent City as the eleventh victim. Magoon (1965) reports from interviews that the water was about two feet above normal at Deans Camp, 0.7 miles south of the entrance, and three feet above normal high tide at Panther Creek Lodge, one mile from the mouth. The dock and boats at the



Figure 29. Second Street looking west from L Street. Note typical debris in the foreground and buildings moved into the street in the background. (Used by permission, Wallace Griffin, Crescent City Printing Co.)

Chinook Trailer Court, 1.6 miles above the river mouth, incurred \$1,200 in damage. Four thousand dollars damage was done to the Requa Boat Dock and boats, and strong currents occurred 0.7 miles above the river mouth.

Trinidad. The *Humboldt Standard* (March 28, 1964, p. 1) reports no damage to the dock at Trinidad and a five-foot rise in water. Magoon (1965) reports on 18-foot rise above MLLW, (considerably more than a 5-foot rise). Wiegel (1965b) reports a height of about 17.5 feet elevation above MLLW, a probable tide level of between 4.2 and 5.3 feet for a probable wave amplitude of about 12.2 to 13.3 feet. The town is located on the hillside well above the sea.

Humboldt Bay and Eureka. The Eureka Boat

Basin suffered little damage but the water rose over the ten-foot seawall and eight feet into the street at the height of the rise. The tide was six feet. The bay was filled with logs and debris. Half of the sea and channel markers were moved off their stations by the surge. Nine changes in the tide were reported between midnight and 4:30 A.M. with an eight to nine feet tide at the channel entrance. "It was like someone pulled the cork out of the bay. The velocity was tremendous. It came back in just as fast and kept repeating" (*Humboldt Standard*, March 28, 1964, p. 11).

Wiegel (1965a) reports maximum run-up elevations above the tide stages as probably 3.1 feet at the Coast Guard Station on North Spit, about 4.7 to 5.1 feet at the Municipal Marina, Eureka,

about 4.5 feet at the entrance to King Salmon Slough, and 3.8 feet at the Pacific Gas and Electric Power Plant intake (0.6 miles upstream on the King Salmon Slough.) Magoon (1965) reports 14 knot currents in the channel opposite the Coast Guard Station. Professor Gast, Humboldt State College, estimated the maximum height as 14 feet (7 foot amplitude based on water lines on docks and structures) (Darling, April 22, 1964).

The *Ferndale Enterprise* (April 10, 1964, p. 1, 4) estimated that just past midnight the wave at the boat ramp was one foot above normal tide.

Noyo. The first wave arrived shortly before midnight. The sheriff had tried to alert boat owners, and some had heard of the threat from radio and television. The Coast Guard cutter *Pt. Ledge* cleared the harbor after the first surge. The *La Paz*, a 42-foot drag boat with three tons of fish in its hold was hit by another boat and shot upstream in full reverse slamming into other boats near Casa del Noyo. The crew tried to tie it up but another surge sent it upstream another quarter of a mile and aground against the *Mary R.* It was later salvaged and towed to San Francisco for refitting (*Fort Bragg Advocate-News*, April 2, 1964).

There were four major waves. The first crashed over pilings normally ten feet above high tide. Six larger boats sank. Pilings supporting the dock and boardwalk were snapped off. Three or four skiffs or drays were washed out to sea. The Coast Guard's initial report listed extensive damage to ten vessels and a float. There were about twenty boats in the harbor (*Santa Rosa Press Democrat*, March 29, 1964).

Damage was estimated at \$250,000 to \$500,000 (*Fort Bragg Advocate News*, April 2, 1964) or \$250,000 to \$1 million by the California Disaster Office in 1964. Magoon (1965) reports a maximum height above MLLW of 12.6 feet, damage of \$124,000, and that second and third waves were bores proceeding upriver at 35 miles

per hour as a series of step-like jumps. The *Fort Bragg Advocate News*, April 2, 1964, reports that ten to twenty boats were sunk, half of them commercial fishing boats and another 100 were damaged from slightly to demolished.

Caspar. Waves surged over Highway 1 at Doyle Creek near Caspar but caused no damage (*Santa Rosa Press Democrat*, March 29, 1964).

Albion River. Magoon (1965) reports a maximum water elevation of nine feet above MLLW. The wave was observed as four or five low bores traveling up the river and making a loud noise. It was observed at least 1.25 miles upstream. Currents scoured out the river mouth. About \$500 in damage occurred due to delays to fishing vessels.

Russian Gulch State Park. A maximum height above MLLW of 11.3 feet was reported by Magoon (1965).

Van Damme State Park. A wave with a maximum height above MLLW of 8.8 feet progressed about 500 feet up Little River (Magoon, 1965).

Point Arena Light Station. An estimated maximal height of twelve feet above MLLW was reported at Point Arena Light Station (Magoon, 1965).

Arena Cove. A maximum wave height of twelve feet was reported for Arena Cove (Magoon, 1965). Point Arena had four foot waves on top of the high tide but no damage (*Santa Rosa Press Democrat*, March 29, 1964).

Jenner Beach. An estimated maximum height above MLLW of ten feet was reported by Magoon (1965) with no effect on the Russian River.

Bodega Bay. Campers were evacuated from nearby Wright's Beach and Duran Park (*Santa Rosa Press Democrat*, March 29, 1964). About \$2,000 in damage was done to navigational aids.

Eight knot currents were reported. The maximum wave height was five feet inside the harbor entrance and one foot on the northeast side of the bay (Magoon, 1965).

Tomales Bay. A 25 mile-per-hour current was reported at the mouth of the bay. Six thousand dollars in damage was done to Lawson's Pier. The maximum height of 6.5 feet at the bay entrance was reported by Magoon (1965) and eight feet (above MLLW) at Drakes Beach. Inside the bay at Marshall and Jensen heights of two feet were reported and at Inverness at the far end of the bay one foot was reported. About one-third of the Lawson's Pier was lost as well as four large boat hoist poles (*Santa Rosa Press Democrat*, March 29, 1964).

Bolinas. Isaac Dirksen, 34, was drowned about 3:00 P.M. on March 29, 1964, about 13 hours after the arrival of the first tsunami wave. He was caught by a late surge at high tide while wading across a channel at the end of Maple Avenue at Duxbury Point wearing rubber fishing waders. The surge was about three feet high filling his waders and he was about 30 feet from shore (*San Rafael Independent Journal*, March 30, 1964, p. 4). Duxbury Reef had been exposed four times during the night by the main tsunami waves (*San Rafael Independent Journal*, March 28, 1964, p. 3).

Muir Beach (near Golden Gate). Magoon (1965) reports a maximum water height of nine feet above MLLW.

San Francisco Bay. A maximum water height of 3.7 feet (amplitude) was recorded on the Presidio gage at 1:35 A.M. The first wave arrived at 12:42 A.M. with a rise of 2.3 feet on the high tide and was the highest wave about MLLW as the tide was falling.

San Rafael. Damage centered on the marina on the Marin County Bay shores. In Loch Lomond Marina at San Raphael about 2:30 A.M. the largest wave of about five foot height broke the end off of the dock with about 20 boats still

moored to it. It crashed into a neighboring dock bending it into a crumpled "S". A 32-foot cruiser sank but was later raised and repaired. "F" Dock with 30 boats attached was lifted over a levee and deposited a quarter mile away. The greatest damage occurred to other docks where several craft tore loose from their moorings, crashed into others, and parts of the dock were torn loose. Four or five boats sank including a new, \$30,000 36-foot boat. Gasoline spilled, raising the possibility of fire. Sparks from parting electrical lines looked like the 4th of July. The water had a strong current and rose about four feet. One fishing boat reportedly sank at Kappas Yacht Harbor at the Chris Craft sales. One boat was holed and sank. Damage was done to the docks' floats.

A fireman reported the water level dropped seven feet at Tiburon before the largest wave. Only minor damage occurred there. A few garages and driveways were flooded at Strawberry Circle.

The Coast Guard sent its vessels to sea after the first wave. Harbors were left partly filled with silt and mud. There were four major crests.

Sausalito. The old ferryboat *Berkeley*, being used as a floating store "Trade Fair," was loosened of all but one of its moorings and a large section of pilings were torn loose by the old ferry and they floated in the bay (*San Rafael Independent Journal*, March 28, 1964).

Magoon (1965) reports maximum wave heights of four feet at the Marinship Yacht Harbor and Clipper Yacht Harbor at Sausalito. One hundred thousand dollars damage occurred at the Clipper Yacht Harbor to floating structures and boats. Water reached about 6.5 feet (eight feet above MLLW) at the San Rafael Yacht Harbor with \$7,500 in damage to floating structures and boats. Water reached five feet at Lowrie Yacht Harbor and caused \$10,000 in damage. He reports only \$100 damage at the Berkeley Yacht Harbor and boats touching the bottom of the Red Rock Marina. The wave heights and locations are also given in Table 8. Total damage to

Marin County was put at \$1 million by the California Disaster Office.

Table 8. Wave Amplitudes in San Francisco Bay; March 28, 1964 Tsunami (Magoon, 1965)

Location	Max. Amplitude/Feet
Belvedere	
San Francisco Yacht Club	2.5
Point San Pablo	
Standard Oil Company	2.2
San Pablo	
Yacht Harbor	3.2
Richmond	
Yacht Service	0.8
Yacht Harbor	3.5
Channel Marina	4.5
Oakland	
Jack London Marina	3.5
Norwalk Yacht Harbor	3.7
Embarcadero Yacht Harbor	4.0
Alameda	
Naval Air Station	2.7
Alviso Sough (bay entrance)	0.6
Benicia	0.2
Collinsville & beyond	<0.1

Pacifica. Magoon (1965) reports a maximum wave of nine feet.

Half Moon Bay. Magoon (1965) reports a maximum height above MLLW as 10.1 feet. Four boats at the Pillar Point breakwater were damaged. An abalone boat was sunk but later raised with \$500 damage to it. An 18-foot craft was swept to sea but was recovered. Two other small crafts were forced onto the rocks of the western arm of the breakwater but pulled off without serious damage. Before the second wave at 2:00 A.M. the water dropped precipitously returning as an eight to twelve foot wave. It reached the top of the banks but did not spill over. A late surge at 7:00 A.M. created currents of ten to twelve knots. Extensive evacuation had

moved 2,000 people away from the beaches and low areas (*Half Moon Bay Recorder and Pescadero Pebble*, April 2, 1964, p. 1).

Martins Beach. Magoon (1965) reports a maximum wave height of about 20 feet above MLLW which seems unusually high.

Santa Cruz. Frank Monnich, the owner of the 38-foot *Big Boy II*, and Jim Adams, a passenger, set out for open water after being warned of the tsunami. On the way out he hit something and about half a mile from shore he realized he was in trouble. He tried to beach the boat but at about 200 yards from shore their boat disintegrated. They jumped into the water and were rescued by another boat.

A 10-by 35-foot dredge sank immediately and may have been the object the *Big Boy* hit. Thirty of its floats were in the bay and were sunk by shooting holes in them as they were navigational hazards. The waves caused a ten-foot rise, then left the harbor dry and boats on their side when they went out. Damage to the boats was slight. An auxiliary platform was broken up, a small boat overturned, and several others were scratched. The water reached the steps to the boardwalk but caused no damage (*Santa Cruz Sentinel*, March 29, 1964). The *Watsonville Register-Pajaronian* (March 28, 1964) reported the first wave at 1:15 A.M. as being eight feet and that two waves followed. Magoon (1965) reports \$100,000 in damage and a maximum wave 12.4 feet above MLLW (10 foot height).

Capitola. Water surged over the Esplanade seawall, a common happening at high tide (*Santa Cruz Sentinel*, March 29, 1964). Magoon (1965) reports a 14-foot wave at Capitola. He also reports a maximum of five feet and minimum of minus one foot MLLW for a total height of six feet at Seacliff.

Rio del Mar. Hundreds of people lined the cliffs and jammed the roads to see the tsunami, creating a problem for police. The retreating sea

revealed the crumbling wreck of a cement ship at Seacliff. It then advanced to the shore end of the jetty from the river mouth (*Watsonville Register-Pajaronian*, March 28, 1964).

Moss Landing. Magoon (1965) reports a maximum wave height of five feet, a damaged skiff and strong currents.

Monterey. Waves 8.5 feet high surged into the bay. A finger float was broken off, and some utilities were cut. After the warning, about a dozen skippers took their boats out of the harbor. The waves came at about 20 minute intervals beginning at 12:15 A.M. as measured on a tide gage on Pier 2 (*Monterey Peninsula Herald*, March 28, 1964). Magoon (1965) reports losses of \$1,000 and a maximum elevation of 7.5 feet. Whirlpools were formed at the seaward end of Monterey breakwaters.

Pacific Grove. Magoon (1965) reports a maximum elevation of seven feet above MLLW and a maximum wave height of six feet.

San Simeon. Campers and trailers were evacuated from San Simeon State Park, Cambria, and Cayucos Beaches. No damage was reported to the beaches, but campers were drenched as the waves struck high on the beaches.

Cayucos. The most obvious result of the wave which arrived at 1:20 A.M. was the mud and debris left in the parking lot by the Cayucos Memorial Building. Many stranded fish provided dinner for some. Observers reported that they could have walked around the end of the Cayucos Pier when the water went down. At Moro Strand, residents reported seeing rocks not previously seen when the water withdrew with a sucking sound ("Cayucos By the Sea," *Sun*, April 2, 1964).

Morro Bay. Worst hit was the Morro Bay Marina which lost its fuel dock. It broke free and hit several boats. Damage was reported to floats, pilings, and one boat. The Morro Bay Yacht Club lost its house boat which had been

moored near the south Embarcadero boat launching ramp. It broke free along with the walkway and sailed down the bay on a 20 mile-per-hour outgoing tide. It rammed into the end of the C&L dock splintering the houseboat completely and it sank. Brown's oyster barge also broke loose, came down the bay at a great speed and took out two lumber pilings at the same pier.

The barge ran into another boat. Possibly \$10,000 damage was done to the newly planted oyster beds by silting and washing oysters to sea. The early warning helped save much equipment. Two boats which had broken their moorings were saved (*Morro Bay Sun*, April 2, 1964). The trestle was in danger of being washed out (*San Luis Obispo Telegram Tribune*, April 1, 1964).

The tide changed about ten feet in ten minutes. The current carried away an 18 foot inboard motor craft after first swamping it at the dock. Many small boats broke loose from the dock and were known to be lost. Others were in "dry dock" having been washed aground on a sand spit inside of the harbor. One boat, the 44-foot *Adventure* was just clearing the harbor when the large surge came at 12:45 A.M. Although making nine knots speed it was pushed back into the breakwater (*San Luis Obispo Daily Telegram*, March 28, 1964).

Avila. Waves came to within two feet of the top of the pier (*San Luis Obispo Telegram Tribune*, April 1, 1964). A few boats broke loose from their moorings (*San Luis Obispo Daily Tribune*, March 28, 1964).

Pismo Beach. Waves washed up against the sea wall (*San Luis Obispo Telegram Tribune*, April 1, 1964).

Oceano. Water rose to the dunes but did not reach the community. Heavy surf action was reported along a three mile strip (*San Luis Obispo Daily Telegram*, March 28, 1964).

Santa Barbara. Five-foot surges on 20-minute cycles continued into the day making boat handling hazardous. Two boats caught in the harbor entrance slammed into a piling on the slip nearest the entrance and snapped it off. One walkway was damaged. Several big mooring drums ended up in the middle of the channel and several boats dragged their anchors (*Santa Barbara News-Press*, March 28, 1964). The gage dropped from 5.4 feet to 2.7 feet in ten minutes (*Santa Barbara News-Press*, March 30, 1964, p. 5).

Oxnard. Large swells reported after daylight (*Oxnard Press Courier*, March 28, 1964).

Ventura. Tide said to have dropped eight feet to an all time low tide.

Santa Monica. One 16-foot outboard motor boat was damaged, capsized and sunk, and a fueling station and floating anchorage damaged at Marina del Rey. Eight surges hit the marina between 1:45 A.M. and 7:00 A.M. with the last one tearing the oil company fueling float loose. It was quickly caught and caused no damage. Several other of the 800 boats in the marina were damaged.

A maximum 52-inch change in water (26 inch amplitude) generated 15 mile per hour currents. Damage estimates were as high as \$100,000 (*Santa Monica Evening Outlook*, March 30, 1964, p. 7). Tides changed from minus one foot to plus six feet within half an hour (*Santa Monica Evening Outlook*, March 28, 1964, p. 1).

Los Angeles. Most damage occurred to berths 206, 207, and 208 of the Fellows and Stewart Yacht Harbor on the Terminal Island side of Cerritos Channel. The damage occurred around 6:00 A.M. when a high swift surge entered the channel wrenching boats and finger piers loose from their moorings. At one time about 75 to 100 boats were floating free. Three boats were sunk. A surge of about six feet moved through the channel at 10:20 A.M., about the same size as the 6:00 A.M. surge, but caused no apparent

damage (*San Pedro News Pilot*, March 28, 1964).

A longshoreman was killed at Wilmington Saturday when a boom with a pallet was being swung back on board the *Philippines Presidential Magsaysay*. A cable snapped and went out of control, crushing him. Also, the Union Oil tanker *Santa Maria* ripped out a 175-foot section of dock when it was suddenly pushed against it while being moved by tug boats. The backlash from the tanker propeller racing to prevent the crash swamped an 18-foot boat and sank it. The *Santa Maria* incident was blamed on continuing surges in the channel and the longshoreman's death may also have been caused by stresses in the cable due to the ship's motions. The press did not report the time of either event. (*San Pedro News Pilot*, March 29, 1964)

Santa Catalina Island. Spontaneous waves as high as ten feet hit Santa Catalina Island but caused no damage. The first wave was four feet high (*San Diego Union*, March 29, 1964, p. 2).

San Diego. The channel into Shelter Island Yacht Harbor looked like a rapid flowing river. Water rushed in and out of Mission Bay Channel but the effect was less noted. Water rose 6.5 feet in ten minutes. Surges continued through the night with one surge breaking the mooring at the Bali Ha'i restaurant on Shelter Island and another wrenching the 60-foot schooner from its moorings. The currents were strong enough at 4:00 A.M. to move two sections of a floating concrete pier at the Navy Amphibious Base on the Silver Strand. The sections were anchored by 5,000 pound anchors. One was dragged 100 yards by the current (*San Diego Union*, March 29, 1964, p. 2).

SUMMARY

This tsunami illustrates several factors. Recent past tsunamis were poor indicators of the tsunami threat from great tsunamis. Crescent

City businessmen who returned to their businesses too early, placing themselves at risk to later and larger waves could have saved risking their lives if they had a better knowledge of the continuing tsunami hazard. Waves of destructive size or causing swift currents can occur more than twelve hours after the initial arrivals.

Table 9. Instrumental Data for the March 28, 1964 Tsunami

Location	Max. Amplitude/Feet
California:	
Alameda	2.7
Alamitos	1.4
Avila	5.2
La Jolla	1.1
Los Angeles, Berth 60*	1.6
Monterey	4.7
Neah Bay	2.4
Newport Bay	0.9
Rincon Island	3.0
San Diego	1.9
San Francisco	3.7
Santa Monica	3.3
Oregon:	
Astoria	1.2
Washington:	
Friday Harbor	1.2
Seattle	0.4
* Spaeth and Berkman, 1972	

In protected harbors, such as Loch Lomond in San Francisco Bay, the potential for damage depends on the wave height almost independent of the tide stages, as it is the current which is the main hazard and not flooding. Marinas are often not designed for the currents which can occur during major tsunamis. Sightseers obstruct necessary movement in the hazard area as well as putting themselves at risk. Radio and television broadcasts should stress that non-emergency personal should evacuate and remain

out of the area. While it is inherently dangerous, actions to evacuate boats to the open water before the arrival of large waves and strong currents seem to be beneficial. Tending to boats in the harbor during tsunamis was successful in this case but also hazardous.

Most of the fatalities would have been avoided if the people had not left the buildings during quiet periods in the wave activity. These periods are brief and soon give way to strong currents as the water reverses its flow. Data gathering, particularly for the Washington and Oregon coasts was completely inadequate. This is the largest event to have happened to the west coast and is probably the design event for tsunamis in this area. The few available reports concentrated on maximum runup heights and dollar damage without detail.

1965, February 4, 05:01 GMT. A magnitude 8.2 earthquake in the Rat Islands, Aleutian Islands, generated a wave that was widely recorded throughout the Pacific Basin. On the west coast it was observed directly only at Santa Cruz where the water rose two feet at 4:00 A.M. and dropped back to normal (*Santa Cruz Sentinel*, February 4, 1965). It was recorded at Crescent City with an amplitude of one foot, and at Santa Monica with an amplitude of three inches (Von Hake and Cloud, 1967; Soloviev and Go, 1974). Validity 4.

1966, October 17, 21:42 GMT. A magnitude 8.0 earthquake near Peru generated a 1.5-meter amplitude wave locally. On the west coast it was recorded as a one-foot wave at Crescent City and at less than four inches elsewhere. (Iida et al., 1967) (See Figures 141, 142, 143, and 144, pages 205–207.) Validity 4.

1968, May 16, 00:49 GMT. A magnitude 7.9 earthquake east of Honshu, Japan generated a 5-meter wave locally that flooded houses. It destroyed more than 100 ships. On the west coast it was recorded with amplitudes of two feet at Crescent City, eight inches at Santa Monica, California and Newport, Oregon, four inches at

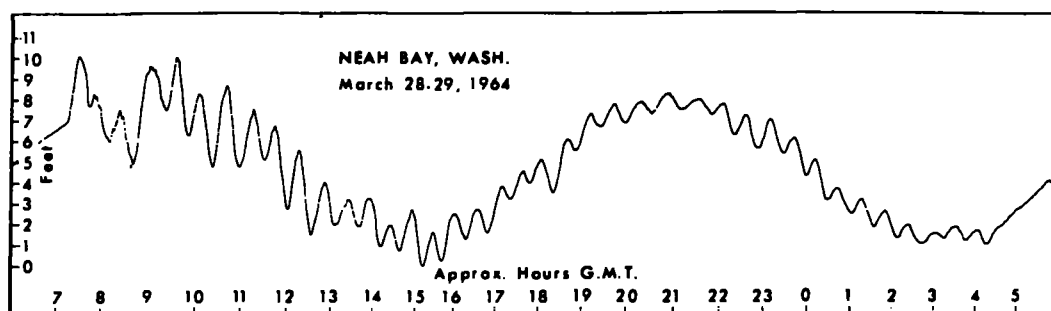


Figure 136.

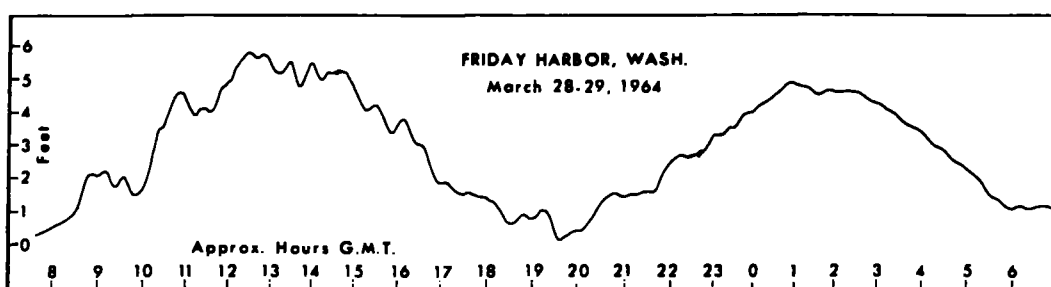


Figure 137.

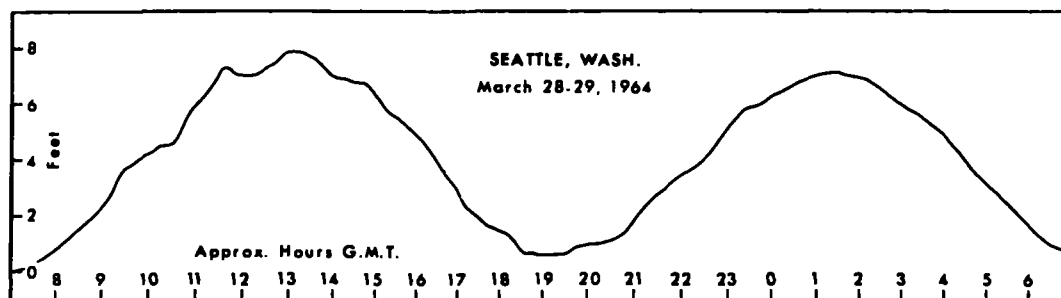
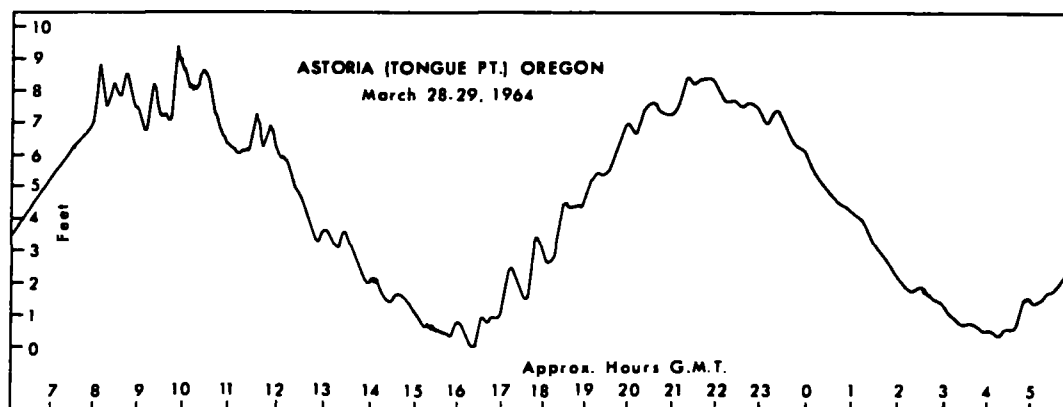


Figure 138.



Spaeth and Berkman (1972)

Figure 139.