Coastal Environments, Inc.
Oceanographic and Coastal Services

9 September 2022

Mr. J. Kevin Jenkins, Esq.
24 North Church Street #407
Wailuku, HI 96793
Via E-mail: Kevin@jenkinsmauilaw.com

Beach Impacts of Maalaea Harbor, Maui

Dear Mr. Jenkins:

This report is in response to your request for my evaluation of the influence of Maui's Maalaea Harbor on beach erosion along Maalaea Beach east of the harbor, and recommendations for mitigation of its impacts.

In particular, you requested consideration of the harbor's influence on, and possible mitigation measures for, beaches fronting the following properties that stretch about one-half mile from west to east: The Mermaid and Maalaea Yacht Marina (both inside the harbor), Milowai (inside and outside), Maalaea Kai, Lauloa, Island Sands, Maalaea Banyans, a private home, a vacant lot, Kanai A Nalu, Hono Kai, and Makani A Kai (all east of the harbor). This reach is referred to below as the "impact area" bordered on the northeast by Haycraft Park.

My qualifications to conduct this evaluation, including my resume and list of publications, are attached to this report. My findings, conclusions, and recommendations presented in the following paragraphs are based on my education, knowledge, and experience as a coastal oceanographer, and the images, documents, and data available to me as of this date. My findings, conclusions, and recommendations may change as warranted by additional information or review.

CONCLUSIONS SUMMARY

South Maui's geological and physical setting produces relatively sparse beach sediment supply with limited wave-induced transport, making its beaches highly sensitive to interruptions of supply or transport.

Construction of the Maalaea Harbor jetties beginning in the 1950's shifted natural eastward longshore sediment transport offshore depriving the impact area of its main sand supply. This destroyed the beach fronting the subject properties, and precipitated construction of hard coastal protection works to defend existing developments.

Maalaea Harbor is a multi-dimensional failure that doesn't adequately serve its primary purpose of sheltering small craft from wave action, and furthermore traps sand along the jetties and inside the harbor, diverts sediment onto the adjacent reef, while starving the downdrift beach.

Recommendations include actions that could benefit the public, the harbor, and the beach.

FINDINGS

1. Maalaea Harbor is located on the west side of Maalaea Bay, which is shaped by the arcing southern coast of the low-lying isthmus joining two ancient volcanoes – West Maui (Mauna Kahalewai), and Haleakalā (east) – that formed the island of Maui. Maalaea Bay is part of the Kihei Region coastal system (Figure 1).

2. The Maalaea Harbor breakwater jetties and other infrastructure were built in stages starting in 1952 (Joerger and Kaschko 1979).

3. Of the major Hawaiian Islands, Maui is the second youngest at about 1 million years old. West Maui is deemed extinct, and Haleakalā dormant. The Big Island of Hawaii is the youngest, at less than 1 million years old, and still growing from Kilauea eruptions.

4. As a relatively young island, Maui is undergoing post-volcanic subsidence and flexure, with higher relative mean sea level rise (MSLR) rates and resulting beach erosion greater than that observed in the older islands of Oahu (2-3 million years) and Kauai (5 million years), which are more stable (Romine et al. 2013).

5. For the same reason, Maui has had less time for terrestrial and reef erosion to provide beach sand.

6. Hawaii beaches are generally formed of carbonate marine organisms, including coral, algae, and plankton that produce "white sand," or of "black sand" from eroded volcanic rock, or a combination of both (Harney 2013).

7. Extensive inland carbonate sand deposits occur on Maui's isthmus, having provided millions of tons of material for concrete production (SSFM International 2018). While most of these deposits are incompatible with beach nourishment, use for concrete production, and especially for export, has been curtailed, partly to preserve beach-compatible sand (Nu'u et al. 2008).

8. The Maalaea Bay shoreline is mainly white sand. Sand transport paths toward Maalaea Harbor include wave-driven movement from south to north along the western shore, and east to west along the northern crescent from Kealia dunes and beaches toward Haycraft Park.

9. Anderson et al. (2015) suggest that the influence of MSLR on shoreline change is currently *"minor compared with sediment availability (sum of sources and sinks) related to human impacts and persistent physical processes."* In Maalaea Bay, this presumably encompasses the impact of Maalaea Harbor.

10. However, increases in future rates of MSLR suggest beach erosion in Hawaii, as in most of the world, will intensify. This will make Maui beaches ever more vulnerable.

11. The Kihei coastal system is exposed to southern hemisphere swell, usually highest in summer and fall, and from south-western “Kona” storm waves most prevalent in winter and spring.

12. Maalaea Bay is sheltered from the generally bigger north and northeast waves from North Pacific storms and persistent north-easterly trade winds. However, northerly winds can occasionally blow sand from inland dunes toward the beach, and from the beach offshore.

13. A 1951 air photo shown in Figure 2 suggests that a thin but continuous ribbon of white sand existed along the entire western shore north through the current location of Maalaea Harbor (yellow outline), and east through the impact area toward Kihei. The upper arrow indicates then pre-harbor sand transport path along the shoreline. This photo provides a key reference for beach conditions at the impact area before the existence of the harbor.

14. Figure 2 also implies that sand supply along the western and north-western edge of Maalaea Bay has been sparse, and beaches generally narrow, especially from the impact area (black bracket) to the southwest.

15. The lower arrow in Figure 2 depicts the alteration of the sediment transport path along the natural shoreline before harbor construction that was shifted offshore by the breakwaters. Small arrows suggest sediment transport paths into the harbor, onto the adjacent reef, and bypassing the impact area, and thus starving the beach.

16. Figure 3 is a 1997 air photo of the area (University of Hawaii 2010). A large sand plume appears to stretch from the reef adjacent to the harbor’s east breakwater toward the horseshoe-shaped Kanai A Nalu building, attaching to the beach there. A wider, sandy beach extends east into Haycraft Park. Also noted (arrow) is the sand transport path previously along the shore that was shifted offshore by the breakwaters, as further discussed below.

17. A prominent reef feature (labelled in Figure 2) partly inside and adjacent to the harbor extends northeast about one-third the length of the impact area.

18. Shoreline position determinations based on 1900 USGS Topographic maps (“T-Sheets”), and air photos from 1910, 1949, 1950, 1960, 1975, 1987, 1988, 1992, 1997, and 2007 by the University of Hawaii (2010) and Fletcher et al. (2012) suggest that the impact area adjacent to Maalaea Harbor has eroded at an overall rate of up to about 1.5 ft/yr from about 1900-1987 (Figure 4, black line left panel, “Long-term rates”).

19. Almost all of this erosion has occurred after the 1940’s (Figure 4, black line center panel, “Short-term rates”), strongly suggesting that beach loss at the impact area was directly related to construction of Maalaea Harbor.

20. Erosion since the 1940's east of the impact area (east of Transect 950, Figure 4, left scale), is much smaller and arguably statistically zero given the large 95% confidence band[1] shown as the grey shaded areas surrounding the black lines in Figure 4 (left and center panels).

21. The University of Hawaii (2010) and Fletcher et al. (2012) results are consistent with local knowledge and oral history provided by long-time area residents, including David Kehoe, Fred Haywood, Lois Bruce, and Patricia Mazingo (Peter Cannon, personal communication). They recall continuous beaches along the entire Maalaea region before the harbor was built, and remember walking along the strand to Kihei. Furthermore, they also recall that sand loss, beach erosion, and exposure of rocky substrate was immediate, sudden, and dramatic after construction of the harbor.

22. Maalaea Harbor (Figure 5) consists of two rubble mound breakwater jetties on the west and east, respectively built by the Territory and then State of Hawaii in 1952, and 1958 or 1959 (Joerger and Kaschko 1979; USACE 1992). The harbor entrance faces south and is exposed to waves approaching from that direction.

23. Various problems with Maalaea Harbor were noted after it was built (USACE 1992; Moffatt & Nichol and EA/HHF 2011; Sea Engineering 2012; Chris Hart and Partners 2014), including higher than acceptable wave heights and surge inside the harbor, accumulation of sand inside the harbor, and interference with downstream sand transport (toward the impact area).

24. Littoral sand transport interruption and trapping is an old and common consequence associated with harbors and coastal lagoons, especially with inlets on open ocean coasts world-wide (e.g. Inman and Brush 1973; Dean and Walton 1975; Jaykim Engineers et al. 1986; Bruun 1995; Patsch and Griggs 2008; Bodge 1993; and many others).

25. The USACE dredging website (https://navigation.usace.army.mil/CED) states, *"The US Army Corps of Engineers (USACE) is responsible for maintaining and improving nearly 12,000 miles of shallow-draft (9'-14') inland and intracoastal waterways, 13,000 miles of deep-draft (14' and greater) coastal channels, and 400 ports, harbors, and turning basins throughout the United States. …Yet only a few of them are naturally deep. In most of them, channels must first be excavated to a Congressionally mandated depth and then dredged periodically, so they will remain clear and safe for navigation. Without dredging, many waterways, ports, and harbors would become impassable to commercial and recreational vessels."*

26. This implies that almost all harbors (and wetlands) intercept and trap littoral sand. These include Maalaea as well as Kahului harbors on Maui. Examples in California include (from

[1] The "95% confidence band" shows the range within which the actual erosion rate lies with 95% certainty. In other words, it is only 5% likely to lie outside this range.

north to south) Bodega Bay, Pillar Point, Santa Cruz, Moss Landing, Morro Bay, Monterey, Santa Barbara, Ventura, Channel Islands, Port Hueneme, Marina del Rey, King Harbor, Bolsa Chica wetland, Talbert Marsh, and Newport, Dana Point, and Oceanside harbors, Agua Hedionda, Batiquitos, San Elijo, San Dieguito, and Los Peñasquitos lagoons, and Mission Bay and San Diego Harbor, along with numerous examples along the Gulf and Atlantic coasts.

27. Maalaea Harbor is unusual because of its location adjacent to the extensive reef to the east. The jetties not only divert beach sand offshore, with some being trapped along the jetties and in the harbor, but the reef prevents sediment that makes it past the harbor entrance from reconnecting with the beach at the impact area. A large volume of material apparently becomes impounded on the reef, depriving the downdrift beaches even more, as detailed below (Findings 47-51).

28. Moffatt & Nichol and EA/HHF (2011) were funded by the U.S. Army Corps of Engineers to develop a regional management plan for Maui's western beaches, and recognized that "*the Kihei region has been affected by the construction of the Maalaea Harbor*."

29. Norcross-Nu'u et al. (2008) developed a beach management plan for Maui with support from NOAA's Coastal Zone Management Program, the State of Hawaii Office of Planning, and the County of Maui. This plan remains useful for developing strategies to address erosion issues in the impact area, as outlined in the recommendations presented below (Paragraphs 68-89).

30. Norcross-Nu'u et al. (2008) noted that harbors and [their] channels can act as sediment "sinks" or losses, and *"construction of harbors and navigational channels, and actions leading to the degradation of coral reefs, can also contribute to sediment deficiencies."* In addition, *"Harbors and navigational channels can interfere with sediment transport. Sand moved by nearshore waves and currents is deposited in these artificial depressions and is removed from the littoral system."*

31. Chris Hart & Partners (2014) found, *"Sand beaches in the Maalaea area have been negatively affected since the construction of the Small Boat Harbor facilities and the break wall and sand dunes are not present in front or adjacent to the project site."* The term "break wall" refers to the Maalaea Harbor east breakwater jetty.

32. Chris Hart & Partners (2014) further found, "…*the lack of sand fronting the Milowai is primarily due to the impact of the Maalaea harbor breakwater*." Figure 3 shows the location of this property.

33. Chris Hart & Partners (2014) also noted that, "…*west of the break wall* [i.e, inside Maalaea Harbor] *is a 75-foot long sandy beach."* And continued, *"The sandy beach within the harbor was created as result of accretion after the construction of the east break wall. The Milowai property's oceanfront shoreline is devoid of beach material. No significant sandy beach is*

present along this stretch of Maalaea Bay shoreline, stretching from the break wall roughly 1800 feet up the coast to the Ocean View Maui Condominiums."

34. The existence of a sandy beach accumulation inside the harbor both proves that it intercepts and traps littoral sand, and helps quantify the rate of sand capture. Additional sand trapped in the entrance channel can also be quantified by using maintenance dredging information. Sand accumulation measurements by Elwany (2020) are presented below. Especially important are measurements of sand accumulation on the adjacent reef (Findings 47-51).

35. Sea Engineering (2012) noted, "*Interpretation of the historical shorelines suggests that a beach has been absent from the condominium's Maalaea Bay shoreline since at least 1960, except for a small, fluctuating pocket of beach material next to the jetty*."

36. Sea Engineering (2012) also found, *"…sediment transport paths typically mirror the nearshore current pattern and wave approach direction. The absence of a sandy beach along the western reach of Maalaea Bay's shoreline supports this generalization. Wave approach is from the south and southwest along the shoreline here, driving sediment transport to the northeast. With Maalaea Harbor's east jetty cutting off transport from further upstream to the west, this area is starved from sediment delivery from that portion of the littoral cell."*

37. Modifications to reduce undesirable wave action inside the harbor were described by USACE (1992), with modeling by Cialone et al. (1992) as updated by Hadley et al. (1998). Focus was on protecting the inner harbor from southerly approaching waves with additional structures inside the harbor, or alterations and/or additions to the jetties so the entrance would face either east or west. Potential impacts on surfing areas near the harbor were considered, however detrimental sand transport and beach erosion effects were not.

38. The sediment supply to the impact area has been cut off. It is continually eroding, which necessitated protection for developments with various seawalls and revetments constructed since at least the 1960's. Many are now in need of repair or replacement (e.g. County of Maui 2014).

39. In addition, three beach nourishment projects to slow erosion added 1,500, 3,000, and another 3,000 cubic yards of sand to the impact area in 1997, 1998, and 2003, respectively.

40. Scarcity of sediment along western and northwestern Maalaea Bay makes the area's beaches especially vulnerable to further deprivation or interruption of sand supply or transport.

41. The deterioration of the Maalaea reef system has further reduced the availability of new sand for the area's beaches. This poses an additional major problem for Maalaea Beach, since most of the littoral sand is derived from reef erosion.

42. Sparks et al. (2015) points out that, *"In 1972, the coral reefs within Maalaea Bay were described as being "striking in their diversity and in the presence of rare corals species" (Kinzie, 1972). Similarly, a U.S. Fish and Wildlife environmental assessment in 1993 estimated coral cover in the vicinity of the current CRAMP survey stations to be between 50% and 75% (USF&W, 1994). These scientific assessments describe a once healthy and diverse reef ecosystem. The Maalaea reef is now extremely degraded and has experienced periods of heavy algal overgrowth."* While there is no mention in this assessment of sediment accumulation on the reef, results presented in the following paragraphs suggest that this may be a contributing factor in reef decline.

43. Elwany (2020) presents research results by Coastal Environments, Inc. (CE) concerning sand transport, and accumulation and loss in and around Maalaea Harbor, including the reef and the beaches in the impact area to the east. These findings are summarized and incorporated herein as the following Findings 44-51.

44. Since no wave measurements are available from Maalaea Bay, CE estimated wave-driven sand transport rates from 3,000 ft west to 7,000 ft east of Maalaea Harbor for 2016-2020 using the "Simulating Waves Nearshore" (SWAN) model-derived wave condition estimates from the University of Hawaii PacIOS observing system (https://www.pacioos.hawaii.edu).

45. The wave information was combined with the bathymetry data to calculate hourly potential longshore wave-driven sand transport following USACE (1984) Shore Protection Manual procedures. "Potential" is the maximum amount of sand that can be moved by existing wave conditions. Actual transport may be less if there is insufficient sand for the waves to move.

46. The CE results suggest that the potential transport adjacent to Maalaea Harbor ranges from 1,700-3,000 cubic meters per year (m^3/yr), averaging about 2,300 m^3/yr, predominantly to the east. As expected, this is a relatively low rate commensurate with the moderate wave climate. In comparison, sand transport rates along the southern California coast range from about 100,000-1,000,000 m^3/yr, depending on location and wave conditions.

47. CE also analyzed 1999 and 2013 NOAA LiDAR bathymetry datasets to estimate sediment volume changes inside and adjacent to the harbor, on the reef, and offshore in Maalaea Bay.

48. The nearshore results from depths of 1-5 m showed accretion of about: +3,600 m^3 south of the west breakwater (Elwany 2020, Figure 4-4); +3,100 m^3 inside the harbor and its entrance channel, after accounting for channel dredging (Figure 4-5); and +13,500 m^3 on the reef adjacent to the east breakwater (Figure 4-6).

49. The nearshore results also showed erosion of about: -1,500 m^3 along western Maalaea Bay south of the harbor (Figure 4-4); and -8,600 m^3 at the eastern portion of the impact area east of the reef (Figure 4-6).

50. Annual volume changes corresponding to accretion (+) and erosion (-) data from 1999-2013 are summarized in Elwany (2000, Table 4-1), reproduced below (with edits) as Table 1.

51. The table shows total accretion of +260 m^3/yr along the west breakwater, +225 m^3/yr inside the harbor, and +968 m^3/yr deposition on the adjacent reef to the east. The total deposition of 1,453 m^3/yr is about 63%, or a substantial fraction of the average sediment transport rate of 2,300 m^3/yr, with over 40% ending up on the reef. The table also shows -611 m^3/yr erosion loss (bold) along the eastern section of the impact area between 1999 and 2013.

Table 1. Maalaea Study Region Sediment Volume Change 1999-2013

Location	Volume change (m^3/yr)
South of west breakwater	+260
Inside harbor and entrance channel	+225
Reef east of east breakwater	+968
Southwest of Maalaea Harbor	-105
Eastern half of impact area	**-611**

52. The Norcross-Nu'u et al. (2008) beach management plan for Maui was an important basis for advancing the Maui County General Plan (2010), Maui Island Plan (2012), and the State‘s Hawaii Ocean Resource Management Plan (2020).

53. The Maui County General Plan (2010), "… *is a long-term, comprehensive blueprint for the physical, economic, environmental development and cultural identity of the county."* [It] *"... establishes urban and rural growth areas that indicate where development is intended and will be supported. Growth areas will provide for less costly services, reduced commuting, protection of community character and the preservation of agriculture, open space and cultural and natural resources. The plan comprises goals, policies, programs and actions which are based on an assessment of current and future needs and available resources. The plan becomes the principal tool for the County and its citizens to use when evaluating public and private projects on Maui island and their impacts on land use, the economy, environment, infrastructure, and cultural resources."* This plan provides guidance through 2030.

54. The Maui Island Plan (2012), "…*provides direction for future growth, the economy, and social and environmental decisions on the island through 2030. The Maui Island Plan establishes a vision, founded on core values that break down into goals, objectives, policies,*

and actions. In addition, the Plan incorporates lessons from the past. The Maui Island Plan is the second component of the decennial General Plan update."

55. The Hawaii Ocean Resource Management Plan (ORMP 2020), *"is a statewide plan that seeks to resolve coastal problems and issues that are not adequately addressed by existing laws and rules. The plan is a requirement under Hawaii Revised Statutes §205A-62(1) and is a main component of the CZM* [Coastal Zone Management] *Program. Unlike plans that are created and administered by a single entity, the ORMP is unique in its collaborative implementation through the CZM Network, which includes Federal, State, County, and community representation."*

56. Consideration of the aforementioned planning documents and their policy implications and action requirements that may affect property owners in the impact area seeking solutions to the erosion problems created by Maalaea Harbor, are well beyond the scope of this evaluation.

57. However, the Norcross-Nu'u et al. (2008) beach management plan for Maui developed a number of recommendations that are relevant and may be useful to this endeavor. These are summarized and incorporated into this evaluation following the conclusions listed below.

CONCLUSIONS

58. Maui's geological setting results in relatively sparse beach sand supply along most of its coast. Nevertheless, a continuous sand beach existed along Maalaea Bay before about 1950, including the impact area.

59. Southern Maui is sheltered from large wave exposure compared to its northern coast, resulting in relatively low wave-induced potential sediment transport. Together with natural reefs, this reduces the ability of wave action to more evenly distribute sediment along beaches.

60. The geological setting and modest wave climate make beaches along Maalaea Bay highly sensitive to interruptions in sediment supply and transport.

61. Before construction of Maalaea Harbor, sediment was able to move eastward along the shoreline behind the reef fronting the western portion of the impact area. There was a continuous ribbon of beach sand along the entire reach (Figure 2).

62. The west and east breakwaters at Maalaea Harbor, constructed beginning about 1952, shifted the eastward transport of sediment offshore (Figures 2 and 3), radically reducing availability to the impact area shoreline by changing deposition patterns in the following ways:

    - The west breakwater accumulates a portion of the sediment along its southern face that previously moved eastward along the natural shoreline;

- Additional sediment, also previously transported eastward along the shoreline, is now funneled into the south-facing harbor entrance where it accumulates in the channel, the harbor, and along the west side of the east breakwater;

- Sediment previously also available to the shoreline is now redirected onto the reef east of the harbor. This has presumably enhanced degradation of the reef along with other factors including poor water quality from excessive nutrient runoff (Hawaii Division of Aquatic Resources 2014; Sparks et al. 2015).

63. The harbor and its jetties work to divert sediment offshore, trap it along the west jetty and in the harbor, and divert large amounts onto the eastern reef. In total, these effects have deprived the impact area shoreline of scarce sediment causing catastrophic beach erosion.

64. The erosion made necessary construction of seawalls and revetments along the impact area to protect existing developments. Without the harbor, construction of these coastal defenses would certainly have been delayed, or perhaps avoided.

65. Offshore shift of the littoral sediment transport accounts for the sediment accumulations south of the west breakwater and over the eastern reef, and the near-total loss of beach sand along most of the impact area. Observed movement of sediment back toward shore east of the reef at the eastern end of the impact area is consistent with this deduction (Figure 3).

66. These findings lead to the conclusion that the functional design and placement of Maalaea Harbor is deficient in at least four ways:

- The harbor is not adequate for its primary purpose, which is to provide sheltered berthing and moorage for small craft. This is evidenced by the unacceptably high waves that penetrate the south-facing entrance, and repeated re-design efforts to address the problem;

- The harbor breakwaters have interrupted the relatively meager longshore sediment transport by deflecting it offshore, thereby robbing the downcoast impact area of its major supply;

- The harbor traps a significant volume of sediment along the west breakwater and in its entrance and interior that is then also unavailable to the beach. Presumably, sediment in the harbor is available for regular bypassing to aid in replenishing at least some of the losses at the impact area;

- Offshore transport diversion greatly increases the amount of sediment available for wave action to push up onto the reef east of the harbor, as evidenced by the substantial volume accumulation there between 1999 and 2013.

67. Maalaea Harbor re-design proposals (USACE 1992; Cialone et al. 1992; Hadley et al. 1998) focus on reducing harbor wave height and surge by altering the jetties so the entrance would face east or west. Either option would likely make the sediment transport interruption worse if it reduces the amount trapped in the harbor, thus making it less accessible for bypassing.

RECOMMENDATIONS

68. Presumably, the coastal oceanographic findings and conclusions above have better defined the causes of erosion at the Maalaea Beach impact area. Identifying and implementing solutions will require extensive cooperation to produce a “sediment management plan” to restore, or at least increase, sand supply to the impact area. A number of actions can begin this process. This will involve costs, including engineering studies, mechanical or hydraulic dredging, transport, and redeposition at beach receiver site(s). Projects will have to be coordinated with harbor authorities and permitting agencies.

69. Data and anecdotal evidence suggest that substantial quantities of sand have accumulated inside the harbor (Elwany 2020; Peter Cannon, personal communication). Restoring at least some sediment to the impact area beach through “bypassing” material trapped in the harbor by physically moving it onto the beach periodically may be fairly straightforward as part of regular harbor maintenance.

70. According to Elwany (2020) an average of 225 m^3/yr was trapped in the harbor, with 260 m^3/yr deposited along the west breakwater, and 968 m^3/yr winding up on the adjacent reef over the 20 years from 1993-2013 (Table 1). However, over the entire 70-year life of the harbor, sufficient sand likely accumulated to at least partially “restore” the impact area beach.

71. First, detailed harbor sediment deposition volume and typing (sand or fine) surveys should be conducted to determine the volume of sand in the harbor available to restore and maintain the impact area beach.

72. If sufficient sand is found in the harbor, a one-time dredging should be considered to provide sand to the impact area. This would offer mutual public and private benefits by deepening the harbor, thus reducing wave shoaling, and providing property protection, public access, and mitigation for the visual impacts of the coastal armoring.

73. In addition, a qualified coastal engineer should evaluate the feasibility of removing rock from the shoreward end of the east breakwater to create an “engineered gap” enabling natural wave action to move sand onto the adjacent impact area beach. Concurrently, this might facilitate mechanical or hydraulic movement of sand out of the harbor and onto the beach.

74. Second, a management plan should determine feasibility of retrieving sediment accumulated south of the west breakwater and also bypassing it to the impact area. This likewise incurs expenses and requires engaging a competent coastal engineer with local knowledge and experience in sediment management, along with harbor authorities, and permitting agencies.

75. Third, a management plan should examine the feasibility of recovering sediment deposited on the reef and restoring it to the beach. This may be the most difficult part of such a plan, and may not be feasible, which would be unfortunate, considering that up to 70% of the impact area sand loss is likely trapped on the reef. However, sediment removal from the reef could enhance other efforts, such as water quality improvements in Maalaea Bay, to restore coral growth. This is crucial for long-term sand supply, which originates largely from coral.

76. Fourth, all parties, including the State of Hawaii, should support the efforts of the Maui County government, the Maalaea Village Association, and the residents of Maalaea to improve the health of Maalaea Bay. The Bay is designated a 303D impaired body of water by the Environmental Protection Agency. The Hawaii Division of Aquatic Resources (2014) estimated that only 8% of the original Maalaea Bay reef remained. A healthy coral reef is the first line of defense against shoreline erosion. No coral means that no new sand is created. Restoring the reef to a healthy condition is a critically important factor in mitigating beach erosion.

77. Fifth, good public agency management practice encourages action to address all major factors impairing the health of Maalaea Bay, especially erosion and loss of coral. Actions should include the replacement of all community injection well wastewater systems with a modern, regional wastewater treatment plant to stop the dumping of pathogens and nutrients into the nearshore. Furthermore, urgent intervention is needed to reduce fine sediment runoff, another major destroyer of coral, from the lands above Maalaea Bay where road construction and other projects have diverted upland streams away from the Maalaea mudflats natural filtration system that slowed runoff allowing sediments to settle. Rainwater now runs directly into the bay resulting in major coastal "brown water" events after every downpour.

78. Finally, it likely will become increasingly important to repair, rebuild, and/or upgrade existing coastal defense systems, including revetments and seawalls. New types of structures such as sand retention groins that have proven effective on many coasts, including Hawaii, may also be required. This is undesirable for many reasons including cost, but is highly likely to eventually become necessary to avoid more frequent and intense flooding and structure damage. Proactive management by affected property owners can facilitate this admittedly controversial, difficult, and costly process, as outlined below.

79. If reef sand sediment recovery is indeed infeasible, other sources of replacement material should be established in the sediment management plan, along with funding sources for obtaining, moving, and placing this material.

80. Maui County in September 2021 began a year-long "Maalaea Village Coastal Resilience and Erosion Plan" study encompassing Maalaea Harbor and adjacent beaches. This work, "*Seeks a proactive and holistic approach to manage worsening coastal erosion at Maalaea Bay Beach by exploring the feasibility of coastal resilience strategies, including erosion mitigation options and relocation of threatened structures. The project area spans from Maalaea Harbor to Haycraft Park."*

81. Reporting by Maui Now (2021) suggests that the study will, "*Explore managed retreat options, contractors will be developing an analysis of the planning steps involved in the relocation of buildings and infrastructure."* Of course, this deserves close attention to determine both any opportunities for cooperation, and the long-term impact of the findings and resulting policy on property owners.

82. Additionally, more general recommendations below are substantially based on Norcross-Nu'u et al. (2008), and begin with developing an individual management plan for the impact area to address shoreline change, and manage coastal erosion and other concerns consistently.

83. Consider and develop viable plans, including permitting, engineering, and financing, for beach sand nourishment in the impact area beyond recovering as much sand as possible from harbor and reef bypassing sources.

84. Review available guidelines for shoreline protection measures, and the environmental concerns and permitting requirements of each.

85. Become familiar with, and consider and plan for current and future MSLR, which will become the leading driver of beach loss world-wide, likely by mid- to late-century.

86. Consider "proactive" management in the conceptual and planning stages for any future coastal improvements or re-development considering coastal processes and hazards, and the potential impacts of development on the beach and other nearshore areas. This step will almost certainly be required in any coastal permit application process.

87. Consider a Beach Management District on the scale of the impact area to provide a mechanism for multi-property erosion mitigation projects. Such districts streamline permitting for shore protection and beach nourishment, and facilitate cost sharing among property owners and public agencies (e.g. Hwang and Fletcher 1992). In California, such entities are known as Geologic Hazard Abatement Districts (GHAD) enabled by the state legislature in 1979. Similar authorities may be available in Hawaii.

88. Condominiums and resorts at Napili and Kapalua Bay have created a foundation for tax-deductible donations to support sand replenishment. Private homeowners in Spreckelsville have proposed establishing a not-for-profit for the same purpose.

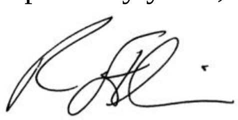
89. Encourage public officials to promote public awareness and education concerning coastal hazards, especially erosion and future MSLR complications.

90. Encourage and promote research to continue increasing our knowledge and understanding of coastal processes and the impacts of climate change on present and future beach conditions.

91. Encourage development of funding mechanisms by public agencies for managing coastal erosion, especially beach loss, including beach nourishment, and ultimately acquisition of coastal lands as protecting developments becomes increasingly difficult and expensive.

Thank you for the opportunity to evaluate the erosion at Maalaea Beach. Please contact me by email (dr.reinhardflick@gmail.com) or phone (858-945-4262) if you have questions or require additional information.

Respectfully yours,



Reinhard E. Flick, Ph.D.
Consulting Coastal Oceanographer
Coastal Environments, Inc.

2166 Avenida de la Playa, Suite E ◆ La Jolla, CA 92037 ◆ Tel: (858) 459-0008 ◆ Fax: (858) 459-0107

REFERENCES

Fletcher, C.H., B.M. Romine, A.S. Genz, M.M. Barbee, M. Dyer, T.R. Anderson, S.C. Lim, S. Vitousek, C. Bochicchio, and B.M. Richmond, 2012. *National Assessment of Shoreline Change: Historical Shoreline Change in the Hawaiian Islands*, U.S. Geological Survey, Open-File Report 2011-1051, 67 pp.

Hawaii Division of Aquatic Resources, 2014. Hawaii Coral Reef Initiative, 2 pp. https://dlnr.hawaii.gov/dar/files/2014/04/MauiReefDeclines.pdf.

Hwang, D.J. and C.H. Fletcher, 1992. *Beach Management Plan with Beach Management Districts*, Report submitted to Hawaii Office of State Planning, Coastal Zone Management Program, Honolulu, 192 pp. https://www.govinfo.gov/content/pkg/CZIC-gc57-2-h35-1992/html/CZIC-gc57-2-h35-1992.htm.

Inman, D.L. and B.M. Brush, 1973. The Coastal Challenge, *Science*, 181(4094), 20-32.

Jaykim Engineers, D.L. Inman, R.T. Guza, D.W. Skelly, and T.E. White, 1986. *Southern California Coastal Processes Data Summary, Coast of California Storm and Tidal Waves Study*, Report 86-1, Los Angeles, CA: U.S. Army Corps of Engineers, Los Angeles District, 572 pp.

Joerger, P.K. and M.W. Kaschko, 1979. *A Cultural History Overview of the Kahoma Stream Flood Control Project, Lahaina, Maui and the Maalaea Small Boat Harbor Project, Maalaea, Maui, Hawaii*, Report prepared for Corps of Engineers, Department of the Army by Hawaii Marine Research, Inc., 33 pp.

Maui County General Plan, 2010. County of Maui, 2030 General Plan, Countywide Policy Plan, Report, County of Maui, 108 pp. https://www.mauicounty.gov/420/Countywide-Policy-Plan.

Maui Island Plan, 2012. *Maui Island Plan, General Plan 2030*, Report prepared by County of Maui, Planning Department, Long Range Division, 513 pp. https://www.mauicounty.gov/1503/Maui-Island-Plan.

Maui Now, 2021. *Maui News, Maui County Begins Coastal Resilience Planning for Maalaea*, https://mauinow.com/2021/09/18/maui-county-begins-coastal-resilience-planning-for-maalaea/.

Moffat & Nichol and EA/HHF Joint Venture, 2011. *Hawaii Regional Sediment Management, Kahului and Kihei Regions, Final Report, Geomorphology, Coastal Processes, Shoreline*

Change, and Potential RSM Projects, Prepared for U.S. Army Corps of Engineers and State of Hawaii, 129 pp.

Norcross-Nu'u, Z., C.E. Fletcher, and T. Abbott, 2008. *Beach Management Plan For Maui, Second Edition,* Report, University of Hawaii, Sea Grant College Program, 47 pp.

Patsch, K. and G. Griggs, 2008. A sand budget for the Santa Barbara Littoral Cell, California, *Mar. Geology,* 252, 50-61.

Romine B.M., C.H. Fletcher, M.M. Barbee, T.R. Anderson, and L.N. Frazer, 2013. Are beach erosion rates and sea level rise related in Hawaii?, *Glob. Planet Change,* 108, 149–157.

Sea Engineering, 2012. *Coastal Engineering Report, Milowai Condominiums, Maalaea, Maui, Hawaii,* Report prepared for Milowai Association of Apartment Owners, 44 pp.

Shepard, F.P., G.A. Macdonald, and D.C. Cox, 1949. *The Tsunami of April 1, 1946*, Report and Supplemental Plates, Bull. Scripps Institution of Oceanography, 5(6), 391-528.

Sparks, R., K. Stone, D. White, M. Ross, and I. Williams, 2015. *Maui and Lanai Monitoring Report,* Hawaii Department of Land and Natural Resources, Division of Aquatic Resources, 42 pp. https://dlnr.hawaii.gov/dar/files/2016/07/Maui_Mon_Report.pdf.

SSFM International, 2018. *2018 Update: Maui Inland Sand Resource Quantification Study*, Report prepared for County of Maui, Department of Public Works, Engineering Division, 32 pp.

University of Hawaii, 2010. *Maalaea Harbor, Maui, Hawaii, Historical Shoreline Position and Change Rate Map*, Coastal Geology Group, School of Ocean and Earth Science and Technology, https://www.soest.hawaii.edu/coasts/index.php/resources/, and: https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&cad=rja&uact=8&ved=2ahUKEwj0uIC9uer3AhW4IUQIHcKiBY0QFnoECAcQAQ&url=http%3A%2F%2Frsm.usace.army.mil%2FHawaii%2Fdocuments%2Fkihei%2Fmaalaea_shoreline_change.pdf&usg=AOvVaw0nBz54pd4-Mm9p9hRmm00A.

USACE, 1965. *History of the Honolulu Engineer District, 1905-1965,* U.S. Army Corps of Engineers, Honolulu District, 165 pp.

USACE, 1984. *Shore Protection Manual*, Washington, DC: Department of the Army, U.S. Army Corps of Engineers, Coastal Engineering Research Center, Vol. I, 652 pp.

USACE, 1992. *Draft Supplemental Environmental Impact Statement for Maalaea Harbor for Light-Draft Vessels Maui, Hawaii*, Report prepared by U.S. Army Engineer District, Honolulu, HI for State of Hawaii, Department of Transportation, 394 pp.

USACE, 2011. *Hawaii Regional Sediment Management Kahului and Kihei Regions, Final Report: Geomorphology, Coastal Processes, Shoreline Change, and Potential RSM Projects, Maui*, Prepared by Moffat & Nichol and EA/HHF, 129 pp.

Vencore Labs, 2017. *W912HZ-14-C-0026, Information Dredging, Task 1: Historic Information, Dredging, Chief's Report Processing Design and Results, Task 2, Deliverable: Option 2 Final Report, Document Number: W912HZ-14-C-0026-Extraction-201709, Document Date 29 September 2017*, Prepared for Army Corp of Engineers by: Vencore Labs, 66 pp. https://dots.el.erdc.dren.mil/dig/ChiefsReportsFinal/ACE_Dredging_Final_Report_20170929.pdf.

Watts, G.M., 1953. *Study of sand movement at South Lake Worth Inlet, Florida*, Tech. Mem. No. 42, Washington, DC: U.S. Army Beach Erosion Board, 24 pp.

FIGURES

Figure 1. Overview of Kihei Region coastal system, south coast of Maui. Maalaea Harbor and adjacent eastern Maalaea Bay Beach, upper center (USACE 2011).

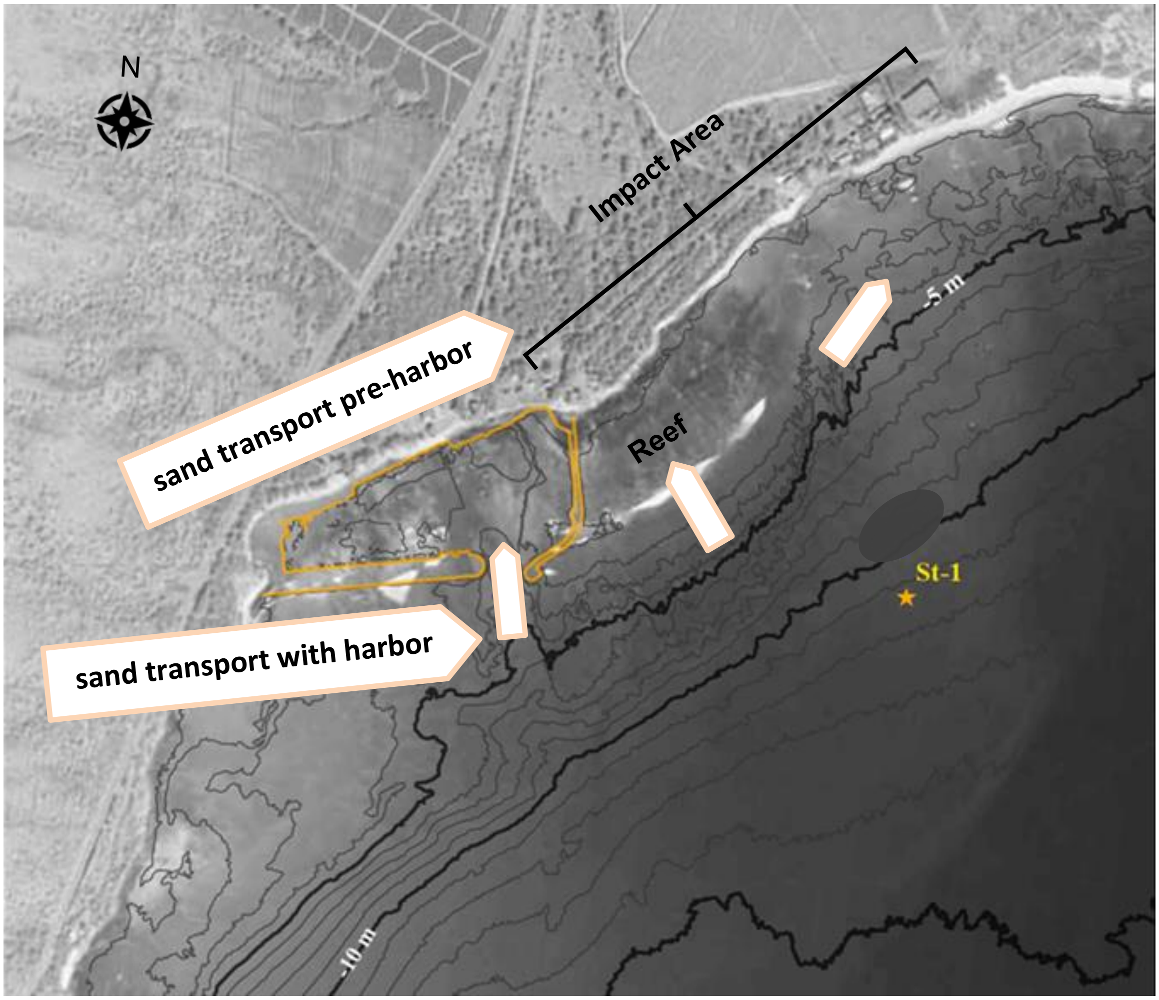


Figure 2. 1951 air photo (courtesy Elwany 2020) suggests presence of white beach sand along entire reach including impact area before Maalaea Harbor construction (yellow outline). Sediment transport before harbor construction was along natural shore, but was shifted offshore by the breakwaters (large arrows). Small arrows suggest sand paths into harbor, onto reef, and bypassing impact area (see Figure 5).

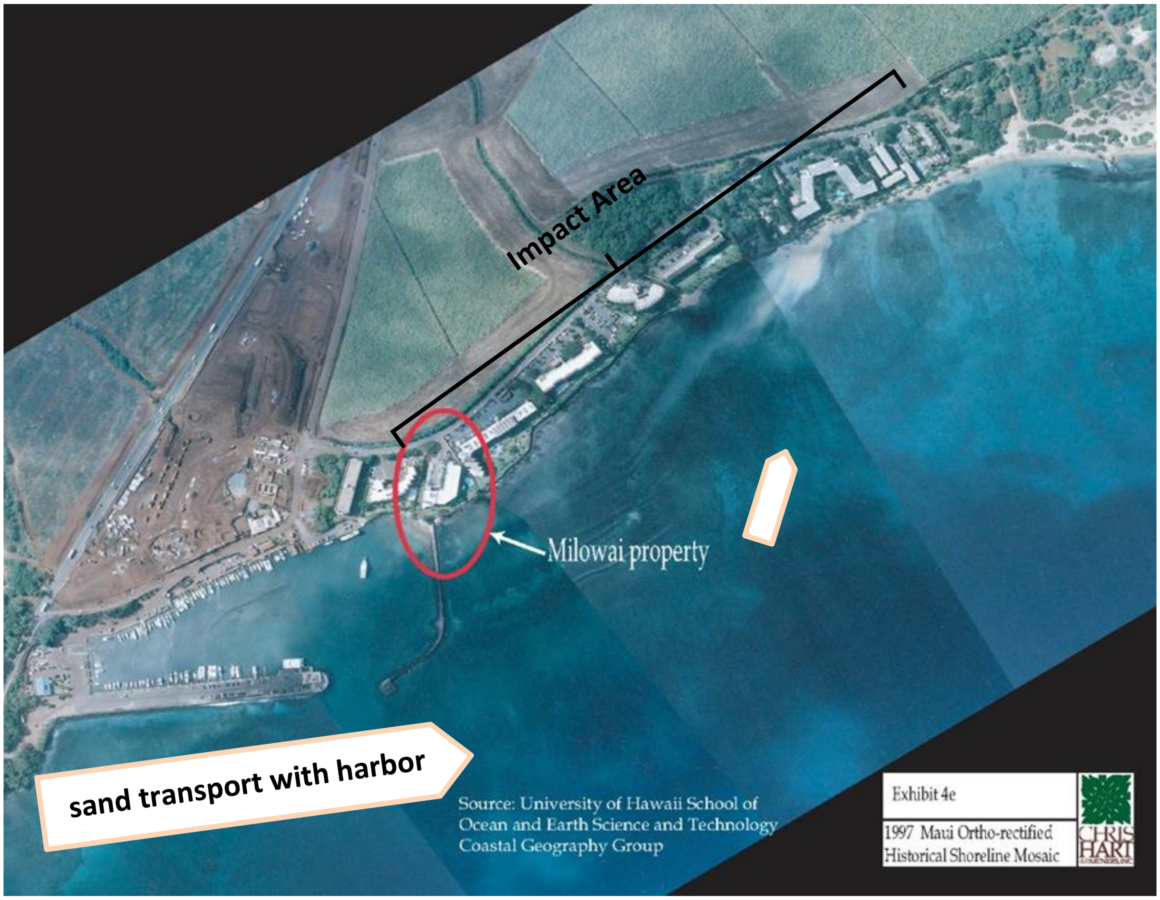


Figure 3. Maalaea Harbor with impact area, 1997 air photo (County of Maui 2014; Chris Hart & Partners 2014). West breakwater diverts sediment transport offshore of natural shoreline. Note sand plume extending from reef east of harbor attaching to shoreline at horse-shoe shaped Kanai A Nalu.

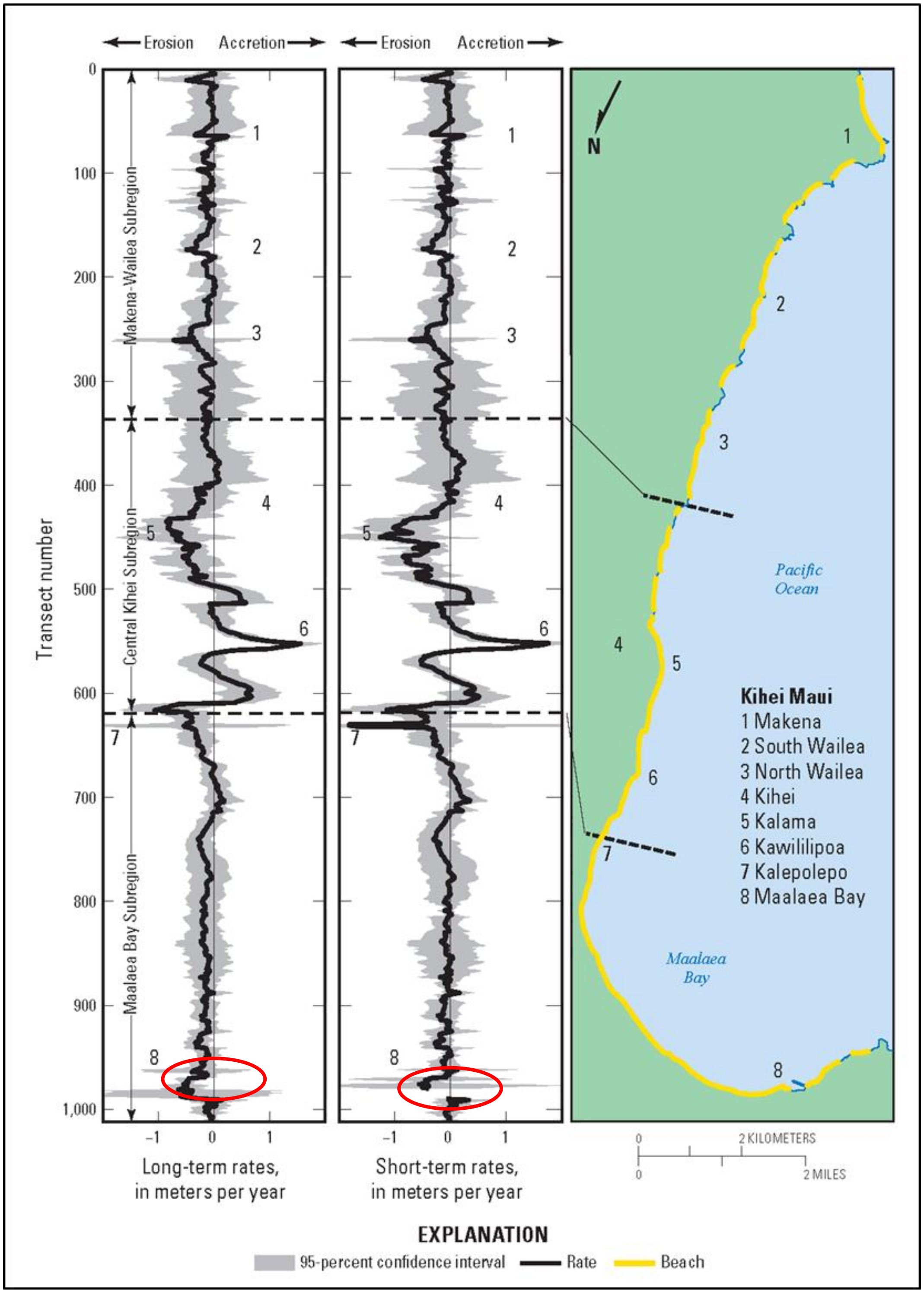


Figure 4. Kihei region historical shoreline erosion rates from Fletcher et al. (2012, Figure 35). Long-term rates ca. 1900-2007; short-term from 1940's. Impact area in red ovals (Transects 950-990).

Figure 5. Maalaea Harbor 2009 air view with jetty configurations and southerly approaching wave patterns (USACE 2011). Note wave action covering eastern half of harbor made unsuitable for moorage and berthing. Breakers along west jetties and reef to east show shoreline, surf zone, and related sediment transport moved offshore.

QUALIFICATIONS – RESUME

REINHARD E. FLICK, Ph.D.
Consulting Coastal Oceanographer
dr.reinhardflick@gmail.com
(858) 945-4262

Education

- Ph.D. Oceanography, Scripps Institution of Oceanography, University of California San Diego, 1978
- B.S. Physics, Cooper Union for the Advancement of Science and Art, New York, 1970

Positions

- California Department of Parks and Recreation, Staff Oceanographer, 2013-2020
- California Department of Boating and Waterways, Staff Oceanographer, 1984-2013
- Scripps Institution of Oceanography, Research Associate, 1984-present
- TerraCosta Consulting Group, Principal and Consulting Oceanographer, 2006-2021
- Scripps Institution of Oceanography, Assistant Research Oceanographer & Academic Administrator, 1978-1984
- Scripps Institution of Oceanography, University of California San Diego, Research Assistant & Graduate Student, 1970-1977
- Mid Ocean Dynamics Experiment (MODE) Summer Institute, Boulder, CO, Fellow, summer 1972
- R.V. Thomas Washington, Pacific Ocean Kuroshio Cruise, Scripps Institution of Oceanography, summer 1971
- R.V. Chain Cruise 99, Indian Ocean, Woods Hole Oceanographic Institution, summer 1970
- Woods Hole Oceanographic Institution, Woods Hole, MA, Summer Fellow, 1969
- United Nations Headquarters, NY, Statistical Clerk, summers 1967, 1968

Experience

- Academic research, lecturing, administration, contract management, consultant and expert witness, and public service in nearshore and beach processes, including waves, tides, sea level, and coastal erosion, and storm damage
- Published over 80 scientific works, 100 technical reports and abstracts, given scores of presentations
- Yesterday Camp, Antarctica - Response of the Ross Ice Shelf to Wave Induced Vibrations, 2014
- SERDP-funded Navy study, *A Methodology for Assessing the Impact of Sea Level Rise on Representative Military Installations on the Southwestern United States,* 2009-2013
- Executive Editor, *Shore & Beach*, American Shore and Beach Preservation Association, 2004-2010
- National Academy of Sciences Committee, *Restoration and Protection of Coastal Louisiana*, 2005
- California Shore and Beach Preservation Association, Director, 1984-present, President, 1991-1996
- Cabrillo National Monument Foundation, Trustee 1997-2003

Awards and Memberships

- CA State Parks Director’s (Inaugural) Adaptation Award, 2018
- Joe Johnson Outstanding Service Award, California Shore and Beach Preservation Association, 2016
- Morrough P. O'Brien Award, American Shore and Beach Preservation Association, 2002
- The Oceanography Society, Life Member
- American Geophysical Union
- American Shore and Beach Preservation Association

Personal

Born Freiburg, West Germany; speaks German fluently; immigrated to New York City 1951; resides in Escondido, CA; enjoys sailing (US Coast Guard Master Credential, volunteer Maritime Museum San Diego), classic British cars, stamp collecting, and ham radio (amateur license K6REF).

QUALIFICATIONS – PUBLICATIONS

(1) Sanford, T.B. and R.E. Flick, 1975. On the Relationship Between Transport and Motional Electric Potentials in Broad, Shallow Currents, J. Mar. Res., 33(1).

(2) Inman, D.L., C.E. Nordstrom and R.E. Flick, 1976. Currents in Submarine Canyons: an Air-Sea-Land Interaction, Ann. Rev. Fluid Mech., 8.

(3) Flick, R.E., R.L. Lowe, M.H. Freilich and J.C. Boylls, 1979. Coastal and Laboratory Wavestaff System, Proc. Oceans '79, Inst. Electrical and Electronic Eng. and Mar. Tech. Soc.

(4) Flick, R.E. and R.T. Guza, 1980. Paddle Generated Waves in Laboratory Channels, J. Waterway, Port, Coastal and Ocean Div., Amer. Soc. Civil Eng., 106(ww1).

(5) Flick, R.E. and M.E. Parker, 1980. Geomagnetic Induction to Measure Strong Nearshore Flow Velocities, Proc. Oceans '80, Inst. Electrical and Electronic Eng.

(6) Flick, R.E., D.L. Inman and R.T. Guza, 1980. Two-Dimensional Surf Beat, Proc. 17th Int. Conf. Coastal Eng., Amer. Soc. Civil Eng., 1.

(7) Flick, R.E., R.T. Guza and D.L. Inman, 1981. Elevation and Velocity Measurements of Laboratory Shoaling Waves, J. Geophys. Res., 86(C5).

(8) Waldorf, B.W. and R.E. Flick, 1982. Monitoring Beach Erosion Control Alternatives - Southern California Examples, Proc. Oceans '82, Inst. Electrical and Electronic Eng. and Mar. Tech. Society.

(9) Flick, R.E., and B.W. Waldorf, 1984. Performance Documentation of the Longard Tube at Del Mar, California, 1980-1983, Coastal Eng., 8.

(10) Flick, R.E. and D.R. Cayan, 1984. Extreme Sea Levels on the Coast of California, Proc. 19th Int. Conf. Coastal Eng., Amer. Soc. Civil Eng.

(11) Zetler, B.D. and R.E. Flick, 1985. Predicted Extreme High Tides for California, 1983-2000, J. Waterway Port, Coastal and Ocean Eng., Amer. Soc. Civil Eng., 111(4).

(12) Zetler, B.D. and R.E. Flick, 1985. Predicted Extreme High Tides for Mixed-Tide Regimes, J. Phys. Oceanog., 15(3).

(13) Flick, R.E., 1986. A Review of Conditions Associated with High Sea Levels in Southern California, Sci. Total Env., 55.

(14) Walker, J.R., A. Bertolotti, R.E. Flick and C.R. Feldmeth, 1988. Hydraulic Aspects of Wetland Design, Proc. 21st Int. Conf. Coastal Eng., Amer. Soc. Civil Eng., III.

(15) Flick, R.E. and A. Badan-Dangon, 1989. Coastal Sea Levels During the January 1988 Storm off the Californias, Shore & Beach, 57(4).

(16) Armstrong, G. and R.E. Flick, 1989. Storm Damage Assessment for the January 1988 Storm Along the Southern California Shoreline, Shore & Beach, 57(4).

(17) Flick, R.E. and R.A. George, 1991. Turbulence Scales in the Surf and Swash, Proc. 22nd Int. Conf. Coastal Eng., Amer. Soc. Civil Eng.

(18) Flick, R.E., G.A. Armstrong and E.H. Sterrett, 1991. Shoreline Erosion Assessment and Atlas of the San Diego Region, The California Coastal Zone Experience, Coastlines of the World Series, Coastal Zone '91, Amer. Soc. Civil Eng.

(19) Harker, A.H. and R.E. Flick, 1991. Beach and Cliff Erosion Processes at Solana Beach, California, 1984-1990, Coastal Zone '91, Proc. Seventh Symp. Coastal and Ocean Mgmt., Amer. Soc. Civil Eng.

(20) Flick, R.E., 1991. Joint Occurrence of High Tide and Storm Surge in California, Proc. World Marina '91, Amer. Soc. Civil Eng.

(21) Flick, R.E., D.D. McGehee, R.J. Seymour and R.T Guza, 1993. The Coastal Data Information Program, a Successful Federal, State and University Cooperation, Coastal Engineering Considerations in Coastal Zone Management, Coastlines of the World Series, Coastal Zone '93, Amer. Soc. Civil Eng.v

(22) Flick, R.E., 1993. The Myth and Reality of Southern California Beaches, Shore & Beach, 61(3).

(23) George, R.A., R.E. Flick and R.T. Guza, 1994. Observations of Turbulence in the Surf Zone, J. Geophys. Res., 99(C1).

(24) Flick, R.E., 1994. Shoreline Erosion Assessment and Atlas of the San Diego Region, 2 Vols., Editor, Sacramento CA: California Department of Boating and Waterways and San Diego Association of Governments.

(25) Elwany, M.H.S., W.C. O'Reilly, R.T. Guza and R.E. Flick, 1995. Effects of Southern California Kelp Beds on Waves, J. Waterway, Port, Coastal and Ocean Eng., Amer. Soc. Civil Eng., 121(2), 143-150.Elwany, M.H.S. and R.E. Flick, 1996, Relationship Between Kelp Beds and Beach Width in Southern California, J. Waterway, Port, Coastal and Ocean Eng., Amer. Soc. Civil Eng., 122(1).

(26) Flick, R.E., 1996. The Shoreline of San Diego, Geology and Natural Resources of Coastal San Diego County, California, Guidebook, 1996 Annual Field Trip, T. Munasinghe and P. Rosenberg, Eds., San Diego Association of Geologists.

(27) Flick, R.E., 1996. Special Issue in Honor of Professor Douglas L. Inman, Guest Editorial, Shore & Beach, 64(3), 2.

(28) Flick, R.E., 1996. Useful but elusive, coastal sand is as good as gold, San Diego Union, Oceans Watch Column, 13 Nov 1996, E-2.

(29) Flick, R.E., 1997. Tide, World Book Encyclopedia, World Book Publishing, Chicago, IL.

(30) Flick, R.E., and M.H.S. Elwany, 1997. Tide and Beach Fluctuations and the Mean High Water Line, Proc. California and the World Ocean.

(31) Elwany, M.H.S., A.B. Thum, S. Aijaz, J.M. Boland and R.E. Flick 1997. A Strategy to Maintain Tidal Flushing in Small Coastal Lagoons, Proc. California and the World Ocean.

(32) Elwany, M.H.S., R.E. Flick, and S. Aijaz, 1998. Opening and Closure of a Marginal Southern California Lagoon Inlet, Estuaries 21(2).

(33) Flick, R.E., 1998. Comparison of California Tides, Storm Surges, and Sea Level During the El Niño Winters of 1982-83 and 1997-98, Shore & Beach, 66(3).

(34) Bromirski, P.D., R.E. Flick, and N.E. Graham, 1999. Ocean Wave Height Determined from Inland Seismometer Data: Implications for Investigating Wave Climate Changes in the NE Pacific, J. Geophys. Res., 104(C9.

(35) Flick, R.E., 2000. Time-of-Day of Peak Tides in a Mixed-Tide Regime, Shore & Beach, 68(4).

(36) Flick, R.E., 2002, 2001 Joe Johnson Award Presented by CSBPA to Pawka, Guza, and O'Reilly, Shore & Beach, 70(1).

(37) Elwany, M.H.S., R.E. Flick, and M.M Hamilton, 2003. Effect of a Small Southern California Lagoon Entrance on Adjacent Beaches, Estuaries 26(3).

(38) Bromirski, P.D., R.E. Flick, and D.R. Cayan, 2003. Storminess Variability along the California Coast: 1858 - 2000, J. Climate 16(6).

(39) Flick, R.E., J.F. Murray and L.C. Ewing, 2003. Trends in United States Tidal Datum Statistics and Tide Range, J. Waterway, Port, Coastal and Ocean Eng., Amer. Soc. Civil Eng., 129(4).

(40) Flick, R.E., 2004. The Climate and Oceanography of Point Loma, Chap. 2, The Natural Resources of Point Loma, Cabrillo National Monument Foundation, San Diego, CA.

(41) Elwany, M.H.S., R.E. Flick, M.M Hamilton, and R.S. Grove, 2005. Impacts of Short- and Long-Term Weather Events on Southern California Coastal Environments, Proc. California and the World Ocean '02, O.T. Magoon, H. Converse, B. Baird, and B. Jines, Eds.

(42) Flick, R.E., 2005. New-Book Review: Secrets of the Tide, Shore & Beach, 73(10).

(43) Bromirski, P.D., D.R. Cayan, and R.E. Flick, 2005. Wave Spectral Energy Variability in the Northeast Pacific, J. Geophys. Res., 110, C03005.

(44) Flick, R.E., 2005. Dana Point to the International Border, Chap. 20, Living with the Changing California Coast, G. Griggs, K. Patch, and L. Savoy, Eds., Univ. Calif. Press, Berkeley, CA.

(45) Dean, R., J. Benoit, S. Farber, R. E. Flick, M. Garcia, P. Goodwin, D. Huppert, J. Kelley, L. Levin, S. Nixon, J. M. Teal, and L. D. Wright, 2006. Drawing Louisiana's New Map: Addressing Land Loss in Coastal Louisiana, Report of the Committee on the Restoration and Protection of Coastal Louisiana, National Academy of Sciences, National Research Council, Washington D. C.

(46) Elwany, M.H.S. and R. E. Flick, 2006. A Comparison of Bardawil Lagoon and Venice Lagoon, Shore & Beach, 74(4).

(47) Cayan, D., P. Bromirski, K. Hayhoe, M. Tyree, M. Dettinger, and R.E. Flick, 2008. Climate Change Projections of Sea Level Extremes along the California Coast, Climatic Change, 87(S1).

(48) Bromirski, P.D. and R.E. Flick, 2008. Storm surge in the San Francisco Bay/Delta and nearby coastal locations, Shore & Beach, 76(3).

(49) Kendall, T. R., L. Dean, O. T. Magoon, L. A. Dengler, R.E. Flick, P. D. Bromirski, 2008. High Resolution Analysis of the 1960 Chilean Tsunami at Crescent City, California, Proc., Solutions to Coastal Disasters 2008: Tsunamis, Amer. Soc. Civil Eng., (313)16.

(50) Flick, R.E. and L.C. Ewing, 2009. Sand volume needs of Southern California beaches as a function of future sea level rise rates, Shore & Beach, 77(4).

(51) Young, A.P., R.T. Guza, R.E. Flick, W.C. O'Reilly, and R. Gutierrez, 2009. Rain, waves, and short-term evolution of composite seacliffs in southern California, Marine Geology, 267(1-2).

(52) Young, A. P., R.E. Flick, R. Gutierrez, and R.T. Guza, 2009. Comparison of short-term seacliff retreat measurement methods in Del Mar, California, Geomorphology, 112(3-4).

(53) Young, A.P., M.J. Olsen, N. Driscoll, R.E. Flick, R. Gutierrez, R.T. Guza, E. Johnstone, and F. Kuester, 2010. Comparison of Airborne and Terrestrial Lidar Estimates of Seacliff Erosion in Southern California, Photogram. Eng. and Rem. Sens. 76(4).

(54) Young, A.P., J.H. Raymond, J. Sorenson, E.A. Johnstone, N.W. Driscoll, R.E. Flick, and R.T., Guza, 2010. Coarse Sediment Yields from Seacliff Erosion in the Oceanside Littoral Cell, J. Coastal Res., 26(3).

(55) Ewing, L.C., R.E. Flick, and C.E. Synolakis, 2010. A review of coastal community vulnerabilities toward resilience benefits from disaster reduction measures, Environ. Hazards, 9.

(56) Flick, R.E., J.R. Wanetick, M. Hany S. Elwany, R.S. Grove, and B.W. Waldorf, 2010. Beach Changes from Construction of San Onofre Nuclear Generating Station 1964-1989, Shore & Beach, 78(4).

(57) Young, A.P., R.T. Guza, W.C. O'Reilly, R.E. Flick, and R. Gutierrez, 2011. Short-term retreat statistics of a slowly eroding coastal cliff, Natural Hazards & Earth Sys. Sci., 11(1).

(58) Bromirski, P.D., A.J. Miller, R.E. Flick, and G. Auad, 2011. Dynamical Suppression of Sea Level Rise Along the Pacific Coast of North America: Indications for Imminent Acceleration, J. Geophys. Res. C., 116(C7).

(59) Young, A.P, P.N. Adams, W.C. O'Reilly, R.E. Flick, and R.T. Guza, 2011. Coastal cliff ground motions from local ocean swell and infragravity waves in southern California, J. Geophys. Res. C., 116, C09007.

(60) Chadwick, D.B, R. Flick, J. Helly, T. Nishikawa, P.F. Wang, W. O'Reilly, R. Guza, P. Bromirski, A. Young, W. Crampton, B. Wild, and I. Canner, 2011. A Framework for Sea Level Rise Vulnerability Assessment for Southwest U.S. Military Installations, Proc. Oceans 11, Mar. Tech. Soc., Inst. Electrical and Electronic Eng., 110426-001.

(61) Young, A.P, P.N. Adams, W.C. O'Reilly, R.E. Flick, and R.T. Guza, 2012. Cross-shore decay of cliff top ground motions driven by local ocean swell and infragravity waves, J. Geophys. Res. C., 117(C6).

(62) Bromirski, P.D., A.J. Miller, and R.E. Flick, 2012. North Pacific Sea Level Trends, Eos Trans. AGU, 93(27).

(63) Flick, R.E., D.B. Chadwick, J. Briscoe, and K.C. Harper, 2012. "Flooding" versus "Inundation," Eos Trans. AGU, 93(38).

(64) Flick, R.E., K. Knuuti, and S.K. Gill, 2013. Matching Mean Sea Level Rise Projections to Local Elevation Datums, J. Waterway, Port, Coastal and Ocean Eng., Amer. Soc. Civil Eng, 139(2).

(65) Graham, N.E, D.R. Cayan, P.D. Bromirski, and R.E. Flick, 2013. Multi-model projections of 21st century North Pacific winter wave climate under the IPCC A2 scenario, Clim. Dyn., 40(5).

(66) Young, A.P, R.T. Guza, M.E. Dickson, W.C. O'Reilly, and R.E. Flick, 2013. Ground motions on rocky, cliffed, and sandy shorelines generated by ocean waves, J. Geophys. Res. C., 118(12).

(67) Young, A.P., R.E. Flick, W.C. O'Reilly, D.B. Chadwick, R.T. Guza, W.C. Crampton, and J.J. Helly, 2014. Estimating cliff retreat in southern California considering sea level rise using a sand balance approach, Mar. Geology, 348.

(68) Gallien, T.W., B.F. Sanders, and R.E. Flick, 2014. Urban coastal flood prediction: Integrating wave overtopping, flood defenses and drainage, Coastal Eng., 91(C).

(69) Flick, R., 2014. "O'Brien Award Winners: An Interview with Greg Woodell," Shore & Beach, 82(2).

(70) Gallien T.W, W.C. O'Reilly, R.E. Flick and R.T. Guza, 2015. Geometric properties of anthropogenic flood control berms on southern California beaches, Ocean & Coastal Mgmt., 105.

(71) Holmes-Dean, L., M.C. Hendershott, P.D. Bromirski, and R.E. Flick, 2015. Spectral Characteristics of the 1960 Tsunami at Crescent City, CA, Sci. Tsunami Hazards, J. Tsunami Soc. Int., 34(2).

(72) Rasmussen, L., P.D. Bromirski, A.J. Miller, D. Arcas, R.E. Flick, and M.C. Hendershott, 2015. Source Location Impact on Relative Tsunami Strength along the U.S. West Coast, J. Geophys. Res., Oceans, 120.

(73) Kochnower, D., S.M.W. Reddy, and R.E. Flick, 2015. Factors Influencing Local Decisions to use Habitats to Protect Coastal Communities from Hazards, Ocean & Coastal Mgmt., 116.

(74) Young, A.P., R.T. Guza, W.C. O'Reilly, O. Burvingt, and R.E. Flick, 2016. Observations of coastal cliff base waves, sand levels, and cliff top shaking, Earth Surf. Proc. Landforms, 41.

(75) Flick, R.E., 2016. California tides, sea level, and waves – Winter 2015-16, Shore & Beach, 84(2).

(76) Bromirski, P.D., R.E. Flick, and A.J. Miller, 2016. Storm Surge along the Pacific Coast of North America, J. Geophys. Res., Oceans, 121(11).

(77) Young, A.P., R.E. Flick, T.W. Gallien, S.N. Giddings, R.T. Guza, M. Harvey, L. Lenain, B.C. Ludka, W.K. Melville, and W.C. O'Reilly, 2018. Southern California coastal response to the 2015-2016 El Niño, J. Geophys. Res: Earth Surface, 123.

(78) Kalansky, J., D. Cayan, K. Barba, D. Boudreau, K. Brouwer, L. Walsh, T. Amabile, P. Batra, R. Clemesha, J. Crooks, L. Engeman, R.E. Flick, A. Gershunov, S. Giddings, K. Goodrich, M. Grim, K. Guirguis, J. Haas, J. Heys, R. Leiter, M. Jennings, B. Ludka, A. Pairis, D. Pierce, A. Tardy, A.D. Syphard, L. Wiborg, A. Wood, and A. Young, 2018. Climate Change Assessment for the San Diego Region, A Report for: California's Fourth Climate Change Assessment, State of California, Natural Resources Agency.

(79) Flick, R.E. and P.D. Bromirski, 2019. Ham Radio from McMurdo Station and Yesterday Camp, Ross Ice Shelf, Antarctica, QST, J. Amer. Radio Relay League, 103(2).

(80) Flick, R.E., 2019. Waves across the Pacific – and back again, In Memoriam to Walter Munk, Shore & Beach, 87(1).

(81) Ludka, B., R.T. Guza, W.C. O'Reilly, M. Merrifield, R.E. Flick, A. Bak, T. Hesser, R. Bucciarelli, C. Olfe, B. Woodward, W. Boyd, K. Smith, M. Okihiro, R. Grenzeback, L. Parry, and G. Boyd, 2019. Sixteen years of bathymetry and waves at San Diego beaches, Scientific Data, Nature Research, 6(161).

(82) Rasmussen, L.L, M.L. Carter, R.E. Flick, M. Hilbern, J.T. Fumo, B.D. Cornuelle, B.K. Gordon, L.F. Bargatze, R.L. Gordon, and J.A. McGowan, 2020. A Century of Southern California Coastal Ocean Temperature Measurements, Jour. Geophys. Res., 125(5).

(83) Fumo, J.T., M.L. Carter, R.E. Flick, L. Rasmussen, D.L. Rudnick, and S.F. Iacobellis, 2020. Contextualizing marine heat waves in the Southern California Bight under anthropogenic climate change, Jour. Geophys. Res, 125(5).

(84) Bromirski, P.D. and R.E. Flick, 2020. Near-coastal winter wave activity from microseisms, Geophys, Res. Lett., 47.

(85) Jay, D.A., A.T. Devlin, D. Idier, E.W. Prokocki, and R.E. Flick, 2022, Tides and Coastal Geomorphology: The Role of Non-Stationary Processes, in: Coastal and Submarine Geomorphology, in Shroder, J.J.F. (Ed.) Treatise on Geomorphology, Vol. 8, Elsevier, Academic Press.

(86) Coward, E.K., K. Seech, M. Carter, R.E. Flick, and V.H. Grassian, in press. Of sea and smoke: Western US wildfires an unprecedented source of dissolved organic carbon to the coastal Pacific Ocean, Env. Sci. & Tech. Lett.

(87) Byrne, S., M.A. Merrifield, A. Gershunov, M.L. Carter, and R.E. Flick, submitted. Southern California winter precipitation variability revealed by 100-year ocean salinity record, in review, Nature Comm. Earth & Env.