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Kikiaola Light Draft Harbor, Island of Kauai; Hawaii: Regional Sediment Management (RSM)

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PURPOSE: This U.S. Army Corps of Engineers (USACE) Regional Sediment Management Technical Note (RSM-TN) reviews the initial sand bypassing effort conducted by the State of Hawaii, Division of Boating and Ocean Recreation (DOBOR), at Kikiaola Light Draft Harbor (KLDH). DOBOR, as the harbor's non-federal sponsor, implemented a sand bypass project in 2014 to help address the issues of sediment accretion up-drift of the harbor and erosion of the down-drift beaches. This RSM-TN reviews the results of the bypassing effort by performing a shoreline change analysis, reviewing beach profile monitoring reports, and quantifying recent harbor shoaling. The intent is to pave the way for beneficial use of dredged material at KLDH. Recommendations are made with respect to future sand bypass efforts and potential remediation for Kikiaola Gulch, which discharges fine grained terrestrial sediments into the harbor basin. The non-federal sponsor of this RSM study is the State of Hawaii, Department of Land and Natural Resources, Office of Conservation and Coastal Lands.

BACKGROUND: RSM refers to the effective use of littoral, estuarine, and riverine sediment resources in an environmentally sensitive and economically efficient manner. RSM changes the focus of engineering activities from the local or project-specific scale to a broader scale that is defined by natural sediment processes. A prime motivator for the implementation of RSM principles and practices is the potential for reducing construction, maintenance, and operation costs of federally authorized projects.

The RSM program was implemented at the U.S. Army Corps of Engineers (USACE) Honolulu District (POH) in 2004. The POH overarching RSM strategy is to investigate RSM opportunities along all regions in Hawaii. So far, POH has developed sediment budgets for several regions on Oahu, Kauai, and Maui. The Kekaha region on the west shore of Kauai was previously studied under the RSM program in 2010. The Kekaha region contains the federally authorized KLDH, the Waimea River Flood Control Project, and the Kekaha Beach Coastal Flood Risk Management Project.

Previous studies have found that sediment brought to the coast by the Waimea River is transported alongshore to Waimea Beach, Kikiaola Beach, and Oomano Point. However, KLDH intercepts the majority of the alongshore transport before it gets to Kikiaola Beach and Oomano Point. Sediment accumulates on Waimea Beach on the up-drift side of the harbor while Kikiaola Beach on the down-drift side continues to erode since the construction of KLDH in the 1960s. In addition, the harbor captures sediment within its entrance channel and basin, resulting in operation and maintenance dredging requirements. In 2014, DOBOR bypassed approximately

60,000 cubic yards (cy) of sediment around KLDH in compliance with the non-federal items of cooperation for the federally authorized navigation project implemented in 2005. DOBOR secured the services of The Edge of Kauai (TEOK) Investigations to conduct post-sand bypass monitoring. This study considers trends from the shoreline change analysis, results of sand bypass monitoring investigations, and channel shoaling rates. RSM recommendations are proposed to reduce down-drift erosion and channel shoaling as well as to realize beneficial use of dredged material from KLDH (Figure 1).

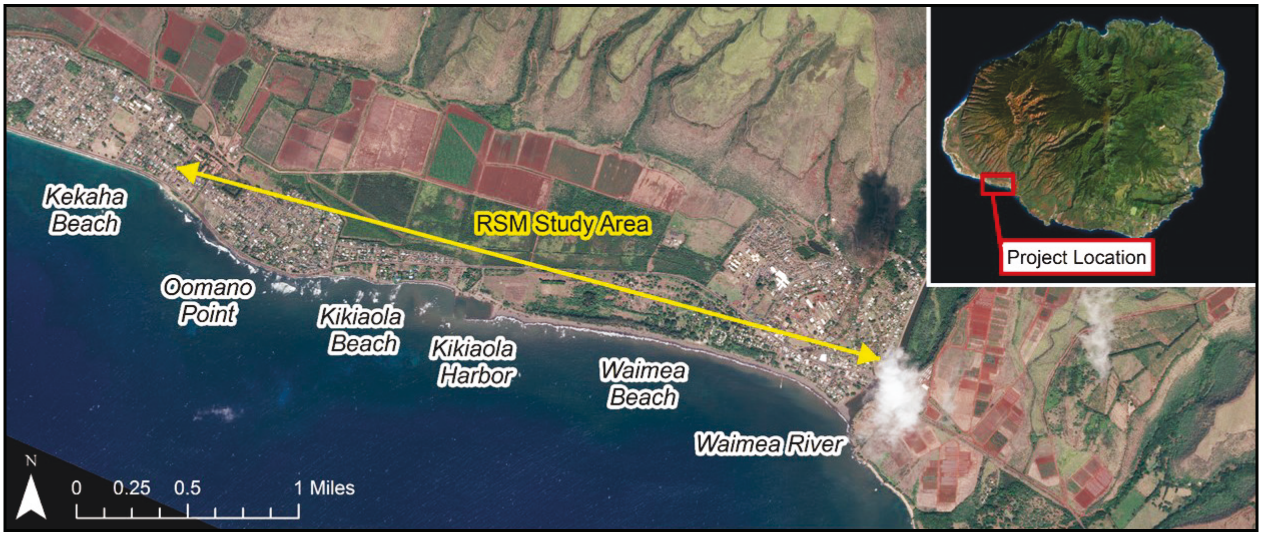

Figure 1. Overview map of the Kikiaola Light Boat Harbor study region.

REVIEW OF PROJECT HISTORY: The State of Hawaii initiated construction of KLDH on 23 March 1959. The navigation features included a harbor basin and 1,800 foot (ft)-long east breakwater to provide protection from waves approaching from the east, south, and west. In 1964, inner and outer stubs were added to the harbor's east breakwater to reduce wave surge within the harbor. In 1965, a 250 ft long groin was constructed adjacent to the boat ramp and loading dock. Other navigation features were also constructed at the harbor by the State prior to federal participation in the project.

Modifications to the KLDH were authorized under Section 101 of the River and Harbor Act of 13 August 1968 (Public Law 90-483). In September 2009, federally authorized modifications of the project were completed. The federal general navigation features at KLDH consist of a 725 ft long, 11 ft deep entrance channel varying in width from 105 to 205 ft, and a 320 ft long, 7 ft deep access channel varying in width from 70 to 105 ft (Figure 2). Federal harbor improvements also included removing 150 ft of the existing outer east stub breakwater, raising the crest elevation and flattening the seaward slope of approximately 764 ft of the existing east breakwater, removing and reconstructing the 71 ft long inner east breakwater, and modifying 245 ft of the seaward portion of the existing west breakwater (Figure 3). These navigation improvements were designed to eliminate dangerous breaking wave conditions within the entrance channel and allow for the safe passage of vessels within the entrance channel and basin. In addition, an estimated 30,000 cy of material were removed from the harbor.

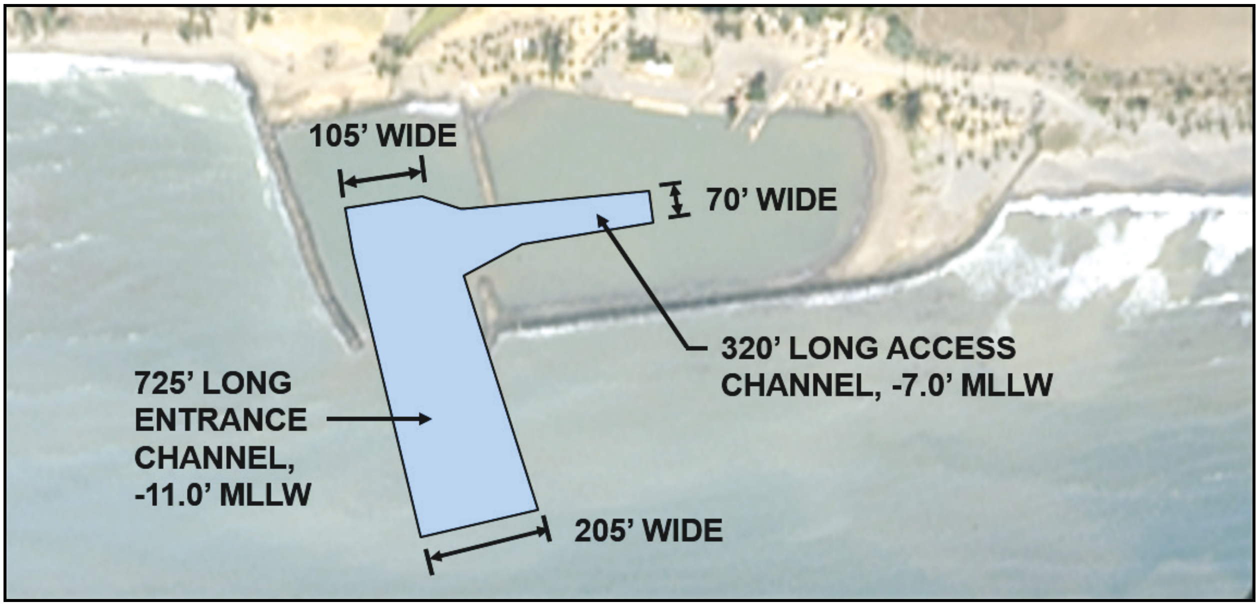

Figure 2. Channel improvements to Kikiaola Harbor constructed in 2009.

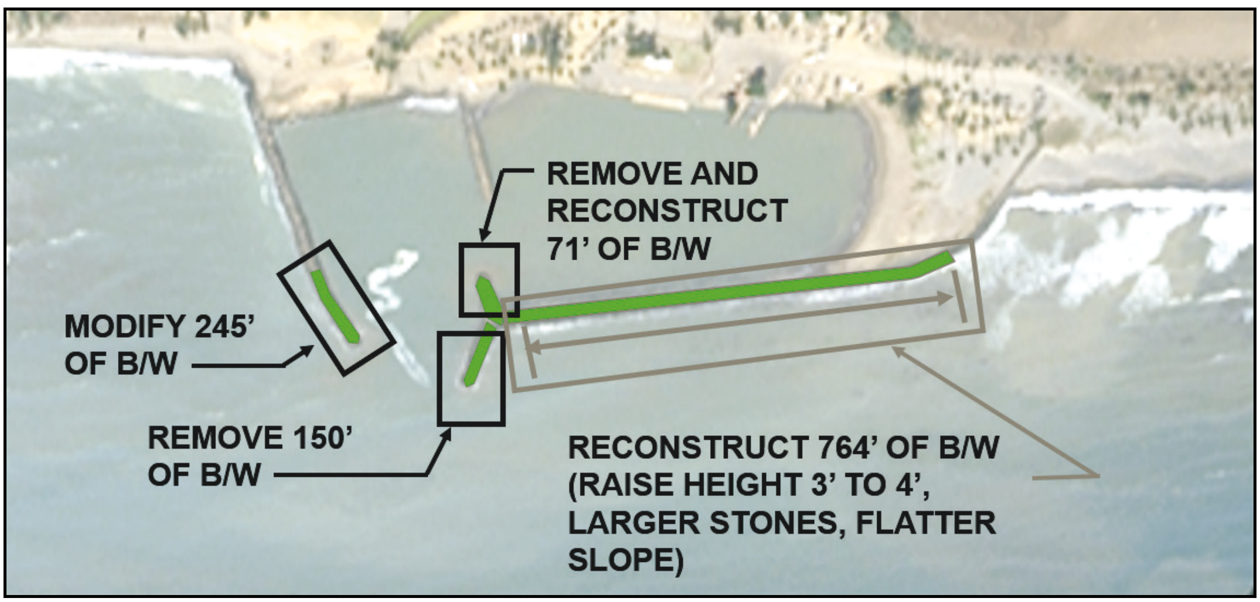

Figure 3. Breakwater improvements to Kikiaola Harbor constructed in 2009.

Previous studies in this region have shown that the construction of KLDH has essentially blocked any sediment exchange between Waimea Beach and Kikiaola Beach (Moffatt and Nichol 2011; Podoski 2013). The RSM studies in Fiscal Year (FY)10 and in FY12 (updated) used shorelines from 1992 to 2006 digitized by the University of Hawaii, Coastal Geology Group (Fletcher et al. 2012) to develop a sediment budget for the region from the Waimea River to Kokole Point. This analysis showed that Waimea Beach has been accreting at a rate of approximately 7,000 cy/year. Material from the Waimea River is transported alongshore from east to west and is trapped by the harbor's east breakwater. On the other side of the harbor, Kikiaola Beach has been steadily eroding at a rate of approximately 5,000 cy/year. The harbor itself accumulates terrestrial sediment from a drainage ditch discharging approximately 1,600 cy/year directly into the harbor. A review of survey data suggested that approximately 3,400 cy/year of sediment is transported into the harbor from offshore. The sediment budget suggested that there is no sediment exchange between the Kikiaola Harbor and Kikiaola Beach. In addition, there seems to be no sediment exchange between Kikiaola Beach and Kekaha Beach due to the rocky headland at Oomano Point (Figure 1). This is evidenced by the distinct sand characteristics on either side of the point: terrigenous sediment to the east and calcareous sediment to the west.

The FY10 RSM study noted that a previous sand bypassing project had been conducted between 1998 and 2001. A total of 15,000 cy of sand were removed from Waimea Beach and placed approximately 1,500 ft west of the harbor on Kikiaola Beach. It was an attempt to protect four shorefront properties from erosion; however, the project was determined unsuccessful because the sand did not remain in place (Sea Engineering 2008).

The sand bypass feature of the KLDH is a non-federal item of cooperation that the State of Hawaii agreed to prior to the construction of federal modification in 2009. USACE investigations identified the littoral impacts of the original project to the down-drift shoreline as 3,000 to 6,000 cy/year (SEI and Group 70 2008). The sand bypass operation was performed by the State of Hawaii in two phases during the summer of 2014. Phase I of the operations, 9 May–6 June 2014, resulted in the movement of approximately 40,000 cy from a mid-point of Waimea Beach. Phase II followed, 24 July–14 August 2014, with the additional movement of approximately 20,000 cy of sand from immediately east of the harbor structure. The sand was placed on Kikiaola Beach directly adjacent to the western breakwater, over a distance of approximately 1,050 ft. The State of Hawaii contracted TEOK Investigations to monitor the project starting in 2013.

SAND BYPASS MONITORING: Baseline sand bypass beach profile surveys were acquired from October to November 2013. A monthly beach profile survey program, initiated April 2014, was implemented to monitor the beach complex for 2 months prior to, 3 months during, and 35 months subsequent to the sand bypass operation. Seven shore-normal profile survey locations were established at which beach morphology, beach width, and profile cross-sectional area were quantified on a monthly basis. The monthly surveyed beach profiles for the seven sand bypass monitoring localities over the 6-month period of 7 January to 8 July 2017 are illustrated in Figure 4. The beach profile locations and distances from the Waimea River mouth are listed in Table 1 (Blay 2017).

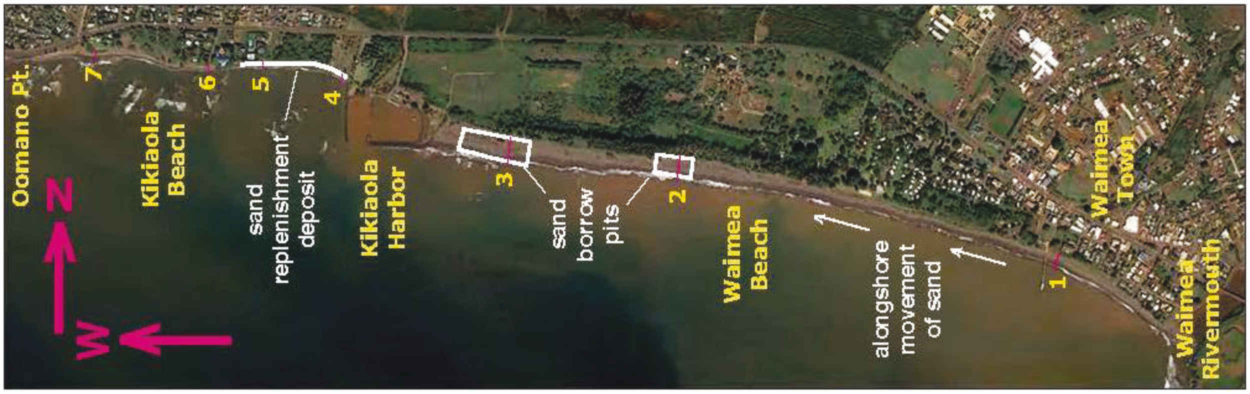

Figure 4. Sand bypass beach profile monitoring locations established by TEOK Investigations. (Names of location numbers shown in Table 1.)

Table 1. TEOK Investigations sand bypass monitoring beach profiles locations and distances from the mouth of the Waimea River. (Location numbers shown in Figure 4.)

Beach Profile Location	Distance from Waimea River Mouth (miles)
OOMANO Point	2.5
7. Oomano Place	2.4
6. Mamo Place	2.2
5. Kikiaola Place	2.1
4. Kikiaola Harbor	1.9
KIKIAOLA HARBOR	1.7
3. Waimea Beach (west)	1.6
2. Waimea Cottages	1.2
1. Waimea Pier	0.4
WAIMEA RIVER MOUTH	0.0

The Waimea Pier location has continued to display a relatively uniform rate of increasing sand volume, certainly not a concern with respect to beach fluctuation. After being impacted significantly by the excavation of tens of thousands of cubic yards of sand (May–August 2014), the excavation sites (Waimea Cottages and Waimea Beach) continued to gradually lose sand for the subsequent 15 to 16 months. However, since September 2015, both sites have displayed relative stability in sand volume, even showing minor increases. The principal sand bypass placement site (Kikiaola Harbor) has displayed a gradual loss of sand since initial construction. The Kikiaola Place location, where some bypass sand was deposited, has displayed the greatest stability in sand volume since it was placed in May–August 2014. Mamo Place, down-drift of the bypass sand placement area, is the only location that displayed a distinct seasonal variation in beach sand volume. It also appears to have experienced a subtle overall increase in sand volume, suggesting that some of the bypassed sand has been transported this far down-drift. At the Oomano Place location, there has been no obvious impact of the sand bypass operation on the beach profile (Blay 2016).

The recent TEOK Investigations interim report (Blay 2017) provides beach survey data from 6 April 2014 through 8 July 2017 with emphasis on the most recent months of January–July 2017. The principal objective of this interim report was to present the results of the monitoring of the Waimea-Kikiaola Beach complex for the most recent months of January through June 2017 with reference to the changes in the beach complex since the initiation of the sand bypass operation in May 2014.

Figure 5 shows excavation of the beach profile during the initial 2014 sand bypass operation at the Waimea Cottages location. Approximately 43,800 cy of material were removed from the upper portion of the subaerial beach from 9 May–6 June 2014. Beach profile surveys were taken in April 2014 prior to sand bypassing and were followed by monthly post-sand bypassing surveys. Figure 6 is a composite graph of the survey data acquired at this location in June 2014, October 2014, and March 2017. As indicated by the figure, the beach profile has continued to recede landward since sand bypassing from this location. The beach profile has reduced in cross-sectional area equal to 1.54 times the cross-sectional area that was excavated during the sand bypass operation (Figure 6). The beach profile cross-sectional area loss totals approximately 360 square yards (sq yd). The corresponding shoreline recession was approximately 75 ft. This is in contrast to the recovery of the beach profile expected following excavation of sand from this location.

Figure 5. Excavation of the subaerial beach profile at Waimea Cottages during the first increment of the 2014 sand bypass operation. (Location number 2 in Figure 4.)

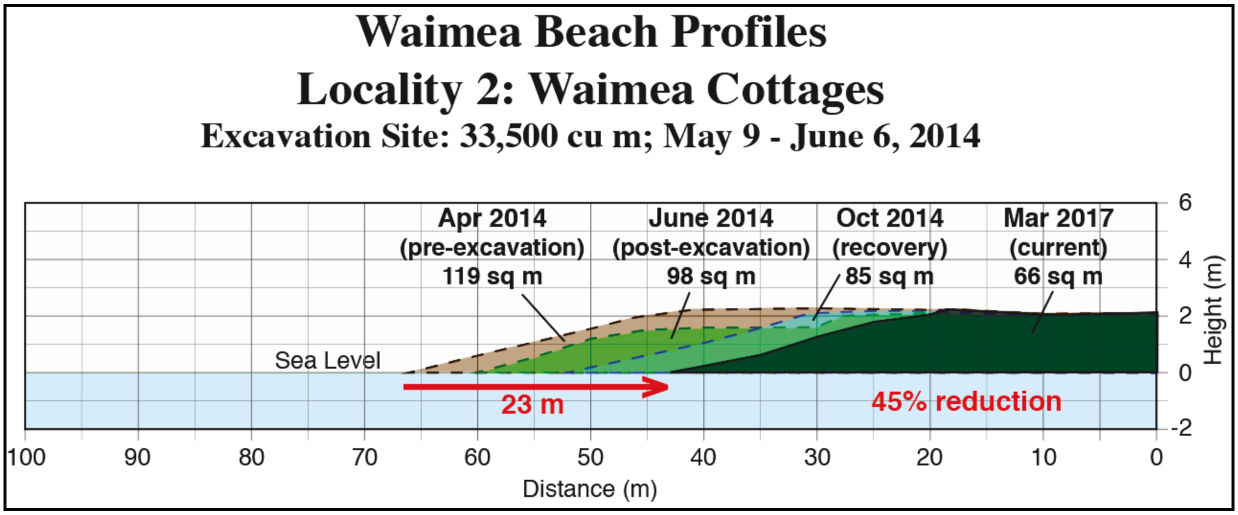

Figure 6. Sand bypass monitoring beach profile surveys taken at the Waimea Cottages location. (Location number 2 in Figure 4.)

Figure 7 shows placement of sand during the second increment of the 2014 bypass operation (24 July–14 August 2014) at the Kikiaola Harbor location. During the first increment, sand was placed below the mean high water shoreline. During the second increment, sand was placed above the mean high water shoreline as displayed in Figure 7. Beach profile surveys were taken in April 2014 prior to sand bypassing, followed by monthly post-sand bypassing surveys. Figure 8 is a composite graph of the survey data acquired at this location in September 2014, January 2015, and March 2017. As indicated by Figure 7, the beach profile has continued to recede landward since sand placement at this location. The total volume of sand bypassed to the down-drift beach was approximately 60,000 cy. This is relative to the beach profile cross-sectional area increase of 158 sq yd at this location. After the first 8 months following completion of the sand bypass operation, 64 sq yd of area were lost from the profile as compared to the subsequent loss of 61 sq yd over the next 26 months. The corresponding shoreline recession was approximately 26 ft. The beach profile cross-sectional area loss rate is therefore approximately 25% of what it was following completion of the sand bypass.

Figure 7. Placement of bypassed sand above the mean high water shoreline at the Kikiaola Harbor location during the second increment of the 2014 sand bypass operation.

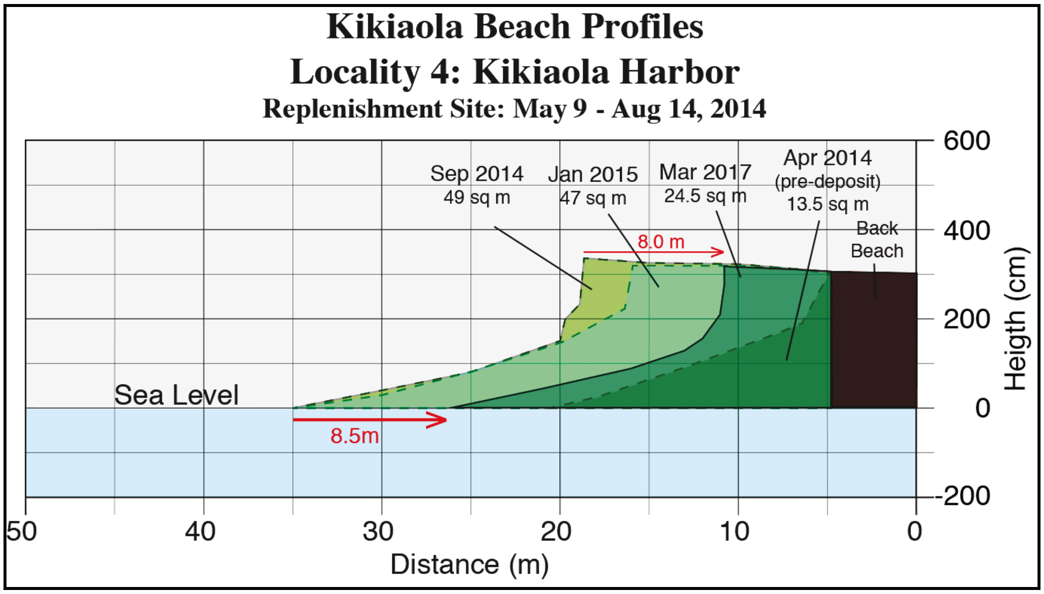

Figure 8. Sand bypass monitoring beach profile surveys taken at the Kikiaola Harbor location.

SHORELINE CHANGE ANALYSIS: In combination with the beach profile surveys, recent shoreline change was assessed for the study area to determine the effectiveness of the sand bypass operation. Shoreline change evaluates the advance or recession of the shoreline over time. Shorelines are typically classified as being stable (no movement), eroding (receding), or accreting (advancing). Understanding shoreline change allows coastal managers to make more informed decisions regarding their shorelines.

To capture changes due to the sand bypass operation, shoreline change for the study area was evaluated. Satellite imagery from the DigitalGlobe database was downloaded for these dates: 26 August 2011, 17 August 2013, 6 October 2014, and 17 August 2016. The imagery was used to estimate and digitize shoreline positions in ArcGIS. Using the Digital Shoreline Analysis System (DSAS) in ArcGIS, an onshore baseline and 490 ft long transects were laid out at 65 ft intervals along the entire region. DSAS then calculated the distance between each shoreline pair and divided by the time difference to determine the shoreline change rate at each transect. Volume change is estimated by applying a conversion value of 0.4 cy of sand per square foot (cy/sq ft) of beach based on guidance provided by the Coastal Engineering Manual (USACE 2002). Assuming that as an unarmored beach erodes, it maintains approximately the same profile above the seaward and landward limits of significant transport. This conversion value of 0.4 cy/sq ft has been employed by POH for Hawaii study areas where there is limited profile data.

The Kikiaola region was broken into four reaches (Figure 9):

- Reach 1 is the farthest west, capturing the rocky headland at Oomano Point and extending to the point at Kekaha Beach where the sand switches from terrigenous to calcareous. The region farther west of this point was previously identified to be a distinct littoral cell.

- Reach 2 extends from Oomano Point to the western breakwater at Kikiaola Harbor.

- Reach 3 extends from the eastern breakwater at Kikiaola Harbor to just past the bypassing excavation areas.

- Reach 4 covers the rest of the region to the Waimea River.

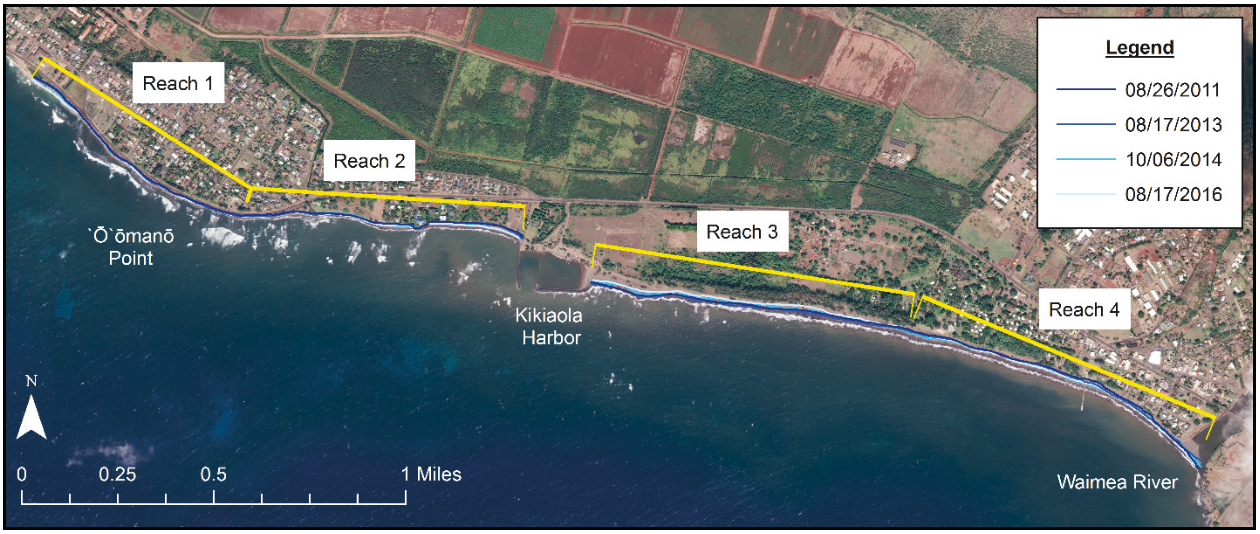

Figure 9. Reaches and shorelines used to determine shoreline change in the region.

Figure 10 shows plots of volume change over the whole region, and Table 2 summarizes the volume change rates for each reach. Volume change between the 2011 and 2013 shorelines represents the pre-bypass state. Reaches 3 and 4 are accreting sand at a much higher rate than Reaches 1 and 2, which correlates to previous regional sediment budgets that indicate the Waimea River introduces sediment to these reaches. The section of Reach 2 adjacent to the harbor shows the highest rate of erosion (Figure 10A).

Since bypassing occurred during May to August 2014, the 2013–2014 shoreline change captures the actual bypassing event. Figure 10B clearly captures the sand excavation that occurred in Reach 3 indicated by the large negative volume change, and the placement of sand to the west of the harbor denoted by the large positive volume change in Reach 2, although equilibrium conditions had not yet been attained. Reach 1 and Reach 4 trend similarly to the pre-bypass shorelines.

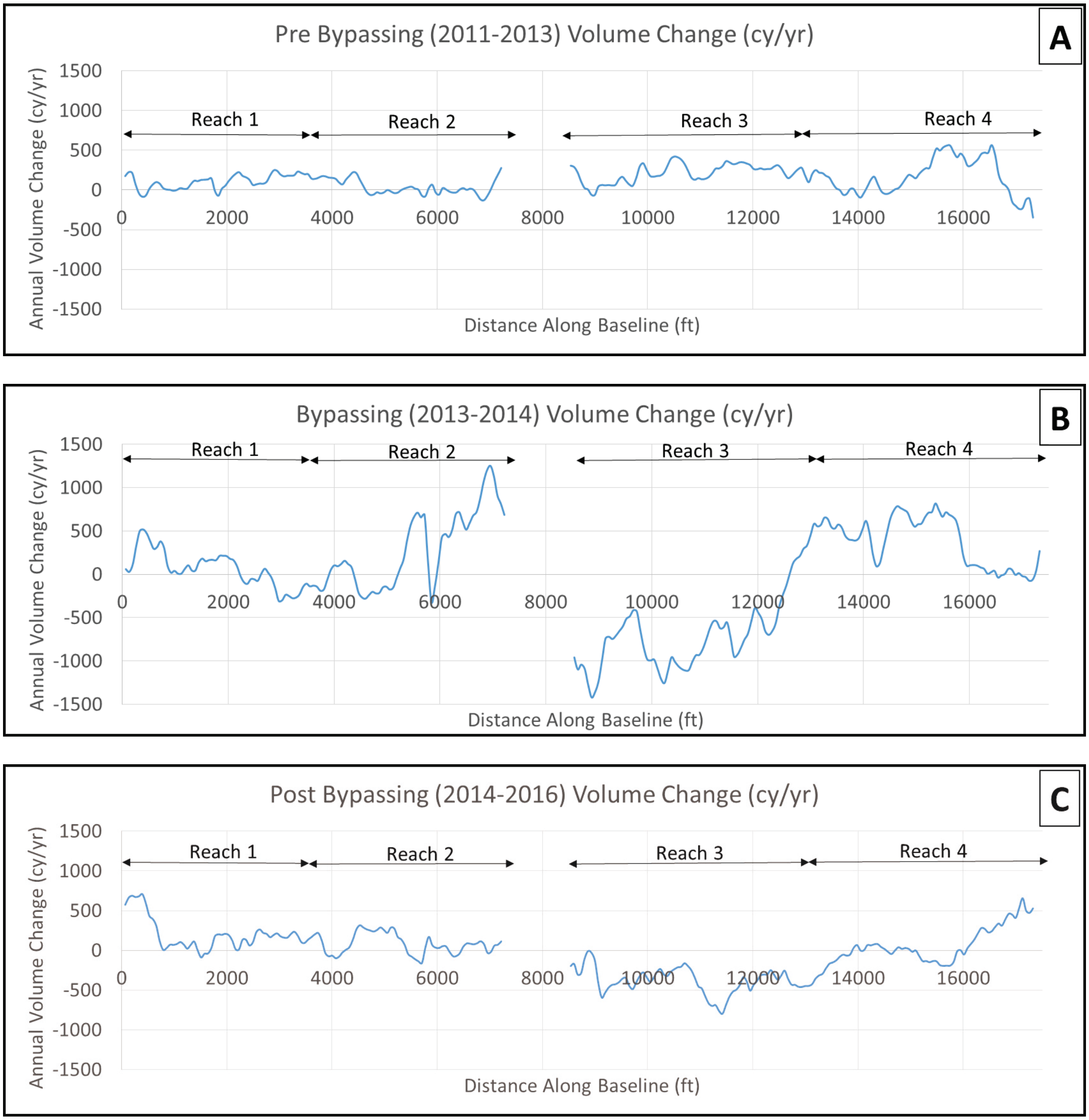

Figure 10. Volume change plots over the project area indicating trends from (A) pre-bypass, (B) during-bypass, and (C) post-bypass.

Table 2. Volume change rates for various reaches within the study area.

Shoreline Reach	Volume Change Rate (cubic yards/year)			
	Pre-Bypass 2011–2013	During-Bypass 2013–2014	Post-Bypass 2014–2016	Overall 2011–2016
Reach 1 – Oomano Point	5,282	3,665	10,657	6,923
Reach 2 - Kikiaola Beach	2,586	15,485	4,861	6,386
Reach 3 – Waimea Beach	14,317	-49,171	-25,179	-14,987
Reach 4 – Waimea River	11,202	26,102	1,964	11,141

The effect of the bypassing is represented by the 2014–2016 shoreline change. The shoreline in Reach 3 is still retreating, suggesting that the excavation sites did not recover and, in fact, continued to erode over that 2-year period. If the introduction of sediment to the system from the Waimea River was low during that period, as evidenced by the low rate of accretion in Reach 4, this could explain why Reach 3 was not able to recover more quickly. The sand placement area in Reach 2 appears to be more stable than prior to sand bypass.

The last column of Table 2 shows the overall trend from 2011 to 2016. Reach 1 was overall relatively stable. The sand bypass operation seemed to benefit the shoreline in Reach 2, but the entire bypassed volume did not seem to remain in place. Reach 3 still appears to be recovering from the excavation of sand from the bypassing. Reach 4 is generally accretive, but the volume change tends to fluctuate depending on how much input comes from the Waimea River.

CHANNEL SHOALING: Channel shoaling at KLDH has consistently decreased since the first condition hydrographic survey was acquired in 2010. As shown in Figure 11, the initial post-construction channel shoaling rate was approximately 11,000 cy/year based on volume changes calculated for the time period of 18 September 2009 to 28 May 2010. This is mainly attributed to the removal of the east breakwater spur, which had impounded sediment on its up-drift side. Once the spur was demolished, a large quantity of sediment was released and subsequently transported into the harbor channel. It can be seen in the shoaling graph (Figure 11) that both the cumulative and incremental (delta) shoaling rates trended to approximately 1,500 cy/year by the date of the latest condition hydrographic survey in 2016. Negative shoaling rates were calculated in the comparison of the 2010–2013 and 2013–2014 surveys. These anomalies are thought to be a result of propeller dredging within the federal project limits rather than survey error. A contract was awarded in September 2017 to dredge within the federal project limits to authorized depths, an estimated 12,000 cy. It is predicted that channel shoaling will be on the order of 1,000 cy/year following completion of the project and into the near future.

PAVING THE WAY FOR BENEFICIAL USE OF DREDGED MATERIAL AT KLDH: Historically, the material dredged from KLDH has not been suitable for beach placement. Silt and clay from the adjoining agriculture land is delivered to the harbor via Kikiaola Gulch (Figure 12).

During heavy rain events, the gulch transports fine grained upland sediment and debris into the harbor, mixing with sediment within the harbor that could potentially be beneficially reused. Alternatives to mediate the input of silt and clay into the harbor via Kikiaola Gulch include construction of a settling basin, gulch diversion, and separation of the fine fraction of sediment from future dredged material.

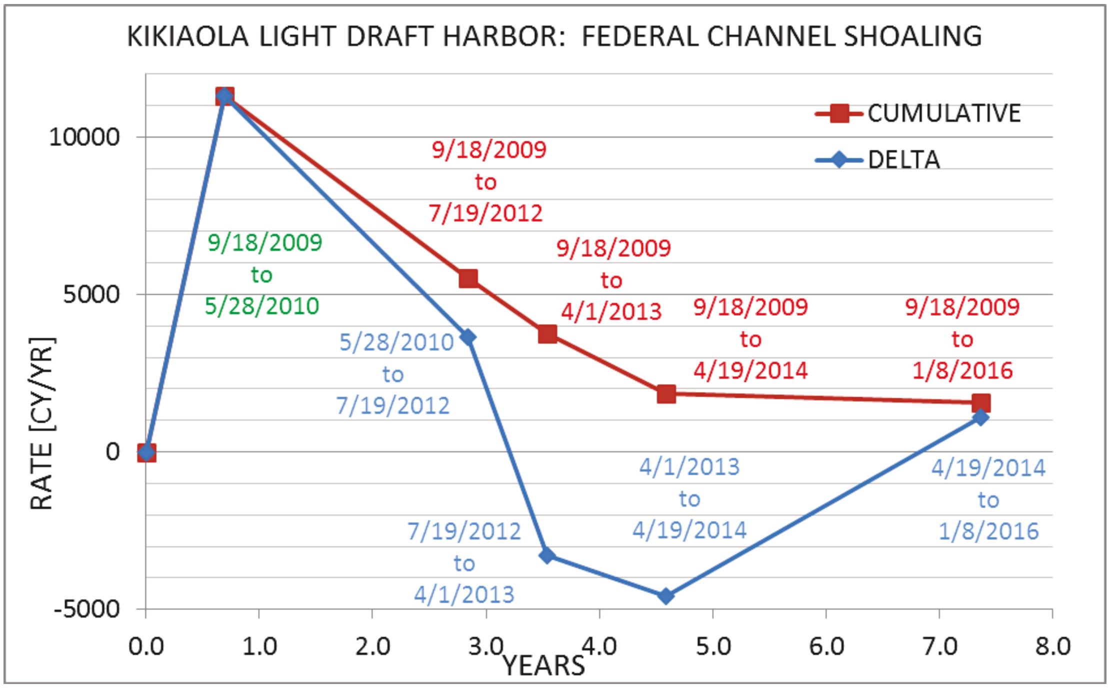

Figure 11. Shoaling rates (cy/year) within the federal project limits at KLDH.

Figure 12. Alternative features considered for mediation of sediment quality within KLDH.

Settling Basin. It was assumed that the settling basin would need the capacity of 10 acre-ft. This would be required since the settling time for silt and clay is on the order of days to weeks as opposed to the duration of the design event (hours). The settling basin can be sited on either side of Kaumualii Highway. More land is available on the mountainside on the highway, which is predominately agricultural land. Available land on the harbor-side of the highway consists of a triangular area that is approximately one acre in size. This area is currently used for tourist-boat clientele parking. Optimistically, only approximately half of this area can be dedicated to a settling basin.

Assuming a capacity requirement of 10 acre-ft, the harbor-side settling basin would need to be at least 20 ft deep. Conversely, the mountainside of the highway can easily accommodate an 8-acre basin requiring a minimum depth of 1.25 ft. Maintenance of the settling basin will be paramount to its success. On the mountainside of the highway, the basin would have to be carefully monitored during significant rain events to ensure that the facility does not overtop and flood the highway. On the harbor-side of the highway, basin overtopping would primarily result in inflow of silty material into the harbor as is currently experienced.

Gulch Diversion. Currently, KLDH serves as an 8-acre settling basin for silt and clay discharged from Kikiaola Gulch (Figure 12). As noted earlier, the input of fine grained terrestrial material renders the littoral sediments transported into the harbor through the entrance channel unsuitable for beach placement. Diversion of the gulch to the west and outside of the harbor (Figure 12) would improve sediment and water quality within the harbor. Environmental impacts and potential mitigation for gulch diversion will need to be quantified to qualify this as a viable alternative. Discharge from Kikiaola Gulch to the west into the Kikiaola Beach nearshore (Figure 1) would dissipate over an extended area as influenced by wave and currents. Impacts to offshore resources can be baselined by existing conditions and compared to future monitoring results. If this alternative is pursued and the Kikiaola Gulch direct discharge to the west (prevented from entering the KLDH) into the nearshore is found to be unacceptable, the present conveyance of gulch discharge into the KLDH can be resumed.

Dredged Material Separation. In the past, material dredged from KLDH was placed in upland locations including contractor-furnished areas and the Kekaha Landfill. Beach placement or other beneficial uses of the material have not been pursued due to undesirable sediment composition of the material. Given the status quo, separation of the fine grained material from the coarse fraction of dredged material will be required to realize beneficial use. Additional cost will be incurred due to the double handing of the material prior to beach placement or other beneficial uses. Hydro-cyclone technology has advanced to the point where component separation may not be cost prohibitive. A pilot project could verify the applicability to this alternative for KLDH.

CONCLUSIONS: The construction of Kikiaola Harbor disrupted the natural sediment transport processes in this region of Kauai. The up-drift shoreline has historically accreted as the sediment coming from the Waimea River was impounded on the harbor's eastern breakwater. The harbor itself acts as a sediment trap, both for fine grained terrestrial sediment coming from Kikiaola Gulch and also for sand coming around the eastern breakwater and settling in the channel. Meanwhile, the down-drift shoreline has become severely sediment starved due to the lack of sediment transport past the harbor. The State's sand bypassing project in 2014 aimed at reducing down-drift erosion and channel shoaling. This report pulled together several data analyses and monitoring tools to evaluate the effectiveness of the bypassing and assess recent trends in harbor shoaling.

Analysis of the channel shoaling rate at KLDH showed that shoaling has steadily decreased from approximately 10,000 cy/year to 1,000 cy/year since construction of federal modifications in 2009.

This is in part due to morphology equilibration after the harbor's modifications and partly due to the sand bypass project. The stub of the outer breakwater previously impounded sediment being transported around the harbor, but when it was demolished in 2009, a large volume of sediment immediately entered the harbor. This trend has reduced significantly over the past 4 to 5 years. Also, the sand bypass project reduced the volume of sand available to be transported into the harbor. Future sand bypass operations will ensure that shoaling will remain at a manageable rate.

A review of the TEOK Investigations beach profile monitoring, and a shoreline change analysis, pointed to several of the same conclusions about the sand bypass project. The up-drift beaches are recovering more slowly than expected. Large volumes of sediment input from terrestrial sources such as the Waimea River are often episodic, such as after a large storm event. It appears that over the past few years, oceanic and atmospheric conditions have resulted in a lack of wave and current action sufficient to transport sand to the Waimea Cottage excavation area. The down-drift beaches have been relatively stable since the sand bypass project. The sand was bypassed immediately down-drift of the harbor, knowing that the natural littoral transport would move the sand westward along Kikiaola Beach. This severely eroded stretch of shoreline has stabilized since completion of the sand bypass project in 2014.

Based on these results, it is recommended that future sand bypass projects consider excavation of material adjacent to the east breakwater. This will provide an area for littoral sediment to be intercepted before it is transported around the east breakwater and into the channel, while not impacting the Waimea Cottage shoreline. Considering that the Waimea Cottage shoreline is taking years to recover, removing sand from this area may be undesirable. Future sand bypass projects should also consider placing the material below the mean high water shoreline on the down-drift beach. This will facilitate re-establishment of the submerged potion of the beach profile and nourishment of beaches to the west of the placement site.

In addition to reducing shoaling in the channel and erosion on the down-drift beach, this RSM study aims to identify ways to beneficially use dredged material from KLDH. The main issue with this is that the beach quality material is mixed with fine grain terrigenous sediment coming from Kikiaola Gulch. Alternatives to improve the quality of sediment within the harbor include, but are not limited to, construction of a settling basin, a gulch diversion and separating the dredged material. These alternatives require additional investigation.

ADDITIONAL INFORMATION: This Regional Sediment Management Technical Note (RSM-TN) was prepared by Lauren K. Molina and Thomas D. Smith, USACE Honolulu District (POH), and Charles T. Blay, TEOK Investigations, with input from the Hawaii RSM Project Delivery Team. The study was conducted as an activity of the USACE National RSM Program, a Navigation Research, Development, and Technology (RD&T) portfolio program administered by Headquarters (HQ) USACE. Additional information pertaining to POH RSM investigations can be found at *http://gis.poh.usace.army.mil/rsm/index.htm*. For information regarding the USACE National RSM Program, please consult *http://rsm.usace.army.mil* or contact the USACE National RSM Program Manager, Katherine E. Brutsché, U.S. Army Engineer Research and Development Center (ERDC), Coastal and Hydraulics Laboratory (CHL), at *Katherine.E.Brutsche@erdc.dren.mil*. For information regarding this RSM-TN, please contact Lauren K. Molina, *Lauren.K.Molina@usace.army.mil*.

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