PRELIMINARY INTERPRETATIONS OF INVESTIGATION OF COASTAL CHANGES AND SAND MINING, APIA AREA, WESTERN SAMOA

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December 1993 *SOPAC Preliminary Report 68*

Prepared for: South Pacific Applied Geoscience Commission (SOPAC)
Coastal Program

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OBJECTIVES

To map the Apia coast, predominantly using airphotos and field observations, establishing historic coastal changes and the distribution of sand bodies, and produce results which will assist in future studies to establish a sand mining strategy for the Apia area.

ACKNOWLEDGEMENT

This project was carried out by the author as a consultancy to the SOPAC Secretariat funded by the Government of Canada.

PRELIMINARY RESULTS

Beach Mapping

The east (oceanward) side of Mulinu'u received the most attention, partially because it is the most active environment and partially because of the nearshore dredging operation going on outside of the Mobil tank farm (see below). The Peninsula beaches have all had some form of seawall shore protection in he past. In most cases the seawall consisted of piles of small (0.2-0.3 m) basalt boulders presumably placed over the toe of an eroding bluff or in front of tombs and houses which were threatened by erosion. Under storm conditions, these structures were either undermined and/or overwashed and collapsed. In some cases, the seawalls were dramatically overstepped and are now seen 10 or more metres offshore from the present coastline.

The beaches are often backed, at the top of the hide tide swash line, by a vine called "fue". It is also present within basalt boulders where these form the upper beach. The fue establishes itself rapidly and acts to hide the extent of vegetation retreat after storms when mapping from air photos. While the entire coastline of the Mulinu'u Peninsula appears to be retreating, there are zones with accretional tendencies in the shorter term (i.e. I am not yet sure whether this means weeks, months or years). Beaches in the accretional zones (e.g. BP tank farm) are 10-15 m wide with a slope of about 8°. The sand is coarse and predominantly carbonate at BP Beach, but is more volcanic at beaches further updrift. Below the low tide step the slope flattens abruptly and there is a gravel lag present at the base of the beach. Large mats of sea grass are found just offshore from the BP Beach and the water depth over the grass is about 0.25-0.5 m. This vegetated zone represents an area of accretion or stability; it was not present on 1980 air photos, but had formed by 1987. Stabilisation by vegetation in front of the beaches may act as a buffer against storms, but it may also prevent sand from reaching the beaches from the reef flat. The development of the vegetated flats in the 1980's may have resulted from the relatively calm weather (no cyclones) or may have something to do with increasing nutrient fluxes.

The water depth just offshore from the grass mats is slightly greater (0.75-1 m) then slopes gently up towards the reef crest and cyclone banks. The beach profiles were difficult to define by informal snorkelling surveys. Conventional beach profiling presently underway as part of the incountry seminar in Western Samoa will provide that information along several lines as identified on the accompanying map.

The width of the vegetated zone decreases proceeding northward from the BP beach. The zone of stabilized or accreting material is therefore decreasing in the erosional zone to the north. Its width reaches a minimum just north of the Falefone where it becomes difficult to trace. It is replaced by a series of vegetated banks at the toes of the beaches just below the low tide line.

The series of groins (installed pre-1970) in front of the Apia Observatory have effectively trapped sand on their updrift sides. Since Cyclone Ofa, the shoreline has retreated to the point where at least one of the groins is no longer attached and is acting like an offshore node with a tombolo formed behind it. Fine silts and clays are found at the toes of the beaches within the groins. Beach sediments are dominantly volcanic (60-90%) and coarse to granular in size with occasional rounded volcanic pebbles and angular fragments of coral. At the toe of the swash zone is a lag accumulation of oblate volcanic pebbles and angular coral fragments overlying poorly sorted fine to coarse grained silty sand. The lag zone slopes seaward at about 3° whereas the beach slopes much more steeply (>10°). Seaward of the lag zone is a burrowed zone without pebbles and which contains a fine grained sand component which is all carbonate sand and a coarser grained sand which contains about 50% volcanic particles. At the base of the beach is a zone of aquatic plants (leafy seaweed) in poorly sorted carbonate sand with volcanic granules.

A moat or shallow channel about 50 m wide is present just seaward of the vegetated banks and the ends of the groins at the Observatory. The moat is up to 0.5 m deeper than the surrounding banks and reef flats. It extends southward and becomes difficult to follow around the BP tank farm. Its origin is unknown, but it may be speculated that it represents a tidal channel. Flood tidal currents within the channel are much stronger than ebb currents (DAP Muller, pers comm.). Within the past 15 years the channel was used by small boats entering near the market. There were no current formed features in it during the one week of field work, but that does not preclude activity during storms or spring tides.

At the northernmost groin a small spit platform of coarse grained carbonate and volcanic sands is growing from the end of the groin. Along the palm-fringed, northwest facing coast the lag zone is only present in the vicinity of the groin. Further along the coast, towards the dredging causeway, the beach consists of an intertidal swash zone with muddy sand at the low tide line. Volcanic and carbonates sediments are present in approximately equal amounts. The palms along the beach are being actively undercut; any remaining seawall has been bypassed. Coral material, probably emplaced during strengthening of the groins and seawalls during the 1970's (Muller pers comm), shows a distinct alongshore trend from coarse (20 cm) close to the groin to finer (5 cm) towards the dredging causeway indicating a north to south component of longshore drift which may have occurred during cyclone Ofa. South of the causeway, dredging by Public Works has completely removed a spit which was present in the 1954 air photos. Dredging down to a depth of about 8-9 m occurred within several metres of the shoreline (Muller, pers comm).

Dredging for Land Reclamation behind the Market

There is a small suction dredge (capacity unknown) operating under contract to Public Works. The dredging is being done to fill in a stretch of coast which extends from the Mobil tank farm to the fish market. The dredge is operating approximately 30-40 metres offshore in water depths of less than 1 m at low tide. The deposit being mined is identifiable on the 1987, 1990 and 1992 air photos, it does not appear to be present in the same configuration on the 1970 or 1980 photo. The implications of the change in configuration to sediment volume is difficult to ascertain without knowledge of the deposit prior to 1987. The dredge owner indicated that he was told by many people that the sand supply was insufficient for the fill project. However a local elder who has lived at the site for more than 50 years told him that there was plenty of sand.

I received conflicting reports on the size of the project. The dredge owner indicated that some 350,000 m^3 of sand will be needed. This figure needs to be confirmed and verified in discussion with Public Works. The area being filled is about 400 long and 50 m wide. Depths vary between 0.5 m and 5 m. A breakwater is being constructed to contain the fill up to the current height of the onshore seawall. The dredge owner is unclear about the height to which the reclamation will rise, but it is assumed that it will be at least 1 m above spring high tide (1.2 m above chart datum). Therefore an approximate requirement for fill based on an average thickness of material of 4 m (2 m above low tide plus 2 m average depth below chart datum) is 80,000 m^3. This estimate could be off by a factor of 2 or more, but it seems unlikely that the fill required would be as much as the figure quoted. It had been previously estimated to be 50,000 m^3 required. If a more accurate estimate is required, a bathymetric survey of the area would have to be undertaken. The area was previously dredged (1970's) for the construction of the Kitano Tusitala Hotel, and holes more than 10 ft deep were reportedly left behind by the dredging then. Since this dredging was performed, sand has reportedly returned and filled in the holes.

Sand movement in the area which is currently being dredged is apparent in the form of sinuous crested 2D ripples which are asymmetrical indicating westward migration. The wavelength is about 30 cm with a height of 5-7 cm. They are formed in coarse grained coral sand with shell and coral granules and flakes in the ripple troughs; there is little volcanic material present. Movement is under the influence of the easterly trades with seas of about 30 to 50 cm. The water depth is about 1 to 1.5 m. The ripple fields are interspersed with fields of sea grass (*Halophila ovalis*) and a small-leafed type of seaweed (genus unknown). The edges of the vegetated flats show evidence of erosion and small blow-outs which may signify expansion of the ripple fields. On the ebb tide, the dredge sediment plume was seen to be moving from west to east along the coast (against a 10 knot trade wind). This behaviour was also noted by Hedgeland (1978). There were no bedforms associated with movement towards the east, so it was either very weak, or a surface phenomenon.

Sediment movement has been noted by the dredge owner, who stated that a 2 m hole was infilled within 6 months. The location and timing of the infill is not known, but apparently occurred between April and November 1993.

Within the vicinity of the current dredging operation the sand blanket extends northeastward across the reef flat as well as north and southward. A transect across the sand body found that vegetated flats were most prominent just below the beach and to the northern end of the body. Close to the reef crest the sand is covered with coral fragments similar in size and shape to those which comprise the cyclone banks. Sand within this zone appears to be thin and occasional patches of coral pavement can be seen. This is also the zone which contains a scattering of Padina, an algae which produces carbonate sand and mud when it dies. It only grows (at least in this area) where there is a relatively stable substrate and relatively slow sedimentation. There are two small, low cyclone banks on the reef crest offshore from the dredging operation. They are separated by a break in the reef which is about 7 fathoms deep (according to the Hydrographic chart-local name is Curry's Gap); a depth which is reached within about 20-30 m for a slope of about 20-30 degrees. The slope of Curry's Gap is covered in coarse sand with little coral rubble. There are no ripples, thus the area appears to be too deep for most waves to affect it. This break in the reef may provide a conduit for return of storm surge waters during large events, especially those which come from the north and northwest. Alternatively, there may be ebb tidal currents during fairweather conditions which could be directed towards that opening by the presence of the large accreting, vegetated sand bank referred to in the previous section. In either case, the deep may represent a significant sand sink which could be extracted without affecting the coastal system since the material is already out of the coastal circulation pattern.

In the dredge's present position, the material being removed is likely destined to move onto the beaches to the west and northwest on Mulinu'u Peninsula. Without knowing the extent of the resource and its rate of replenishment, it seems unwise to continue to exploit it when it is already known that the updrift coast is eroding probably as a result of a shortage of sand.

Drilling

Two boreholes (BH1 and BH2) were drilled using the Apia Observatory rotary drill rig at a site close to the tip of Mulinu'u Peninsula. The holes were within one metre of each other, the second drilled to confirm the findings of the first. The reason for drilling the holes was to explore the possibility that there was some structural control on the morphology of the Mulinu'u Peninsula; in particular, whether bedrock (coral or basalt existed within the upper 5-10 m. The boreholes showed that there is no bedrock down to a depth of 7 m at that location. The uppermost 2 m consisted of a gradational fining upward sequence of mixed 50-50 carbonate and volcanic sand with coral fragments and volcanic pebbles becoming more abundant at the base of the section. The remainder of the core was difficult to interpret due to the abundance of washed material and the poor recoveries of fine material. However, it is reasonably certain that next 1.5 m consists of volcanic gravel with coral fragments in a fine grained sandy, muddy matrix. The upper portion of each core section was washed gravel with a 10-20 cm recovery of muddy material. It is believed that the washed material was a result of using water to drill down the casing. The remainder of borehole 2 (3.5 m to 4.5 m) is carbonate sand, muddy in part with coral rubble and virtually no volcanic input. In BH1 the interval from 4.2 to 7 m was penetrated in one shelby tube push, so that bulldozing of the material below 5 m occurred. Penetration was easy, so that the material was obvious soft, but its components were not ascertained.

Samples were collected which represent the sediment at approximately half metre intervals. They will be brought to Suva from the Apia Observatory where they are presently stored and textural analysis should be performed.

Shore Protection Project

An extensive Japanese-funded project to protect the Apia Harbour and the Mulinu'u Peninsula is presently underway. It consists of a rubble mound seawall along the entire perimeter of the Harbour to the end of the Peninsula. Not having seen the design or the engineering specification, I can only comment on the parts which have been constructed already. On the east side of the harbour close to the port facilities the seawall has a slope of about 30° and is composed of boulders 0.3-1 m in diameter. There is a cement cap extending 1 m above the sidewalk and road; grated drains are provided every 15-20 m. The seawall extends approximately 2.5 m above the high tide line. There appears to be finer material beneath the boulders, but it is difficult to see. Towards the west, where it is more exposed to the southerly directed swell, the seawall rises to a height of about 3-4 m above the high tide line. The average boulder size is 0.5 m and the slope is estimated to be slightly steeper than to the east (about 35-40°). In front of the reclaimed land in front of the clock tower, the seawall is about 2.5 m above high tide with a 20° slope and an average boulder size of about 1 m (up to 2.5 m). Construction is presently concentrating in this area. Additional construction is occurring at the market reclamation (as described above) and along BP beach. At the beach, basalt boulders are being dumped along the shoreline, presumably in preparation for placement. It is not known whether a concrete cap will be used along the entire design length. There does not appear to be filter being applied beneath the boulders at the beach.

According to John Bell, there was originally no plan to toe the protection into the seabed. At his suggestion, the seaward edge to emplaced 1 m below the seabed to provide some protection at the toe of the seawall. Although I am not an engineer, I would be somewhat concerned about the long-term future of the construction given its rather steep profile and lack of toe protection. A prolonged storm could scour and undermine the protection at the toe causing some slumping and failure from above. These concerns are very tentative and should be addressed by a civil engineer.

From the west edge of the reclaimed land to the west end of the produce market (including the small boat anchorage and the fish market) protection is provided by a vertical concrete seawall of unknown age, but probably of pre-World War II vintage. Along the seaward edge of the bus parking lot a rubble mound seawall of small (<0.5 m) basalt boulders is topped by a series of small shops on pilings which extend slightly beyond the seawall. These shops were all destroyed by cyclone Ofa in 1990, but they have since been rebuilt.

Along the road behind the present reclamation project, an old vertical concrete seawall rests on a bed of sand and basalt boulders. The footing is exposed for its entire length and at several places there are small holes in the roadbed immediately behind the wall. This may be evidence of subsidence caused by removal of material at the base and behind the wall. Approximately 10-15 m of the wall have been rebuilt recently (not sure when).

PRELIMINARY INTERPRETATIONS

It is very difficult to separate the natural from the man-induced processes in a developed area such as Apia. A turn-of-the-century post card taken from somewhere along the Mulinu'u Peninsula back towards Apia shows eroded palms on the beach, suggesting that the present state of retreat has probably been going on for at least 100 years. The causes are not known at this time, but it is likely that the progressive protection measures and land reclamations along the Apia Harbour coupled with widespread beach sand mining have gradually reduced the amount of sand available for nourishing the beaches of Mulinu'u Peninsula. Changes in wind patterns, cyclone frequency, river discharge, and coastal configuration may also play a role. The role of the cyclone banks in the formation and maintenance of features such as the Mulinu'u Peninsula is also a question. The banks show some evidence of shoreward movement but the coarseness of the material necessitates large events to initiate transport. The abundance of coarse coral debris in the boreholes below Mulinu'u Peninsula might represent former cyclone deposits which have been infilled with lagoon muds. More extensive coring, especially within Vaiusu Bay may shed some light on that subject.

In general, the sediment forming the present beaches appears to come from a combination of the erosion of the Peninsula itself (mixed volcanic and carbonate sand) and onshore movement of reef-derived carbonate debris.

The Mulinu'u Peninsula is a somewhat enigmatic landform in that it emanates from an embayment rather than a headland. The sources of the sediments which formed it are therefore somewhat mysterious. Previous studies have suggested that the Vaisagano River was an important sediment source. However, even prior to emplacement of the 1964 land reclamation, wave refraction around the reef entrance would have concentrated sedimentation on the west side of the harbour. Longshore drift would also be to the west as at the Paolo Deep on the West Reef. The boreholes at the Point suggest a source which is relatively rich in volcanic material, so that river-derived material was an important component. The depth to basalts in the lagoons and along the wharf is about 30 m below present sealevel. According to a sea level curve presented by Nunn (1991), sea level rose rapidly from 6 m below present 5000 years BP to close to present sea level about 2000 years ago. The alluvial deposits along the coast may represent a higher sea level stand at 1-2 m above present within the past 2000 years. The coastal configuration at that time may have been responsible for the initiation of the Mulinu'u peninsula development. Alternatively, there may be some structural control at the proximal end of the spit.

Sand Movement and Nearshore Dredging

Initial interpretations of the formation of a large sand bank on the south end of the peninsula as a result of Cyclone Ofa were found to be incorrect. The accretional vegetated zones in front of the BP tank farm had formed by 1987 and remained mostly intact through Ofa. There appears to be a transport pathway along the edge of the vegetated mats offshore from the BP beach out through Curry's Gap. This pathway may be a conduit for offshore directed ebb or storm-surge return currents. If so, it could be a source of sand which has been deposited out of reach of the coastal circulation system. Sand within the present dredging zone is moving shoreward under the influence of the easterly tradewinds. This material will ultimately nourish updrift beaches which erode under storm conditions. Therefore it is desirable to use an alternative source of sand for the reclamation at the market. The alternative might be found further offshore at the Curry's Gap. It is probable that the greatest thicknesses of sand will be found at the base of the opening (maximum water depth of 7 fathoms in 1982) and will be thinner along the sides.

PRELIMINARY RECOMMENDATIONS

Recommendation 1

a. Have the dredge move offshore towards the reef opening (Curry's Gap) to investigate the quantity and quality of sand found there. A representative of the Apia Observatory (or one of the other government agencies) should monitor the amount and quality of sand found paying particular attention to the presence or absence of volcanic material and coarse coral fragments.

b. A series of jet probe transects should be performed along the eastern shore of Mulinu'u Peninsula to ascertain the volume of sand present. This information can be compared to a similar study performed by John Harper and Bruce Richmond in 1988 (not reported).

c. In order to ascertain gross rates of sediment transport, the infill rate of the dredged holes should be monitored.

Recommendation 2

Grain size analysis should be performed on the beach and borehole samples to compare the energy of the environments of deposition. Sieve analysis is sufficient for the sands. The percent of silt and clay in each sample should also be measured and the proportion of volcanic versus carbonate sand in each size fraction should be estimated visually.

Recommendation 3

Drill a series of boreholes starting at the proximal end of the spit to ascertain the stratigraphy, grain size and depth to bedrock (if encountered within the upper 10 m).

Recommendation 4

Survey and monitor beach profiles at sites around the Mulinu'u Peninsula to quantify season variations and cyclone bank movement.

APPENDIX

Trip Log

28 November	Travel to Apia spent Sunday afternoon at Ausetalia Titimaea's house
29 November	Map and snorkel beaches at the Observatory. Meet with Ausie to discuss objectives for visit. Talk to dredge operators for dredge operating immediately offshore from the Mobil Tank Farm.
30 November	Map beaches from Mulinu'u Pt to BP tank farm. Choose borehole location and core to 7 m Talk to Herman Ulberg (Mulinu'u Pt dredge operation owner). Meeting with Roger Cornforth (Lands and Environment) and John Bell (Public Works Department about project scope, link to training, and nearshore dredge operation.
1 December	Morning spent at Lands and Environment discussing their requirements and getting info on air photos, map projections, etc. Snorkel to cyclone banks and investigate conditions at the nearshore dredge. Review reports received from Lands and environment.
2 December	Lands and environment - view 1954 and 1970 photos (negatives for 1970 photo are not available), get control points. Drill second hole to confirm recoveries from BH1. Met briefly with P. Nunn student doing a project on coastal change at Apia using air photo. Walked to cyclone banks with Russell Howorth. Discuss plans for Profiling workshop. Went to talk on cyclones by SPREP meteorologist, Neville Koop.
3 December	Meet with John Bell (PWD) tried to obtain reports relevant to the project. Drove around east end of island with John Bell and Roger Cornforth to look at beaches and beach mining potential at Solosolo, Aleipata, and other locations. Review reports obtained from PWD. Discuss preliminary findings and recommendations with Ausie.
4 December	Plot recommended beach profiles on map for Russ and Phil. Summarize reports obtained from PWD (no photocopier available). Map and photograph coast from Vaiala Beach to BP tank farm. Write up notes. Discuss recommendations regarding nearshore dredging with dredge owner.
5-6 December	Return to Suva.