CHAPTER 3

GENERAL DESCRIPTION OF THE STUDY AREAS

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3-1 Environment and Landscape

3-1-1 Marine Ecology and Birds

The flora and fauna are generally studied for this project. These factors should be studied in order to determine how to best implement the conversation plan.

Bali is blessed with a wonderful natural environment including the sun, sky, sea, coral reefs, sand and trees. Therefore, the beach conservation should be carefully planned to be compatible with the environment.

This study includes four locations. These study areas are located at the seashore, so the marine ecology and bird life were investmented.

(1) Study Items

1) Marine Ecology
2) Birds

(2) Study Area

The study areas are categorized into 2 areas, namely the "general study areas" and the "particular study areas" as shown in Fig. 3-1-1-1.

The particular areas are those areas with especially intense erosion, and will probably be provided with new erosion protection facilities in this study. The general study area covers the areas outside the particular study areas.

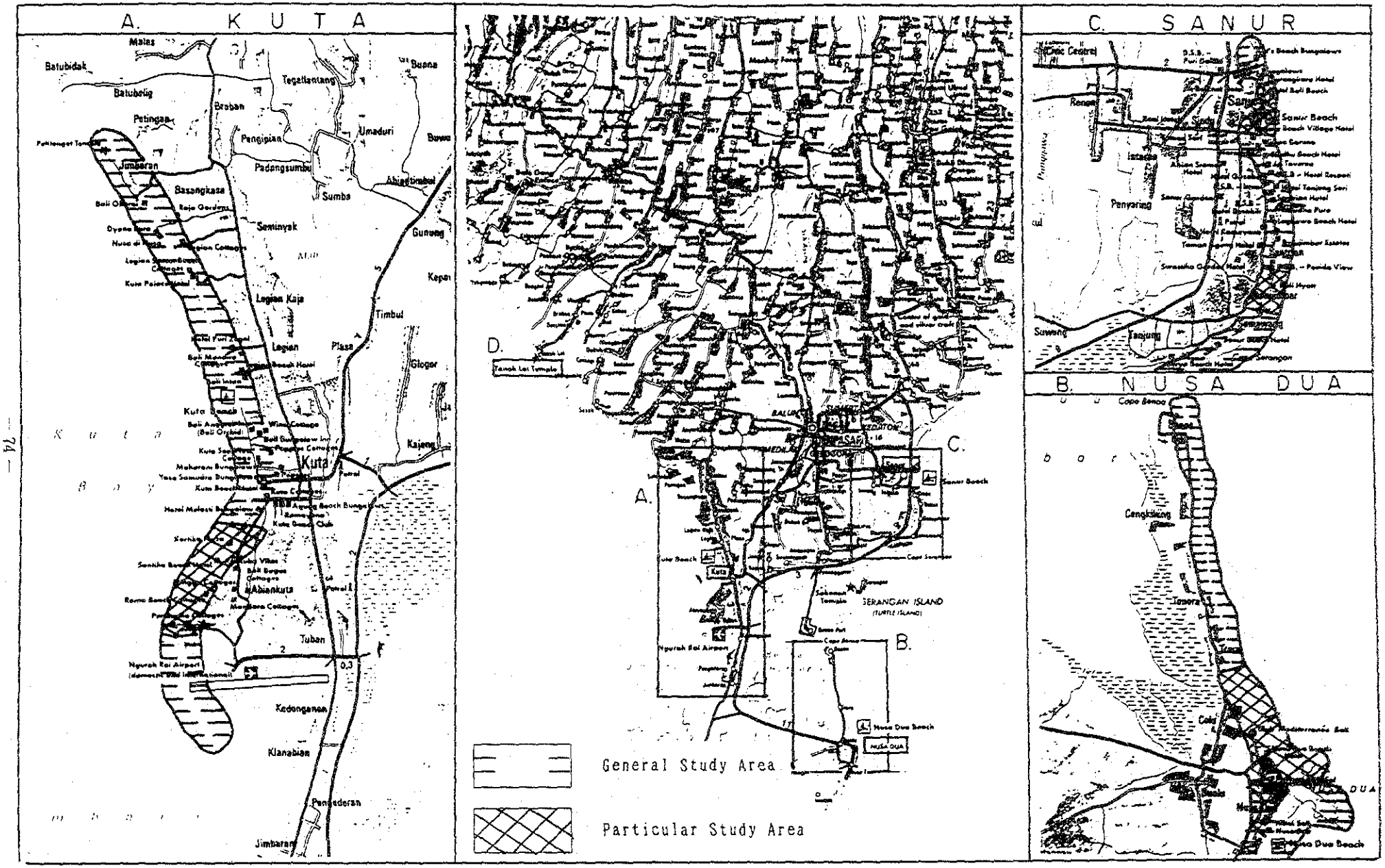


Fig. 3-1-1-1 Study Area

(3) Study Period

The study period is from June 25 to July 2 as shown in Table 3-1-1-1.

Table 3-1-1-1 Study Period

Area / Location	General Study Areas	Particular Study Areas
Kuta	27-28 June, 1988 8:00-16:00	27-28 June, 1988 5:30-8:00, 16:00-18:00
Nusa Dua	29-30 June, 1988 8:00-16:00	29-30 June, 1988 5:30-8:00, 16:00-18:00
Sanur	25-26 June, 1988 8:00-16:00	25-26 June, 1988 5:30-8:00, 16:00-18:00
Tanah Lot	1-2 July, 1988 8:00-16:00	1-2 July, 1988 5:30-8:00, 16:00-18:00

(4) Method

1) Marine Ecology

a. General Study Area

Sighting Method

b. Particular Study Area

Capture Method & Sighting Method

2) Birds

a. General Study Area

Route Census Method

b. Particular Study Area

Point Census Method

(5) Results

One of the objectives of the present study is to compile a list of the species found living in the study areas. The species richness of an ecosystem can be used as an indicator of the condition of the particular ecosystem. More than 105 species of marine fauna and flora, and birds are found (Table 3-1-1-2).

1) Kuta

The beach condition in Kuta is more or less similar to that at Sanur, except that there are no seagrass beds here. The sand is much finer and the slope is gentler than at Sanur. Reefs are found quite near to the coast line, stretching from the airport runway up to the Kartika Plaza Hotel. At the other part of the beach, the reefs are located further seaward.

The coral reefs located near the coast line are in a very bad condition. Since there is very little evidence of physical disturbance (stone coral, which is the main coral collected as building material, is found intact and scattered along the coast), it seems that sedimentation is the main cause of the death of the coral. It is not yet clear whether the sedimentation is natural or a side-effect of human activities, e.g. bad land use further inland or construction of erosion protection facilities.

The flora and fauna of this dead reef are very poor. It seems that sedimentation has severely disturbed the ecosystem. A more detailed study is still needed to clarify the situation.

Two species of seabirds were seen at this study site, i.e. Sterna hirundo and Fregata sp. They were seen feeding out of the coral reef barrier during low tide.

2) Nusa Dua

The beach at Nusa Dua is similar to that at Sanur. Seagrass beds, which are in a very good condition, dominate the coast. These are adjacent to a dead reef zone offshore.

The marine flora and fauna of this particular site is much richer than at Kuta and Sanur. Locals are seen collecting marine animals for food, and coral sand for limestone production, at low tide. Although these activities have taken place regularly for quite a long time, the marine life is still in much better condition than at the other study sites. It is not clear yet whether the richness of this area is natural or because of much less human disturbance.

Two species of seabirds were seen (Sterna hirundo and Fregatta andrewsi). Flocks of two species of plover (Charadrius dubius and Charadius mongolus) were found actively feeding along the shore, while one individual of eastern reef heron Egretta sacra was seen around the beach.

3) Sanur

The beach is dominated by seagrass (Enhalus) approximately 50 to 100 meters wide, adjacent to a dead coral zone of approximately 30 to 70 meters. Seagrass was flourishing at Tanjung which is situated at the southern edge of the area. This condition may result from the sandy-muddy substratum, which is the most favourable condition for the seagrass covering this area. The seagrass is in a much poorer condition at the other locations along the beach, where sand and fragments of coral dominate the substratum. Several types of fish (Gobiids), crabs (Portunus), sea urchins (Diadema), sea cucumbers (Holothuria), and mollusks (Cerithidea, Arcularia) are found living in the seagrass area.

At the dead reef zone, very few animals and algae were found. The scarcity of the common coral dwelling animals and algae may be due to the bad condition of the reef. The present condition may have resulted from the destruction and collection of coral for various purposes, e.g. for building materials, lime production, etc., which is a common practice among the locals.

Only few seabirds were seen during the morning and afternoon

surveys. These birds consist of only one species, Sterna hirundo, a common tern. They were seen diving, but only occasionally. It seems that this site is not their traditional feeding ground. A flock of Pasific swallow (Hirundo tahitica) was also seen flying around the beach.

4) Tanah Lot

The nature of the beach at this site is very different from the other study sites. It consists of volcanic rocks with a small sandy area in between. The marine fauna and flora are typical of a rocky shore. The condition is good, despite disturbance from the tourists during low tide.

Only one seabird was noticed in this area, i.e. Sterna hirundo. From the observations along the rocky wall, it was found that birds had slept in some of the small caves and crevices quite recently. But it seems that this area is not a roosting site, since there was no indication of nesting whatsoever.

(6) Conclusion

Several conclusions are put forward below.

1) The marine life in Kuta is in a bad state. But in Nusa Dua and Sanur, the condition is considered as good, assuming that the level of disturbance is not increasing.

2) The main reason for beach erosion at the three sandy beaches is the destruction of the coral reefs. The destruction may be due to the collection of coral or high siltation. The condition of the seagrass beds which lie between the reefs and coast line depends on the condition of the coral reefs.

3) The observations clearly indicate that human population affects their activities. In less crowded areas (e.g. Nusa Dua), the birds still maintained their feeding activities. Only a few types of birds were seen, probably because the study took place during a period when migratory birds are generally not present.

Table 3-1-1-2 List of Marine Life and Sea and Shore Birds Found in the Four Study Sites

(1)

SPECIES	KUTA	NUSA DUA	SANUR	TANAH LOT
SEAWEEDS				
1. *Ulva lactuca*	-	-	+	+
2. *Caulerpa racemosa*	-	-	+	-
3. *Caulerpa* sp.	-	-	-	+
4. *Valonia macrophysa*	-	-	+	-
5. *Valonia ultracularis*	-	-	-	+
6. *Valonia* sp.	-	-	+	-
7. *Clinoospora* sp.	-	-	+	-
8. *Bryopsis* sp.	-	-	+	-
9. *Sargasum confusum*	-	-	+	-
10. *Sargasum fulvellum,*	-	-	+	-
11. *Sargassum selequosum*	+	-	-	+
12. *Halimeda opuntia*	-	+	-	+
13. *Actinotrochia* sp.	-	-	+	-
14. *Ecklonia cava*	-	-	-	+
15. *Cladophoropsis*	-	-	-	+
16. *Cladophora*	-	-	-	+
17. *Dictyopteris* sp.	-	-	-	+
18. *Chondrococcus* sp.	-	-	-	+
19. *Chlorodesmis* sp.	-	-	-	+
20. *Grateloupia* sp.	-	-	-	+
SEAGRASS				
21. *Enhalus acoroides*	-	+	+	-
CORAL (dead fragments only)				
22. *Goniopora stutchboury*	+	+	+	-
23. *Platispea lamellina*	+	+	+	-
24. *Tubipora musica*	+	+	+	-
25. *Seriatopora hystrix*	+	+	+	-
26. *Fungia fungites*	+	+	+	-
27. *Balanophyllia* sp.	+	+	+	-
MOLLUSKS				
28. *Monetaria annulus*	-	+	+	-
29. *Monetaria moneta*	-	+	-	-
30. *Erronea erroues*	-	-	+	-
31. *Mauritia arabica*	-	+	-	-

SPECIES	KUTA	NUSA DUA	SANUR	TANAH LOT
32. *Cypraea carneola*	-	+	-	-
33. *Cyparea lynx*	-	+	-	-
34. *Cypraea vitellus*	-	+	-	-
35. *Cymatium pilearum*	-	-	+	-
36. *Patella radians*	-	-	+	-
37. *Haliotis asinina*	-	+	-	-
38. *Trochus maculatus*	-	+	-	+
39. *Conus magus*	-	+	-	-
40. *Conus miles*	-	+	-	-
41. *Voluta vespertilio*	-	+	-	-
42. *Acmaea saccharina*	-	-	+	+
43. *Acmaea* sp.	-	-	-	+
44. *Batillaria zonalis*	-	-	+	-
45. *Planaxis sulcatus*	-	+	+	+
46. *Arcularia thersites*	-	-	+	-
47. *Arcularia arcularia*	-	-	+	-
48. *Polynices mamilla*	-	-	+	-
49. *Drupa musiva*	-	-	+	+
50. *Drupa margaritiicola*	-	-	-	+
51. *Nerita undata*	-	-	+	-
52. *Nerita albicilla*	-	-	+	-
53. *Nerita polita*	-	-	+	-
54. *Nerita costata*	-	-	+	-
55. *Dolabella* spp.	-	+	-	-
56. Bulla ampulla	-	-	+	-
57. Clava obeliscus	-	-	-	+
58. Clypeomorus moniliferum	-	-	-	+
59. Cantharus cecillii	-	-	-	+
60. Stombus succintus	-	-	+	-
61. Cardium unedo	-	+	+	+
62. Anadara sp.	+	+	+	-
63. *Spondylus* sp.	-	+	+	+
64. *Crassostrea cucullata*	+	+	+	+
65. *Brachiodontes biloculoris*	-	+	-	-
66. *Pinctada margaritifera*	-	+	-	-
67. *Pinna muricata*	+	+	+	-
68. *Sepia* spp.	-	+	-	+
69. *Loligo* spp.	-	+	-	+
70. *Octopus* sp.	+	+	-	+
CRABS				
71. *Majidea*	+	+	+	-
72. *Porlunus pelagicus*	-	+	+	-
73. *Macropthalmus* spp.	+	+	+	-
74. *Grapsidae*	+	+	+	-
75. *Anomura*	+	+	+	+
76. *Dorippidae*	+	+	+	-

SPECIES	KUTA	NUSA DUA	SANUR	TANAH LOT
FISHES				
77. *Stelophorus* spp.	-	-	+	-
78. *Anguila* spp.	+	+	+	+
79. *Synanceia* spp.	-	-	-	+
80. *Plotosus* spp.	+	-	+	-
81. *Oxyeleotris* spp.	+	+	+	+
82. *Amphiprion xanthanus*	-	-	+	-
SEA URCHINS				
83. *Diadema setosum*	+	+	+	+
84. *Echinometra mathaei*	-	+	-	-
85. *Echinotrix* sp.	+	+	+	-
86. *Salmacis* sp	+	+	+	-
87. *Acanthaster* spp.	-	+	-	-
SEA CUCUMBERS				
88. *Holothuria edulis*	+	+	+	-
89. *Holothuria scabra*	-	-	+	-
90. *Bahadschia* sp.	-	+	-	-
91. *Thelomata* sp.	-	+	+	-
SHOREBIRDS				
92. *Charadrius dubius*	-	+	-	-
93. *Charadrius mongolus*	-	+	-	-
94. *Egretta sacra*	-	+	-	-
SEABIRDS				
95. *Fregata andrewsi*	+	+	-	-
96. *Fregata* sp.	-	+	-	-
97. *Sterna hirundo*	+	+	+	+
98. *Sterna* sp.	+	+	+	-
OTHER BIRDS				
99. *Halcyon chloris*	+	+	+	+
100. *Hirundo tahitica*	+	+	+	+
101. *Rhipidura javanica*	+	-	+	-
102. *Passer montanus*	+	+	+	+
103. *Lanius schach*	+	+	+	-
104. *Lonchura punctulata*	+	-	-	-
105. *Pycnonotus goiavier*	+	+	+	-
106. *Collocalia esculenta*	+	+	+	+

4) It is suggested that the means of protecting the beach from erosion should take aesthetic factors and the conservation of marine and other associated animals into consideration. If erosion protection facitities are needed, they should be built in harmony with nature.

5) With regard to regulations concerning flora and fauna, no protected species are located in the study areas.

3-1-2 Landscape

(1) Factors of Landscape

Land use at the coastal area differs from that further inland.

The coastal area is used as a walkway to the beach and as the site of hotels, restaurants, water sports facilities, etc. for tourists, while the area behind the coastal area is used for access to paddy fields and as a residential area.

The typical landscape in the coastal area in Bali is composed of the sun, sky, sea, coral reef, sand, plants and artificial structures.

The classification of study areas is shown in Fig. 3-1-2-1.

1) Kuta

Kuta can be divided into three parts: northern Kuta (north of the Legian Beach Hotel), central Kuta (the area between the Lengian Beach Hotel and the Santika Plaze Hotel) and southern Kuta (south of the Santika Plaza Hotel)

Northern Kuta:

The beach is the widest and flattest of the three beach. Erosion isn't progressing in this area, so there are few erosion protection facilities other than the Hotel Oberoi which has protection facilities against river erosion.

Recently hotels are being constructed in this area, but land utilization is still low, mostly strolling and sun-bathing.

The landscape of this area is monotonous because the composition

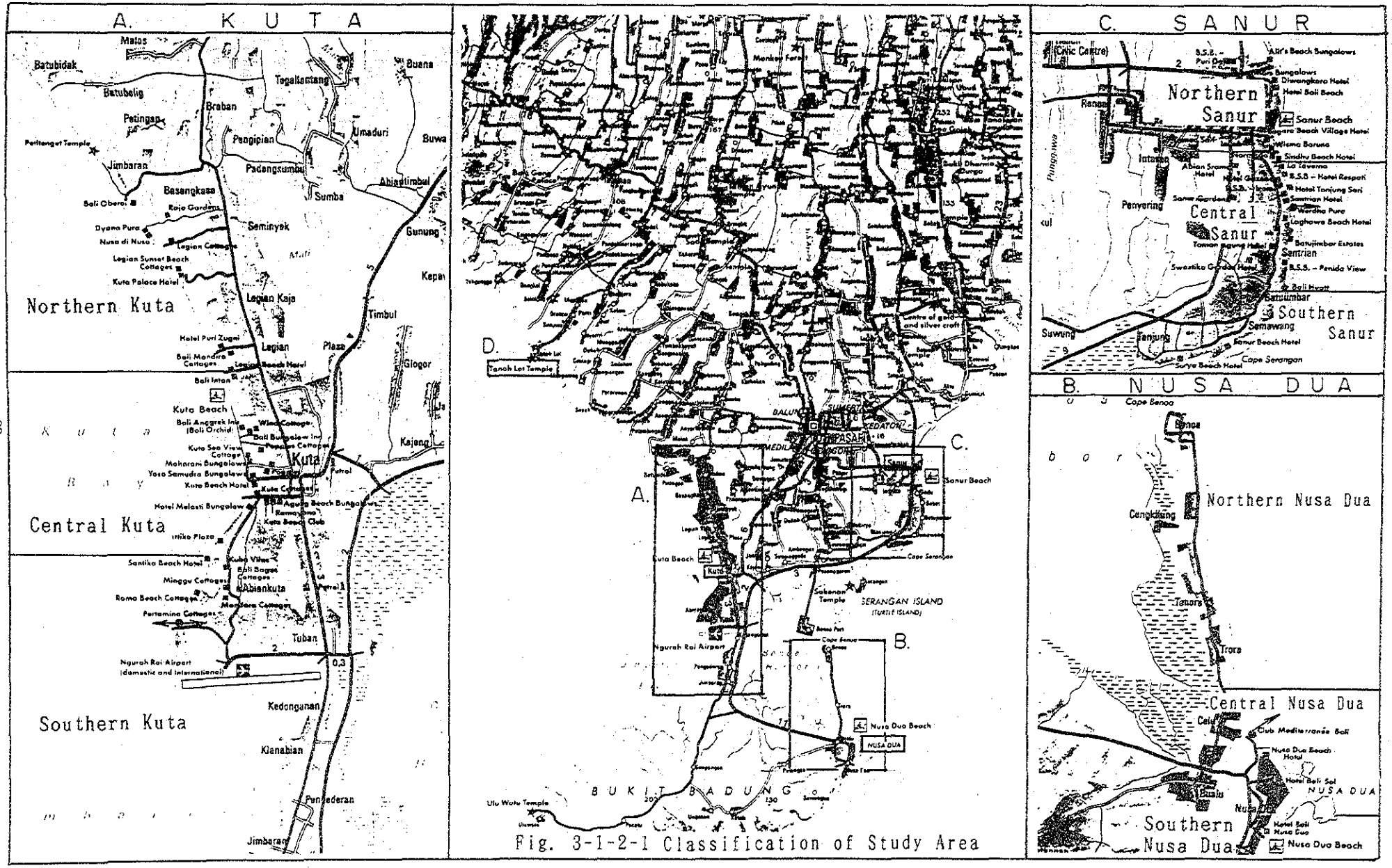


Fig. 3-1-2-1 Classification of Study Area

of this landscape is level, but is very natural because there are few artificial structures.

Central Kuta:

The area has many hotels and restaurants.

The present condition of the beach is narrower and steeper than northern Kuta.

Erosion in this area is progressing, with coconut trees with exposed roots and several erosion protection facilities that are old and have been destroyed. These old structures interfere with the natural landscape.

This area is famous for surfing, so there are many hotels and losmens located behind the beach and many tourists visit this area. And the beautiful sunset is also very famous known.

The landscape of this area is monotonous like northern Kuta, but the beach like a bow so the landscape of this area has a deep appearance.

Southern Kuta:

The area has very little sand, but includes many hotels, restaurants, and erosion protection facilities.

Especially in front of Pertamina Cottages, there is no beach at high water. The shape and color of these erosion protection facilities are not so good and the destroyed hotel is exposed to the wind and rain so the landscape of this area seems desolate.

In this area there are many big hotels, but the main utilization is the view from the hotels and restaurants and strolling at low water.

The landscape of this area has some obstructing factors, but the area has a feeling of variety.

And in the southern area of Ngurah Rai Airport the landscape is similar to that of central Kuta. This area is used for inshore fishery by local people. It isn't used by tourists. But recently marine sports facilities were prepared at Jimbaran, so in future utilization by tourists will increase.

2) Nusa Dua

Nusa Dua can also be divided into three parts: northern Nusa Dua (north of Club Med.), central Nusa Dua (the area between Club Med. and the south island of Nusa Dua) and southern Nusa Dua (the south area of the south island of Nusa Dua).

Northern Nusa Dua:

The beach is the narrowest of the three beaches. There are some erosion protection facilities, and part of them are destroyed but most of them are equipped completely so they do not obstruct the landscape. And waste water is poured into the sea near Tanjung Benoa near a concentration of restaurants.

In this area there are no accommodations. But there are marine sports bases for scuba diving, water skiing, jet skiing, surfing, wind surfing, snorkeling, yachting, fishing, canoeing and para sailing. And there is also a seaweed farm.

The landscape of this area has some negative factors such as no grass and a narrow beach, but it has a feeling of activity because of the marine sports bases.

Central Nusa Dua:

The present condition of beach is narrow and vey steep and erosion is progressing.

In front of Club Med. there are many erosion protection facilities some of them obstruct the landscape but most of them have a reasonable shape, color and decoration. And the sunrise at Nusa Dua is very beautifual.

In this area there are many big hotels, and these hotels are equipped with marine sports facilities like at northern Nusa Dua and many outriggers called "Jukung" by the local people.

Th landscape of this area has a image of variety, because it has many factors especially the islands.

Southern Nusa Dua:

The typical landscape in this area is similar to central Nusa Dua, but it has grass and a wide beach because erosion is scarcely progressing. And there is a tidal area with aquatic plants, animals and birds. On the south island of Nusa Dua there are many

arbors and lawns.

Erosion is scarcely progressing, so there are no erosion protection facilities in this area.

In this area there are big hotels and a beach market, but there are not so many tourists.

So the landscape of this area has a feeling of calm.

3) Sanur

It's possible to divide Sanur into three parts; northern Sanur (north of the Sindu Beach Hotel), central Sanur (the area between the Sindu Beach Hotel and the Bali Hyatt Hotel) and southern Sanur (south of the Bali Hyatt Hotel).

Northern Sanur:

The prersent condition of the beach is not so narrow, but steep. Only the north arera of Bali Beach Hotel has a narrow beach.

The characteristic factors are the main tower building and big groin. In Bali it is prohibited to build structures which are taller than the coconut palms, but this building was built before the regulation was established, and can be seen from far away. The shape, color and decoration are not so good.

The big groin's color and decoration also aren't so good because it is old and destroyed, but it's shape is creative, so it is a land mark in this area.

In this area there are many big hotels with marine sport facilities, so the beach is used as a sports area. And at low tide many tourists stroll on the coral reef.

The landscape of this area has an image of richness because it has various factors.

Central Sanur:

The typical landscape of this area is similar to northern Sanur.

The present condition of the beach is narrow and steep.

In this area erosion is progressing remarkably, so there are many erosion protection facilities. Groins divide the narrow beach and sea walls hinder the utilization of the beach, but offshore

breakwaters are arranged and the design is relatively good.

There are mostly small hotels without sport facilities, so utilization of the beach is limited to strolling and sun-bathing.

The landscape of this area has a poor image because of the narrow beach and lack of sport facilities.

Southern Sanur:

The typical landscape of this area is similar to northern Kuta.

The present condition of the beach is narrow and steep, and some parts of this area have no beach. There are some erosion protection facilities, but some of them are destroyed and divide the beach, so they obstruct this area's landscape.

The landscape of this area isn't so good, but it has a natural feeling because there are few artificial things.

4) Tanah Lot

The characteristics of this area are Tanah Lot as an island, with a rocky shoreline and no beach.

Tanah Lot is a remarkable Hindu Temple situated on a huge rock offshore, so is famous for its special landscape. It is set apart from the land by a stone basin that dries up at low water.

The rock has been eroded by incoming waves, so there are many erosion protection facilities, but some old facilities are not so beautiful. New facilities are under construction, and will not look too artificial.

The utilization of this area is to enjoy the landscape of Tanah Lot and to stroll around the stone basin at low tide. And Tanah Lot is the site of local festivals.

In this way the landscape of Tanah Lot is dynamic and pleasing.

3-1-3 Present Condition of Tourism

In order to grasp the present conditions of tourism, a questionnaire was distributed to ask each tourist in Kuta, Nusa Dua, Sanua Beaches and Tanah Lot. The questionnaire included nationality,

number of visits, purpose of visit, impressions of coastal protection facilities and so forth. The questionnaire was distributed at each site during four days from 5th to 9th July, 1988. The total number of responses was 129 in Kuta Beach, 68 in Sanur Beach, 81 in Nusa Dua Beach and 100 in Tanah Lot. A review of the data obtained from the questionnaires yields the following characteristic information (refer to Appendix 3-1-3).

At Kuta Beach, about half of the tourists are Australian and many tourists visit twice or mainly to enjoy bathing, surfing, diving and touring. In Nusa Dua Beach, tourists from vartious countries over the world visit to enjoy many kinds of marine sports. More than half of the tourists in Sanur Beach are from Europe for the main purpose of bathing and touring. On the other hand, Tanah Lot with its traditional Hindu temple on the top of the cliff is characterized by many domestic tourists.

Impressions of protection facilities against erosion damage (sewall, wave-absorbing blocks, groin, U-shaped breakwater, offshore breakwater) are in general good at every site because there are few negative answers to the questionnaires. However, taking into consideration the high evaluation of the tropical landscape of Bali, the relatively low evaluation of the above facilities might represent feelings that they obstruct the natural setting. However, among these facilities the U-shaped breakwater and four offshore breakwaters at Nusa Dua Beach are evaluated higher than the other facilities. These positive feelings may result from the newness and simplicity in shape, color and decoration and the use of natural coral. Among the coastal protection facilities at every site, groins generally did not receive a high evaluation except for the big groin which was constructed as a heliport in front of the Bali Beach Hotel. This high impression of the big groin might be derived from its good equipment including handrails and lamps.

3-1-4 Sea Water Quality

(1) General

Sea water quality is measured at the area near Benoa Harbor by the local government. The points of measurement are shown in Fig. 3-1-4-

1 and the results are shown in Table 3-1-4-1.

In general the sea water quality is good, but some parameters are not up to standard. This may be because waste water from residential areas in Denpasar is pouring into the sea.

(2) Field Reconnaissance

1) Study Items

Living environmental parameters

①	pH	②	SS	③	T-N	④	T-P
⑤	DO	⑥	COD	⑦	BOD	⑧	E. coli

2) Study Area

The sampling points are shown in Fig. 3-1-4-2.

3) Study Period

Sampling	16-18 June, 1988
Analysis	16-25 June, 1988

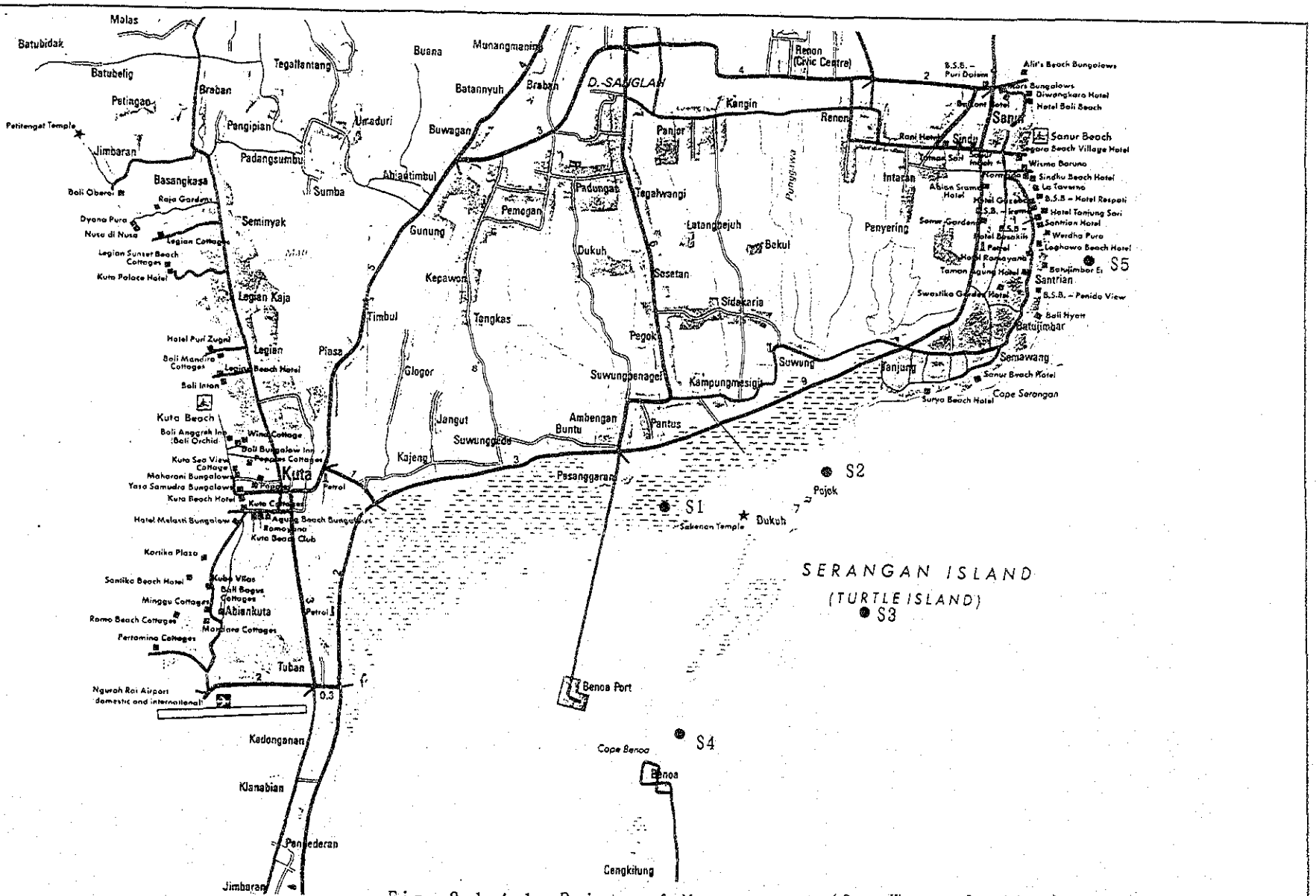


Fig. 3-1-4-1 Points of Measurement (Sea Water Quality)

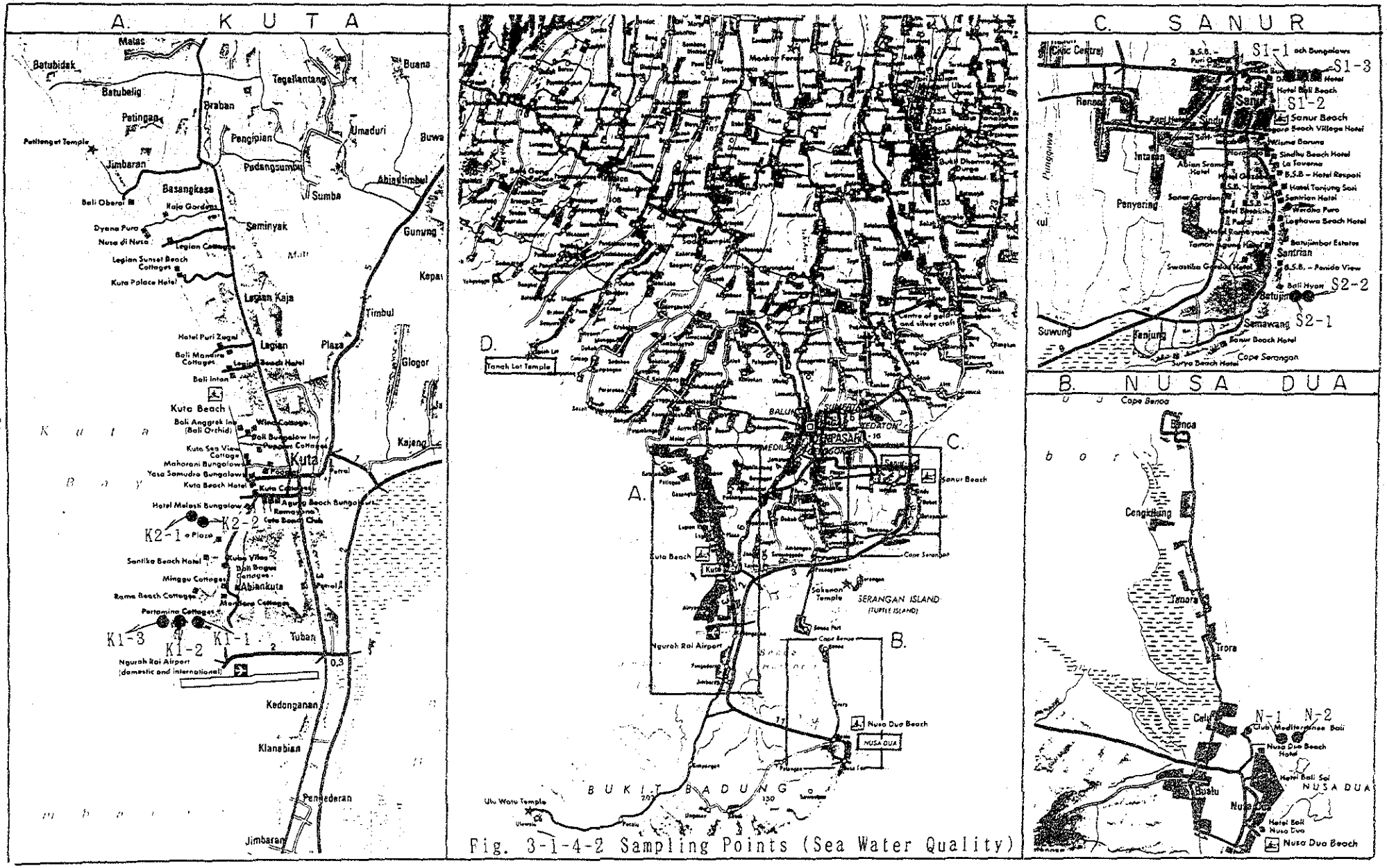


Fig. 3-1-4-2 Sampling Points (Sea Water Quality)

(3) Results

The results of the field survey are shown in Table 3-1-4-2. These are similar to the measurements by the local government. It can be said that the sea water quality at the four study areas is good, but sea water pollution may be increasing in the area around southern Bali.

Table 3-1-4-1 Results of Sea Water Quality Measurement

PARAMETER	UNITY	STATION					STANDARD		
		S1	S2	S3	S4	S5	Bathing and swimming	Sea animals and plants	Develop of the sea animals and plants
pH	–	7.8	7.5	7.3	8.0	7.5	6.5～ 8.5	6.5～ 8.5	6.5～ 8.5
DO	mg / ℓ	4.5	5.8	6.8	5.5	5.5	≧ 5	≧ 4	≧ 5
COD	〃	13.0	5.0	3.1	11.4	9.8	≦ 12	≦ 11	≦ 11
BOD	〃	4.1	4.0	2.9	3.7	6.4	≦ 6.0	≦ 6.0	≦ 6.0
E. coli	MPN/100 ml	21	240	27	5	7.5	≦ 1000	–	≦ 1000

Table 3-1-4-2 Results of Field Survey (Sea Water Quality)

PARAMETER	UNITY	KUTA					NUSA DUA		SANUR					TANAH LOT
		K1-1	K1-2	K1-3	K2-1	K2-2	N-1	N-2	S1-1	S1-2	S1-3	S2-1	S2-2	
pH	–	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.1	8.5	8.5	8.5	8.5	8.5
SS	mg / ℓ	41.9	35.6	40.9	38.1	47.2	47.5	46.5	23.2	40.6	46.9	42.6	40.5	45.7
T-N	〃	2.8	2.8	3.1	3.6	3.1	2.3	2.3	12.6	2.3	2.6	2.0	2.0	3.2
T-P	〃	1.5	1.7	1.9	1.2	1.2	0.3	0.6	4.5	1.7	1.4	1.6	1.6	0.5
DO	〃	6.0	6.0	5.9	5.5	5.7	6.0	6.1	6.5	5.8	6.1	6.0	6.2	7.0
COD	〃	6.3	19.3	14.2	15.8	7.9	4.7	6.3	6.3	3.2	11.1	4.7	4.7	41.1
BOD	〃	2.8	2.8	2.4	3.6	3.6	3.1	3.2	1.8	3.3	2.5	2.8	3.3	2.5
E. coli	MPN/100 ml	4.4	2	2	0	0	0	5	240	2	2	0	0	240

3-2 Land Use

3-2-1 Present Land Use

The three major areas were sparsely populated before the 1960s. There were a few small villages and most of the inhabitants were fishermen and small farmers.

During the mid-sixties, tourism in Bali experienced a rapid growth rate, along with hotel development. Tourist-related service activities were also induced by this development.

The major features of land use for each area are as follows:

Kuta (Fig. 3-2-1-1)

Hotels and rosmen are spread in the narrow area along Kuta beach. The hinterland is used for rice fields.

- This area is mainly composed of two categories; the hotel area and the rosmen area. Almost all the areas are occupied and thus no further construction of new hotels is expected.
- Many shops and restaurants are located along the main street, especially for the tourists. This area has the highest density of shops and restaurants in Bali
- Residential areas are concentrated at both sides of Ngurah Rai International Airport
- The hinterland is used for rice fields

Nusa Dua (Fig. 3-2-1-2)

The Nusa Dua Resort Area is developed and managed by Bali Tourism Development Corporation (BTDC) in the context of the Nusa Dua Master Plan, 1973.

- The BTDC area is designed to create a dominant Balinese atmosphere. It comprises nine hotel lots all of which have been leased to developers. All the construction is of low density with a maximum height limitation of 15 meters. This is called a garden resort in that more than half of the area consists of park land covered with velvety green grass and garnished with

colourful flowers. Actually this is really an international standard resort.

- There are reserved hotel sites in the cape area. Developers plan to construct hotel facilaities at Yeh Kuwu Kaje, Terore Tengah, Terore Kaje, Desa Kampial and Desa Benoa.
- Traditional villages were moved to Bualu and form only one residential area in the Nusa Dua area. Land around the present residential area is reserved for a residential area in the future.

Sanur (Fig. 3-2-1-3)

This area shows the highest degree of various land use categories among the three resort areas.

- The hotel area spreads along Sanur Beach
- In the adjacent hinterland area behind the hotel zone there is a residential area
- Shops and restaurants are located along the main street, but they located rather densely around the Government offices
- The major features is the small number of rosmen. This area is composed of only three categories; hotel, residence and shops/restaurants

3-2-2 Future Land Use

(1) In Kuta and Sanur areas, no new hotels are expected because of land availability. Almost all the areas are already occupied by the existing hotels and rosmen.

(2) Nusa Dua has a glorious prospect for the further development of new hotels and the further expansion of hotel and tourism facilities. In six out of the nine BTDC hotel lots, new hotel buildings and halls are planned by the year 2000. In addition, some hotel construction is planned outside the BTDC area, especially in Terore Tengah.

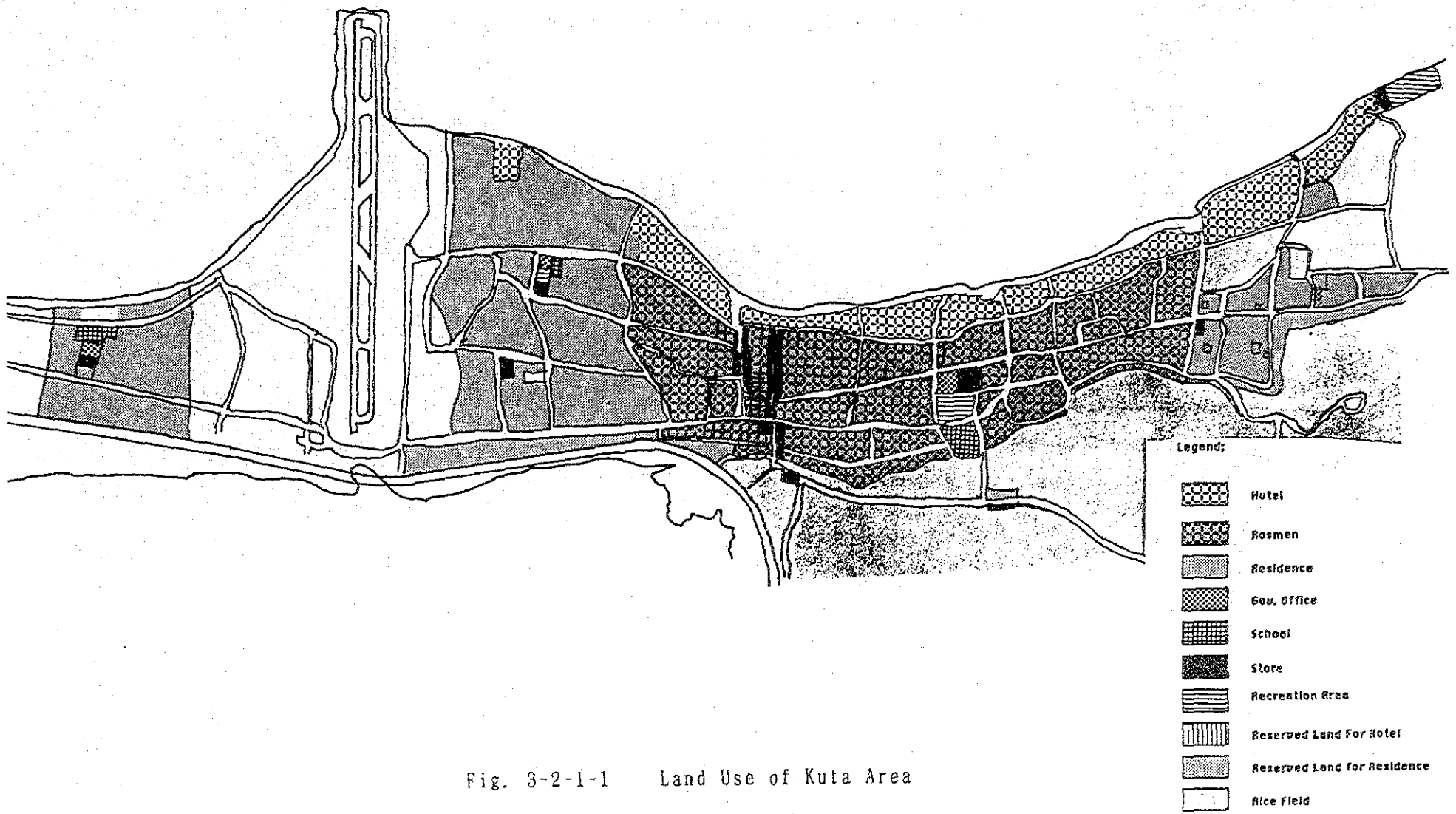


Fig. 3-2-1-1 Land Use of Kuta Area

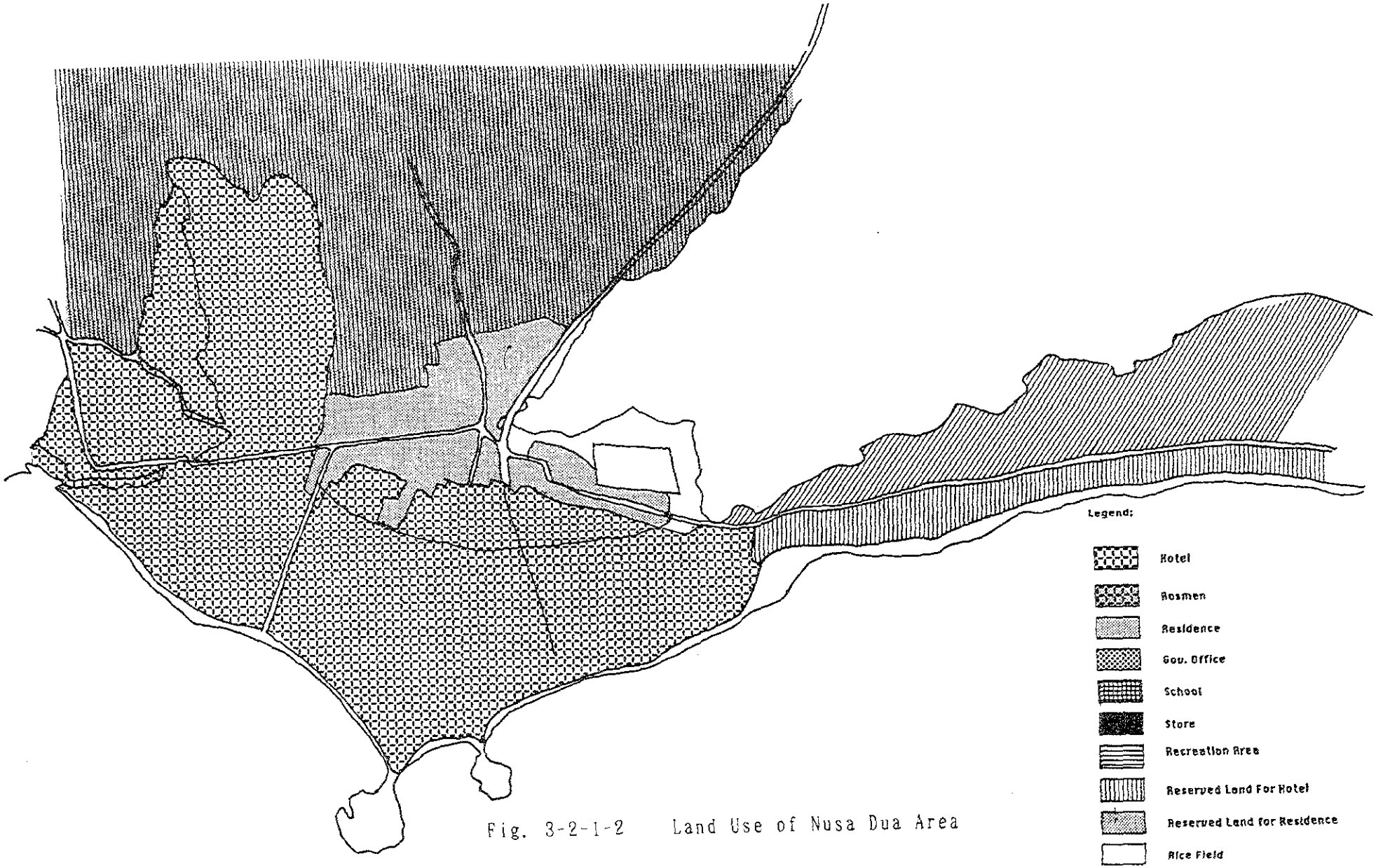


Fig. 3-2-1-2 Land Use of Nusa Dua Area

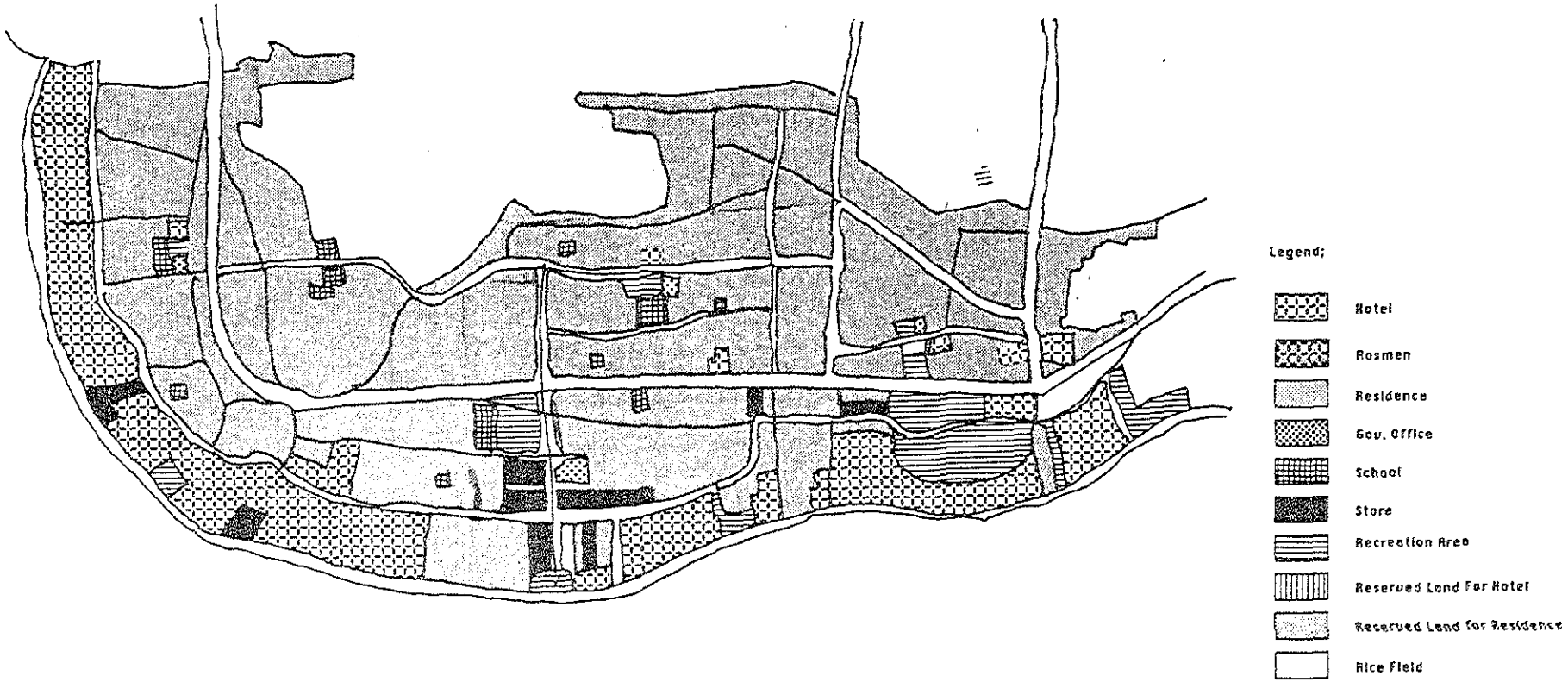


Fig. 3-2-1-3 Land Use of Sanur Area

3-3 Erosion

3-3-1 Erosion in Bali Island

The coastline of Bali island is approximate 430 Km long. The erosion process depends on the waves, tides and currents, etc. which all influence the amount of energy that is transported to the coast.

The locations of beaches and the present problems caused by erosion around Bali are listed in Table 3-3-1-1.

Table 3-3-1-1 Beach Erosion in Bali Island

No.	Location	Region	Length (Km)	Probemns
1	Kuta	Bandung	3	Erosion threat to tourism area
2	Sanur	Bandung	6	Erosion threat to tourism area
3	Nusa Dua	Bandung	3	Erosion threat to tourism area
4	Gumicik	Gianyar	1.5	Erosion caused by river mouth change
5	Lebih	Gianyar	0.8	Erosion threat to resident
6	Siyut	Gianyar	1	Erosion threat to rice field
7	Tegar Basar	Gianyar	1.8	Erosion threat to rice field
8	Sengkidu	Karangasem	1	Erosion threat to rice field
9	Candi Dasa	Karangasem	3	Erosion threat to tourism area
10	Tanha Lot	Tabanan	0.8	Erosion threat to ancient temple
11	Uluwatu	Bandung	0.2	Erosion threat to ancient temple
12	Sudimara	Tabanan	0.8	Erosion threat to fisherman Village
13	Gumrih	Jembrana	1.5	Erosion threat to National road
14	Candi Kusuma	Jembrana	0.5	River mouth closing
15	Pulaki	Buleleng	0.4	Erosion threat to provincial road
16	Gondol	Buleleng	0.4	Erosion threat to road and resident
17	Sangsit	Buleleng	0.2	Erosion threat to fisherman village
18	Bukti	Buleleng	2	Erosion threat to provincial road

Most of the beaches are apparently eroded because there is hardly any source of sediment and the surrounding coral reefs have been disturbed. On the other hand, hotel buildings are built so near to the beach that any loss of a beach is a threat to the tourism industry.

The urgency of beach conservation works is classified into four levels as shown in Table 3-3-1-2.

Table 3-3-1-2 Classification of Urgency for Beach Conservation

No. of Priority	Evaluation of urgency	Location of beach
No. 1	Urgently required	Kuta, Nusa Dua, Sanur, Batu Madeg, Tanah Lot, Uluwatu.
No. 2	Required	Lebih, Siyut, Tegar Besar, Gumicik, Sangsit
No. 3	Protection of Roads	Pulaki, Gondol, Bukit, Gumrih
No. 4	Future Work	Sudimara, Candi Kesuma

Based on the above classification, Kuta Dua, Sanur and Tanah Lot were selected as the project areas.

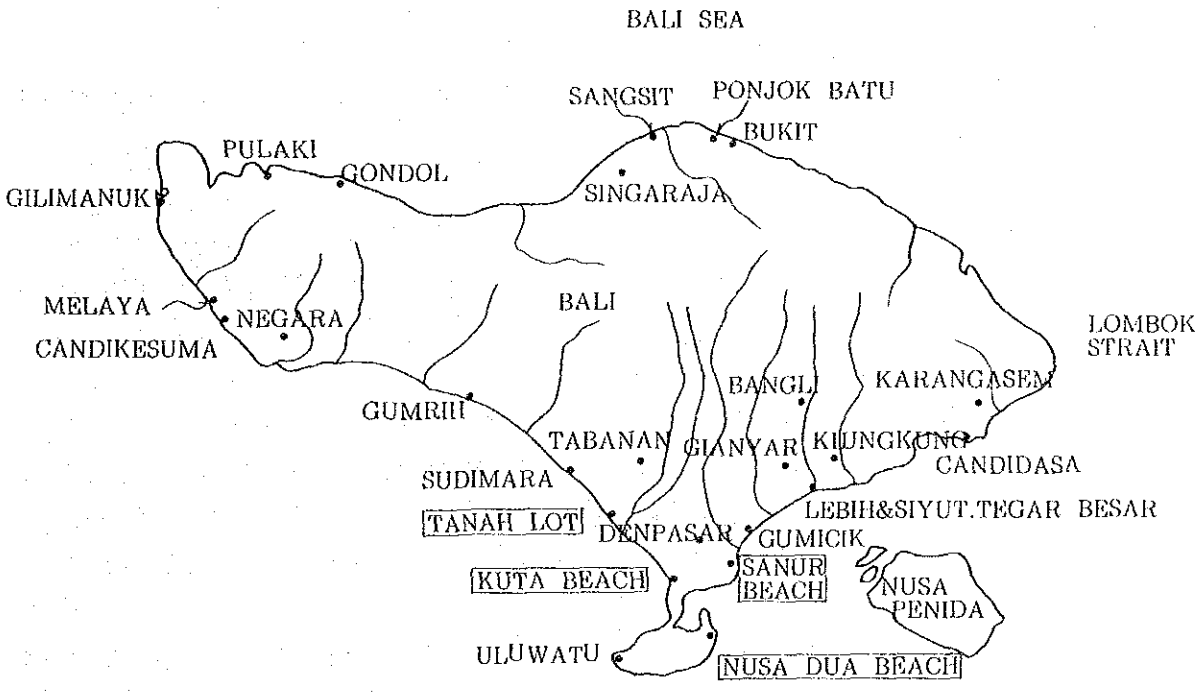


Fig. 3-3-1-1 Location of Beach Erosion in Bali Island

3-3-2 Erosion of Study Areas

(1) Change of shoreline (Kuta)

The existing beach erosion of the project areas is described in this section, based on the following information.

i. The result of the topographic surveys (including the shoreline) at Nusa Dua (1983), Kuta and Sanur (1978) and at all sites (1988).
ii. Reconnaissance surveys.
iii. Interviews with people nearby the study sites.
iv. Previous reports and papers.

The present condition of beach erosion at Kuta beach is described as follows.

Kuta beach is located on the west stretch of the southern part of Bali, and is one of the most attractive spots for tourists.

Beach erosion of Kuta beach seems to have begun right after the completion of the airport runway, around the year 1970. Since then the shoreline has retreated up to 200 meters including 50 meters from 1978 to 1988. Especially, divisions C through F show severe beach erosion.

The length of the study area is about 3.0 kilometers, and the area is divided into seven divisions (A through G) based on the erosion condition (Fig. 3-3-2-1).

1) Division A (1.0 km)

The shoreline in this reach retreated about 10-30 meters from 1978 to 1988.

2) Division B (0.52 km)

The shoreline has moved only 10-30 meters since 1976 because it is protected by the airport runway.

3) Division C (0.28 km)

The shoreline of this section retreated 35 to 45 m from 1978 to 1988.

The erosion at the north end of this division C is affected by the coastal wall constructed by Pertamina Cottage.

The wall had been built as a vertical structure and seemed to accelerate the beach erosion in front of it. But after being rebuilt as a mild slope wall, the deposition of sand is observed in the vicinity of the wall.

The groin on the north tip of the wall was constructed in 1987 and 1988, and is expected to protect the beach from further erosion near the wall.

4) Division D (0.50 km)

The retreat of the shoreline between 1978 and 1988 ranges from 50 to 70 meters, and the shoreline moved 100 up to 200 m between 1960 and 1988. Because of the severe erosion of the beach and the retreat of the shoreline, a number of fallen trees and ruined houses are observed on the foreshore area.

The scarp is about 0.5-1.0 meters high. For the purpose of protecting the beach in front of a former government building, a breakwater was constructed in 1984 by the Public Works Department.

5) Division E (0.28 km)

The shoreline retreated about 20 m from 1978 to 1988.

A groin was constructed by a hotel to protect it's land at the north end of the division.

The structure seems to be effective.

6) Division F (0.56 km)

The shoreline retreated about 20 meters from 1978 to 1988.

The scarp is about 1 meter high.

The land owner prepared conservation works such as groins (made of concrete pipes filled with stones) and wave breakers in front of his properties in an effort to stop the erosion. But all of them are broken or have sunk into the beach. This happened within the last one or two years.

7) Division G

As at Division F, the shoreline has retreated about 20 meters over the last 10 years. The beach is rather narrow.

(2) Change of beach profile (Kuta)

The change of beach profile between the years 1978 and 1988 is shown in Fig. 3-3-2-1～2.

The relation of the amount of the shoreline change (△y) and the change of cross-sectional area (△A) is seen in Fig. 3-3-2-3 which is roughly expressed in the form of△A = 4.0 ×△y.

(3) Volume of eroded beach sand (Kuta)

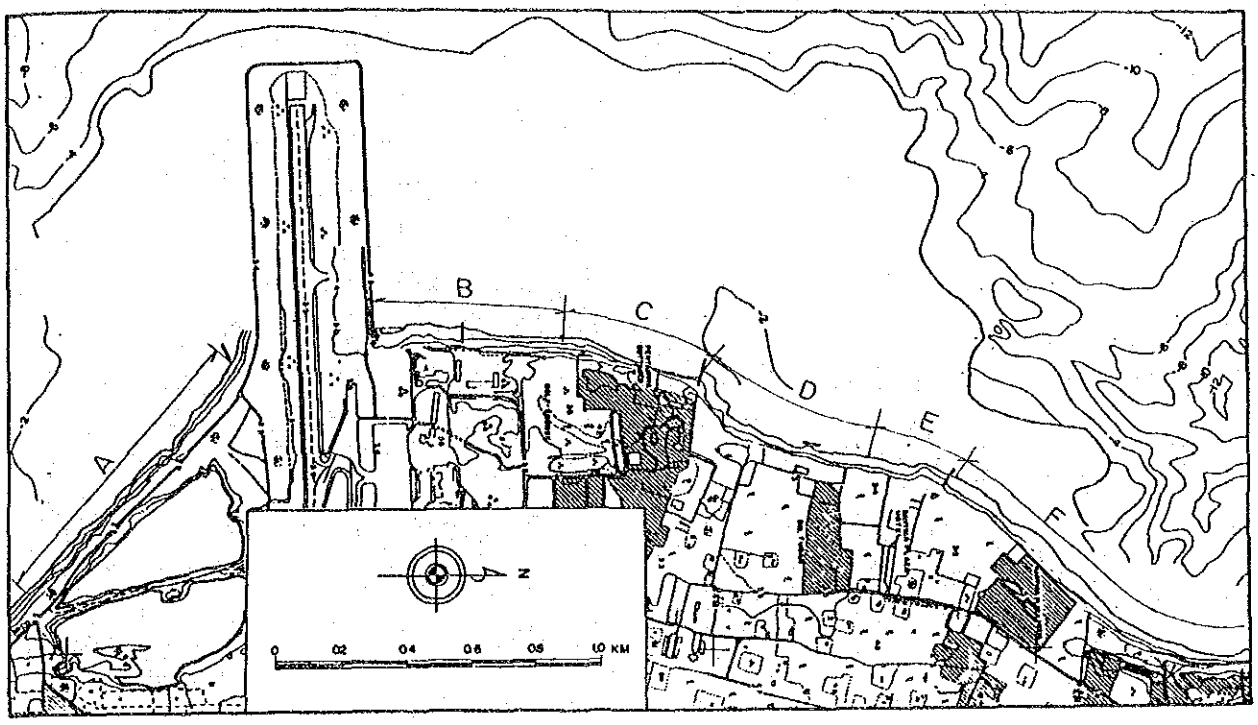
Area	Volume of sand loss
600 ～ 1,000 m	42,800 m^3
1,000 ～ 1,900	94,240
1,900 ～ 2,400	24,200
Total area 1,800 m	161,240 m^3/10 years

The total loss of sand is about 16,000 m^3 per year.

(4) Foreshore slope (Kuta)

Section	Slope	
	1978	1988
1,200 m	1/22	1/21
1,330	1/22	1/20
1,450	1/24	1/23
1,600	1/22	1/29

The foreshore slopes in the years 1978 and 1988 are almost the same; 1/22 ～1/24.



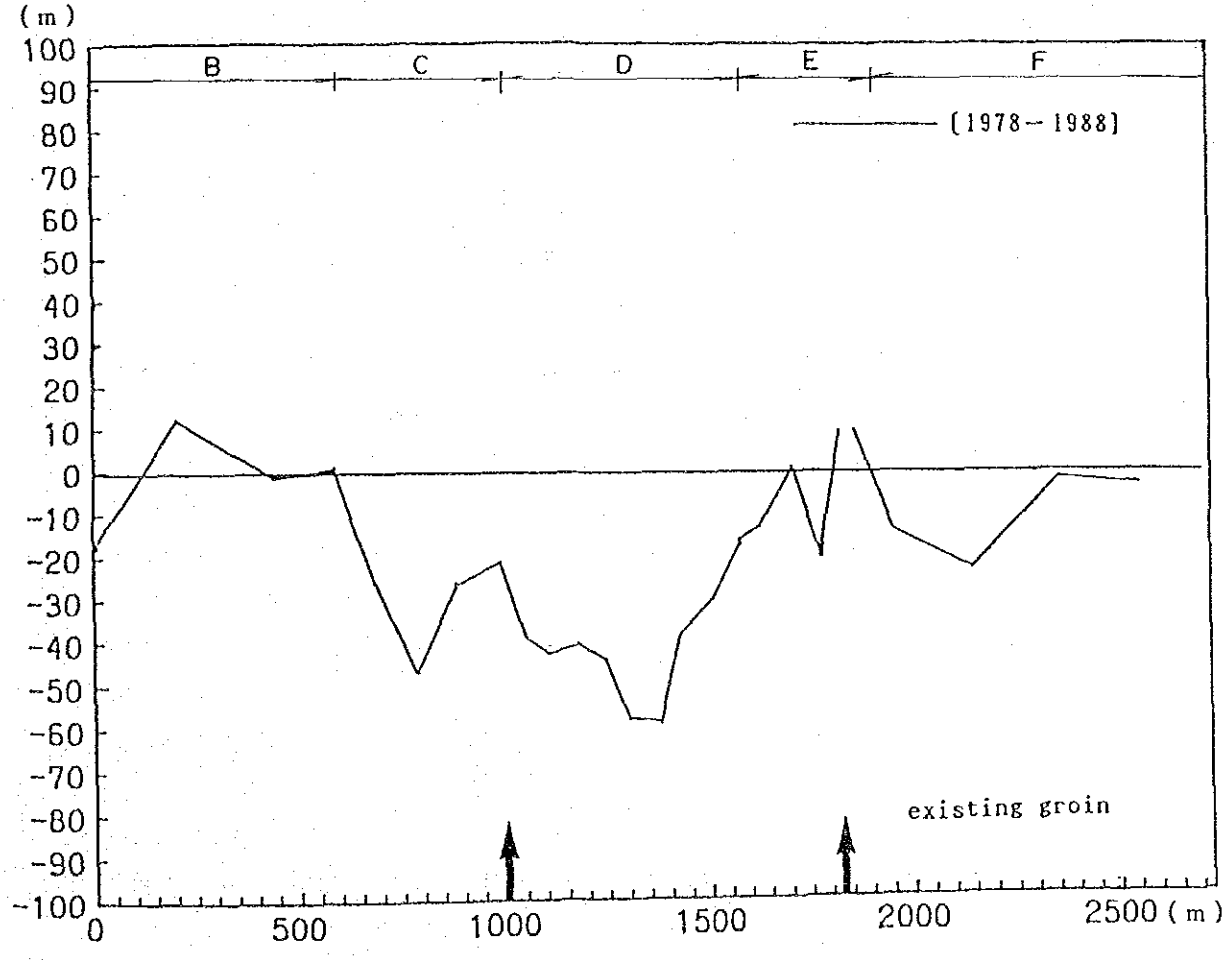


Fig. 3-3-2-1 Shoreline Change at Kuta

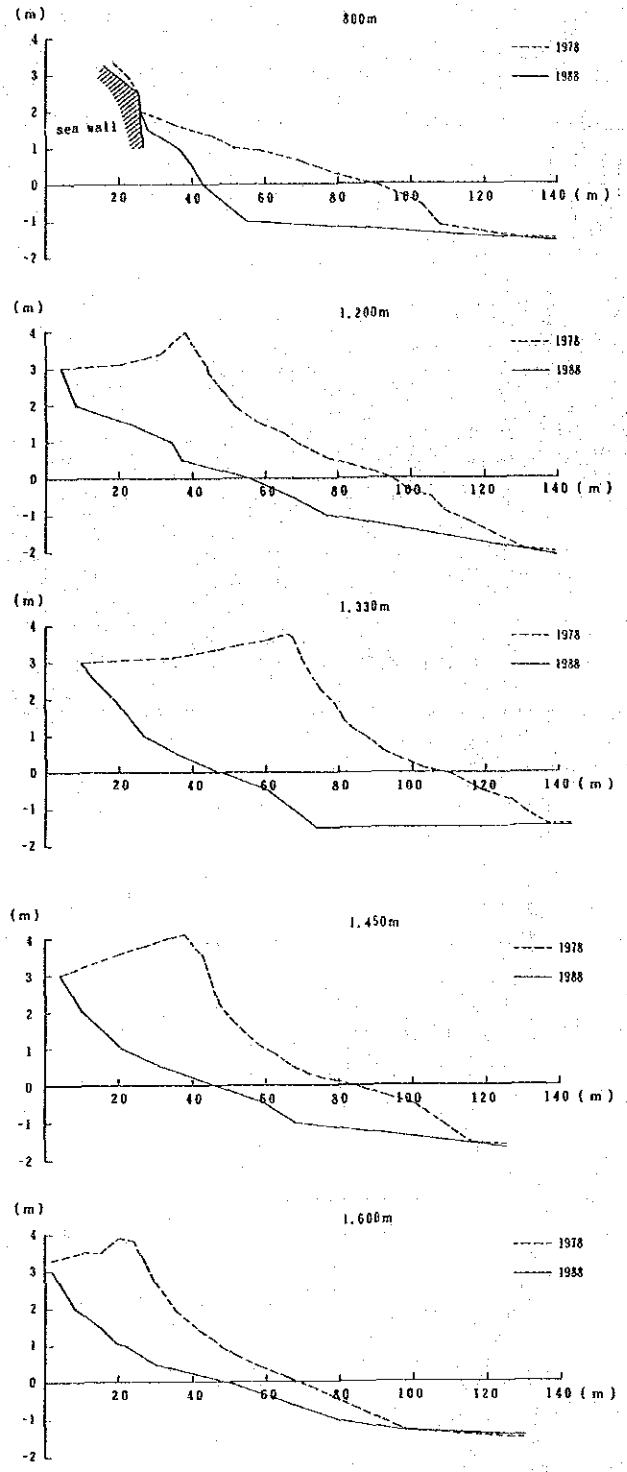


Fig. 3-3-2-2 Beach Profiles at Kuta

Section	△y (m)	△A (m²)
800m	48	186.5
1,200m	40	177.9
1,330m	58	280.6
1,450m	37	188.3
1,600m	16	95.0

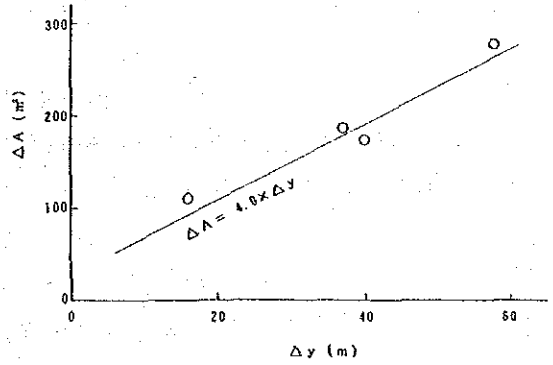


Fig. 3-3-2-3 Relation of △A and △y at Kuta

(1) Change of shoreline (Nasa Dua)

Nusa Dua is one of the beaches which stretch along the eastern coast of Bali. The study area is about 6 kilometers long.

Nasa Dua Beach is located in front of the hotel area in the teritory under Bali Tourism Development Corporation (BTDC), and is one of the important spots for the tourists.

Nusa Dua, meaning two islands, is connected with the main land with littoral sand, which prevents longshore drift to the northword.

This is assumed to be the cause of the beach erosion at the northern stretches of the beach.

The study area is divided into eight divisions from A through H according to the erosion condition (Fig. 3-3-2-4).

1) Division A (0.4 km)

This section, surrounded by two small island, Nusu Kecil and Nusa Besar, forms a stable beach and no retreat is observed on the shoreline between 1988 and 1983.

2) Division B (0.9 km)

Divisions B through F show rather severe erosion for these several years. Many kinds of protective works have been done throughout this beach. The shoreline retreat of division B is especially strong in the southern part of the division based on the results of the topographic surveys in 1983 and 1988.

In order to conserve the shoreline, beach nourishment works are being carried out. At the north end of the division a groin was constructed in 1985 and sand was brought in by the Public Works Department. The work seems to be successfull for shoreline conservation.

The foreshore beach slope is rather steep and beach a scarp (about 1 m in height) is observed at the beach, which suggests that the beach has been eroding.

3) Division C (0.45 km)

Of all the stretches of Nusa Dua beach, Division C shows the most severe erosion.

Comparing the topographic surveys in 1983 and 1988, the shoreline advanced during these five years. This is because of sand nourishment works in 1986 and 1987 and protective works such as detached breakwaters (in 1985) and extension of the groin (at the southern end of the division C) by the Public Works Department.

4) Division D (0.37 km)

This division had been suffering from severe erosion, as at Division C.

The erosion was probably because of the gap in the reef in front of the beach.

In order to block waves from entering the gap and also to prevent sand from being flushed away through the gap, a U-shaped offshore breakwater was constructed in 1987 by the Public Works Department.

And also the groin was extended in 1987 (at the northern of the division D), and sand was brought in to maintain the shoreline.

According to the shorerline survey, the shoreline advanced from 1983 to 1988 the sand tombolo development. The groin seems to

contribute to the stabilization of the beach.

Recently at the end of the rainy season in 1988, a part of the beach in front of Club Med was eroded by waves, which probably entered from the opening between the U-shaped breakwater and the strait offshore breakwater. Countermeasure works are being executed as urgent beach protection.

5) Division E (0.30 km)

In this Division, the shoreline is rapidly retreating.

The beach is narrow in width and rather steep on the foreshore.

6) Division F (0.15 km)

Referring to Fig. 3-3-2-4, the shoreline between the two groins which were built in 1986 and 1987 by the Public Works Department shows variations; the shoreline on the north shows an advance and on the south the shore is retreating.

The land owner has begun protection works on a private basis.

7) Division G (2.8 km)

The shoreline remained stable from 1983 to 1988.

But erosion is observed locally in several places and protection works such as groins are constructed by private land owners.

8) Division H (0.4 km)

This division, located at the north end of Nusa Dua beach, seems to be rather stable.

A groin constructed by the Public Works Dept. results in the deposition of sand on the south side, making the beach wider.

(2) Change of beach profile (Nusa Dua)

The change of the beach profile between 1983 and 1988 is shown in Fig. 3-3-2-4～6.

(3) Volume of eroded beach sand (Nusa Dua)

Change of sand volume within five years (1983-1988)	81,000 m^3
Total volume of sand fill within the same period	-100,000
	-18,900 m^3

The total loss of sand in five years is about 20,000 m^3; 4,000 m^3 per year.

(4) Foreshore slope (Nusa Dua)

Section	Slope	
	1983	1988
1000 m	1/9	1/16
1100	1/8	1/13
1200	1/10	1/8
1300	1/10	1/18

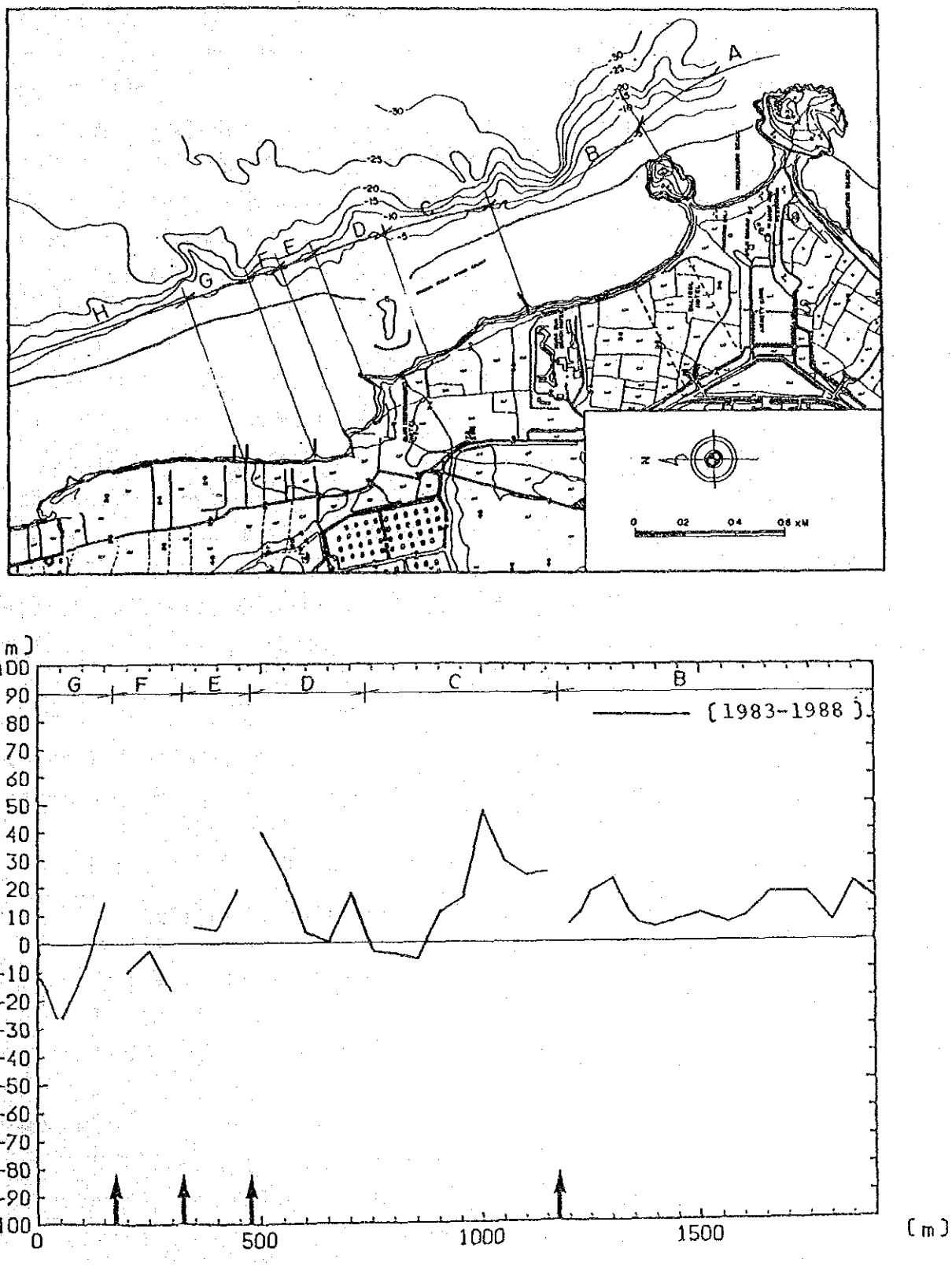


Fig. 3-3-2-4 Shoreline Change at Nusa Dua

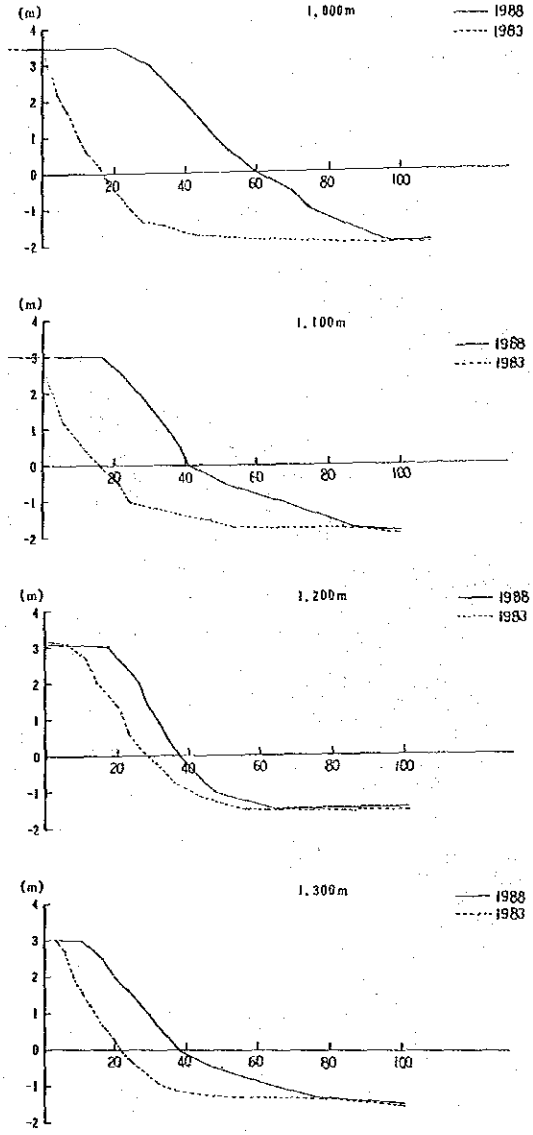


Fig. 3-3-2-5 Beach Profiles at Nusa Dua

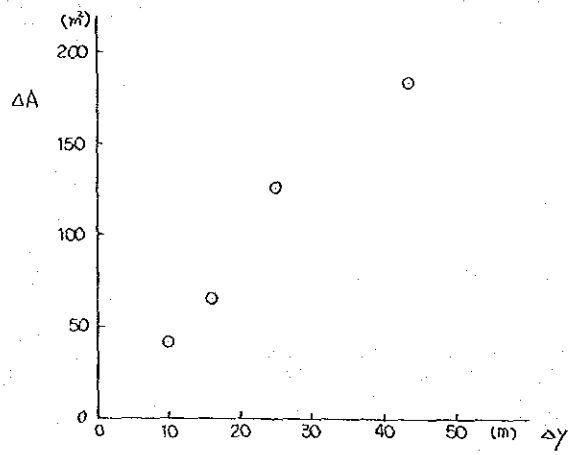


Fig. 3-3-2-6 Relation of △A and △y at Nusa Dua

(1) Change of shore line (Sanur)

Sanur beach stretches up to six kilometers along the east coast of Bali Island.

Shoreline changes are recognized at various places along the whole length of the beach.

Many kinds of protective structures have been constructed to conserve the beach.

Most of them aim at protection of local erosion.

The area is divided into eight divisions from A to H, as shown in Fig. 3-3-2-7.

1) Division A (0.4 km)

Based on the comparison of topographical data from 1978 to 1988, shoreline retreat is observed at the southern part of this reach. In the northern part, the shoreline retreat is about 10 meters.

There is a souvenir shop at the north end of division A which has been suffering from waves and severe erosion at the foundation of the shop which is made of concrete pipes stuffed with sand and stone. Some of them have fallen down due to the scour of the foundation. According to the shop owner, severe erosion has occurred within these one or two years, after the completion of a groin on the north side of the shop built by the Sanur Beach Hotel.

2) Division B (0.5 km)

The present shoreline in front of the Hotel Sanur Beach is about 10-20 meter back from the shoreline 10 years ago.

The groin and shore protection works were constructed in 1980 - 1981 by the hotel. The northern part of this division shows a retreat of about 5-6 meters.

3) Division C (0.5 km)

The shoreline at the southern reach of Division C seems to be rather stable.

But a shop at the north end of the reach is protected from erosion by foot protection works made of concrete pipes, built one or two years ago. There is a small sized scarp on the beach.

4) Division D (0.9 km)

Within this 0.9 km section, the southern part of about 400 m length retreated by about 10 meters from 1978 to 1988.

The northern part (500 meters) is rather stable, but according to people there the height of the foreshore has lowered somewhat these several years.

The slope of the foreshore gets milder as it goes to the northward. This division includes the Hotel Hyatt and other small sized hotels, and is valuable for tourism.

5) Division E (1.0 km)

The shoreline has remained almost stable from 1978 to 1988.

But some of the Division is completely submerged during high tide, leaving no beach to use.

The northern part of the reach, where Hotel Werdhapure is located, is severely eroded and beach protection works including two offshore breakwaters (built in the year 1985 and 1986), concrete pipes and sand nourishment (done in the year 1986) have been carried by the Public Works Department.

The works seem to be successfull at least for this limited reach, resulting in a tombolo and broadening the beach. At the northern part of the Division many beach protection works have been built along the beach (as long as 200 meters in length). The beach is narrow and there is very little beach at high tide.

6) Division F (0.3 km)

The width of the beach is narrow as in Division F.

The shoreline has retreated several meters from 1978 to 1988.

There are many small or medium sized hotels and restaurants along this beach, and it is significant for tourism. The Public Works Department built a groin in 1986 at the north end of this division, to protect the beach from erosion, and some other protection works have been carried out by the land owners (the hotels).

7) Division G (1.1 km)

The beach of this division is about 1,100 meters long. It has a tendency to reteat in the southern part and advance in the northern part.

The shoreline of the southern part has retreated a bit but there is a 10 to 20 meter advance in the northern part near the Bali Beach Hotel.

A groin, constructed in the year 1969 by the hotel, contributes to the shoreline advance by trapping littoral sand along the beach.

8) Division H (1.0 km)

The comparison of shoreline data shows that the shoreline retreated about 10 to 30 meters from 1978 to 1988.

According to the reconnaissance survey, there is severe erosion. The width of the beach is narrow, and the beach is steep in slope on the foreshore. Trees have been knocked down by waves and there is a scarp along the beach, showing the tendency of erosion.

The colour of the sand is black in this division whereas the sand in Division G is white.

Recently, waves have begun to flow into houses near the beach during high tide, according to the local inhabitants.

A series of groins was built in 1980 and 1981 by the Public Works Department.

(2) Change of beach profile (Sanur)

The beach profiles of the years 1978 and 1988 are shown in Fig. 3-3-2-7~8. The relation of the change in shorelines (△y) and the change of cross-sectional area (△A) is seen in Fig. 3-3-2-9, which is approximated in△A = 3.3 ×△y.

(3) Volume of eroded beach sand (Sanur)

Area	Volume of sand loss
400- 500 m (South beach)	27,700 m^3
3,000-4,000 (Central beach)	31,300
4,000-5,000 (North beach)	31,600

The total loss of sand is about 9,000 m^3/year.

(4) Foreshore slope (Sanur)

Section	Slope	
	1978	1988
1,000 m	1/10	1/9
1,900	1/10	1/14
3,200	1/9	1/11
3,600	1/9	1/8

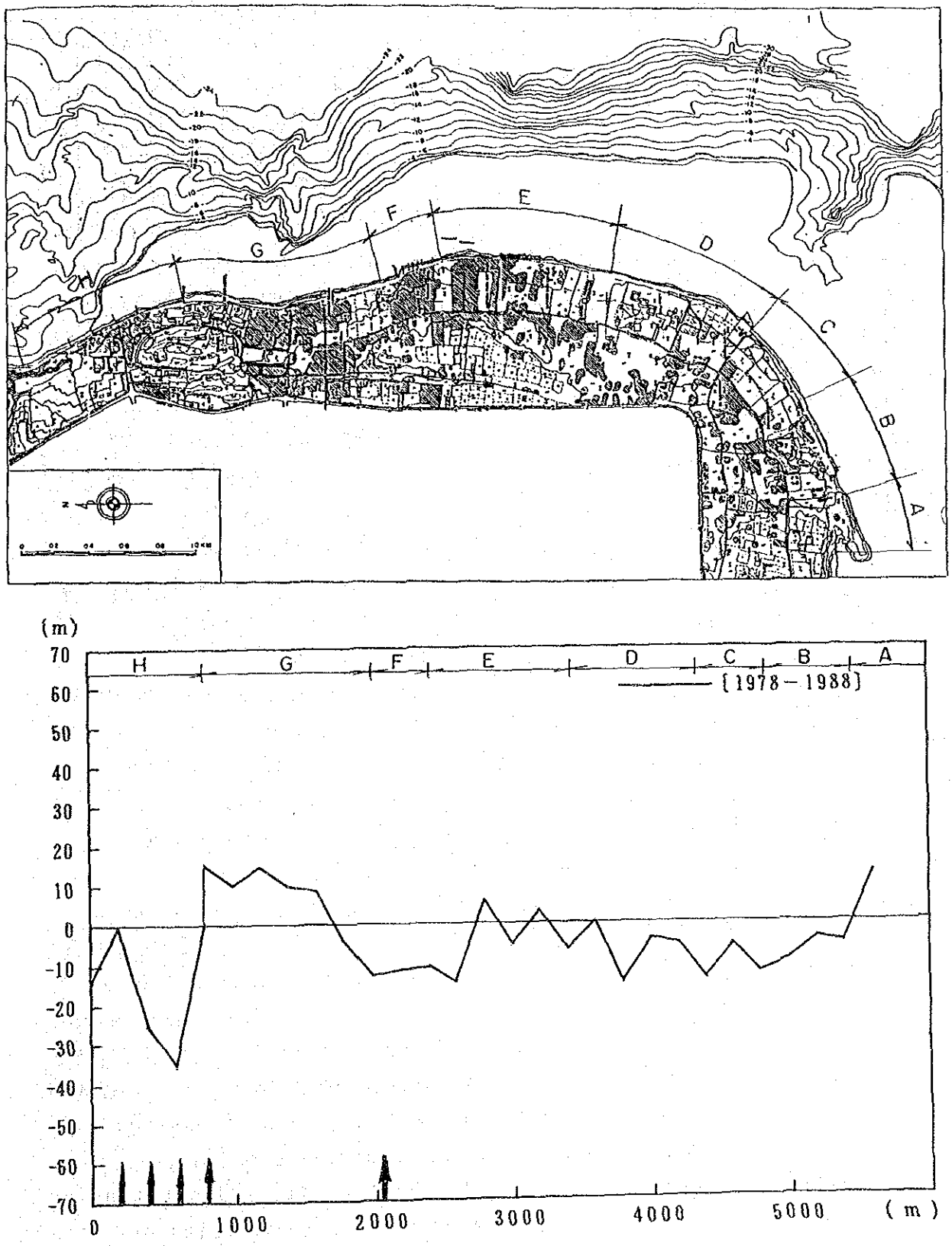


Fig. 3-3-2-7 Shoreline Change at Sanur

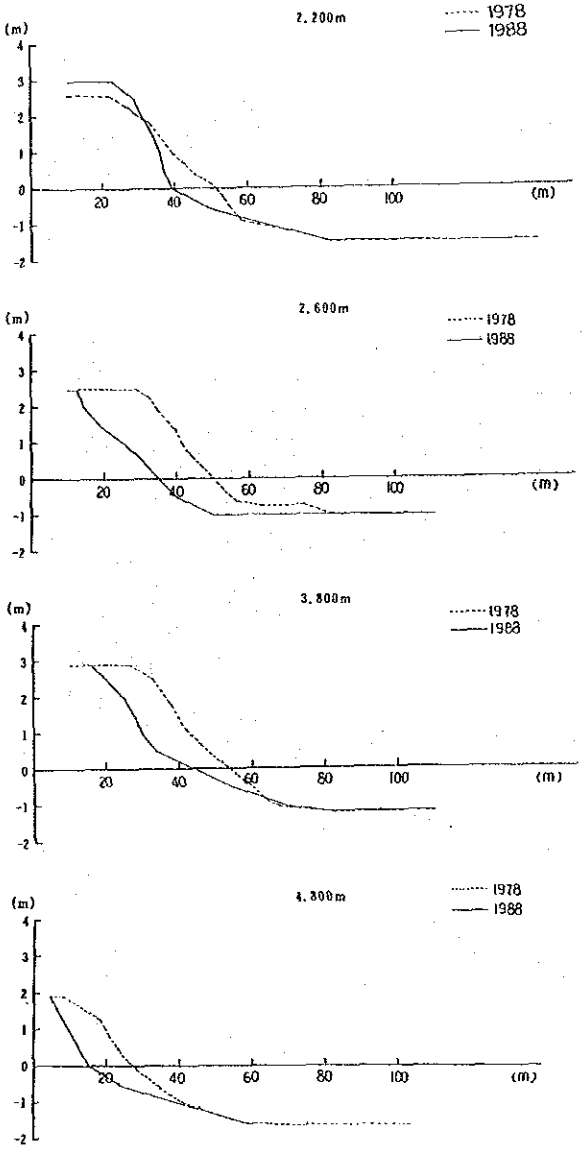


Fig. 3-3-2-8 Beach Profiles at Sanur

Section	Δy (m)	ΔA (m²)
2,200m	12	29.8
2,600m	15	66.4
3,800m	16	44.3
4,800m	10	31.5
AVERAGE	13.3	43.0

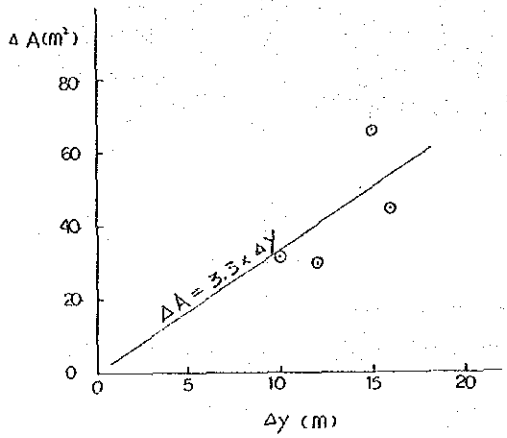


Fig. 3-3-2-9
Relation of △A and △y at Sanur

(4) Tanah Lot

A small rocky island, where Tanah Lot temple is located, has been suffering from severe erosion by waves for a long period of time and shows many eroded holes or caves on the surface. Some of them are very deep and measure up to 10-20 meters in depth.

In order to protect the island urgent protection works using concrete blocks to dissipate wave energy are being carried out by the government.

3-4 Present Situation of the Beach Conservation Works

3-4-1 Design Conditions of Existing Facilities

(1) Design Criteria

Since coastal engineering is a within the rather new field in Indonesia, the design of facilities and even facility planning have so far been experimentally and practically exercised based on the experience at the site rather than theoretically and practically executed. Therefore, no design criteria have been established.

(2) Present Facilities

The present conditions of facilities which have been constructed either privately or by governmental bodies is shown in APP. 3-4-1.

Aside from works by the Public Works Department, sand nourishiment may have been carried out by private bodies individually and locally, but no records are available.

(3) Remarks

1) In order to minimize the destruction of the natural view, the height of arificial facilities is as low as possible while maintaining effectiveness. For instance the top elevation of offshore breakwaters and the heads of groins is about HWL.

For the same purpose, unit concrete pipes for groins are not exposed, but are often covered by natural stones.

2) Unit concrete pipes with in site fills are widely adopted to construct groins, offshore breakwaters and even retaining walls, by either private or governmental bodies. Structural uniformity as a whole is ensured by inserted steel-bars.

The application of this traditional method indicates a high utilization of labor.

3-4-2 Existing Execution Method

(1) Fundamental Idea of Construction Works

The fundamental idea of the method used for the beach conservation works by DPU is as follows:

1) All conservation materials are carried by manpower and these have to be combined to make a structure on the spot.

2) Even in the construction of offshore groins, the transportation of materials for setting works does not use seaborne traffic.

(2) Construction Materials

The existing erosion conservation works have mainly used cement, aggregate, sand and boulders. Among these materials, the stone is supplied from the following three sources.

1) East Quarry

East Quarry is located at the Klungkung town area, 60 km east from Denpasar City. Gravel and sand have been produced in the area which was flooded in the past year at the lower reach of the Unda River. Also, many boulders were seen upstream of the Check Dam in the Unda River.

The gravel and sand at East Quarry is collected using an open cut system. The quarry is rugged and desolate because of the unsystematic mining, and the road in this area winds around many big holes.

2) West Quarry

West Quarry is located at the Gadungan town area, 30 km west direction from Denpasar City. Boulders, gravel and sand have been mind from the middle reach of the Yeb River.

At West Quarry boulders and sand are taken from the mountain stream on the Yeh River using manual labor and loaded onto trucks.

Big stones are scattered all over the river bed and this makes manual loading into trucks impossible.

3) Bukit Quarry

Bukit Badung Quarry is located approximately 20 km south from Denpasar city, and is called "Bukit Quarry". It has been producing a kind of limestone (Batu Kapur).

The collection method of the limestone at this quarry is applying manpower with chisels and hammers, and this method looks like a bench cut system.

The limestone has been used as a make-up stone to give the groin a natural view.

4) Sand Collection

The sand of the beach sand nourishment works has been collected at the following three sites.

① South of Hotel Bualu, Nusa Dua.
② The chinese grave yard, about 2 km north of Nusa Dua.
③ West of Surya Beach Hotel, south of Sanur.

5) Stone Quality

The stone is andesite at both East and West Quarrys and it is sufficient for concrete materials and the volume of stone is also sufficient to supply this project in the future.

The locations of East Quarry, West Quarry, Bukit Quarry and the three sites of sand collection are shown in Fig. 3-4-2-1.

(3) Road Connections

Bali Island has a round circuit road through Denpasar, Karangasem, Singaraja and Gilimanuk towns, and it also has a paved trunk road.

East Quarry and West Quarry are situated along the trunk road. East Quarry and West Quarry are on the way to Karangasem and Gilimanuk from Denpasar city, respectively. The traffic volume between Tabanan town and Kiungkung town through Denpasar City on the trunk road is dense with many cars, trucks, bemos, motor bicycles, etc. in the daytime. Especially, the east road from Denpasar City is crowded for trucks carrying gravel and sand to Denpasar City.

The approach roads from the trunk road to East Quarry- and West

Quarry are controlled by the Desa and are also paved. However, there are so many holes on the road surface that it is difficult for trucks to pass by due to the narrow width.

3-4-3 Completion Works by DPU

(1) General

The erosion protection works at Kuta, Nusa Dua and Sanur beaches have been carried out by DPU to combine groins, offshore groins and beach sand nourishment, and the total completed works from the year 1981 up to date are ten (10) groins with a total length of 540 m, eleven (11) offshore groins with a total length of 603 m, one (1) revetment with a total length of 36 m and seven (7) places of beach sand nourishment with a total volume of approximately 108,150 m^3 at Kuta, Nusa Dua and Sanur beaches. The total cost for the above works was Rp. 2,046,007,000.

The progress of Bali beach conservation works in the past year is shown in Table 3-4-3-1, and Fig. 3-4-3-1.

(2) Kuta

The main work of erosion protection works was completed as below.

Offshore Groin	1 No.	70 m

The total cost was Rp. 335,000,000.

The location of the beach conservation works is shown in Fig. 3-4-3-2.

(3) Nusa Dua

The main works of erosion protection works were completed as given below.

Groin	5 Nos.	343 m
Offshore Groin	5 Nos.	373 m
Beach Sand Nourishment	6 places	101,650 m^3

The total construction costs were Rp. 1,795,067,000.

The location of beach conservation works are shown in Fig. 3-4-3-3.

(4) Sanur

The main works of erosion protection works were completed as given below.

Groin	5 Nos.	197 m
Offshore Groin	5 Nos.	160 m
Beach Sand Nourishment	1 No.	6,500 m^3

The construction cost totalled Rp. 215,940,000.

The location of beach conservation works are shown in Fig. 3-4-3-4.

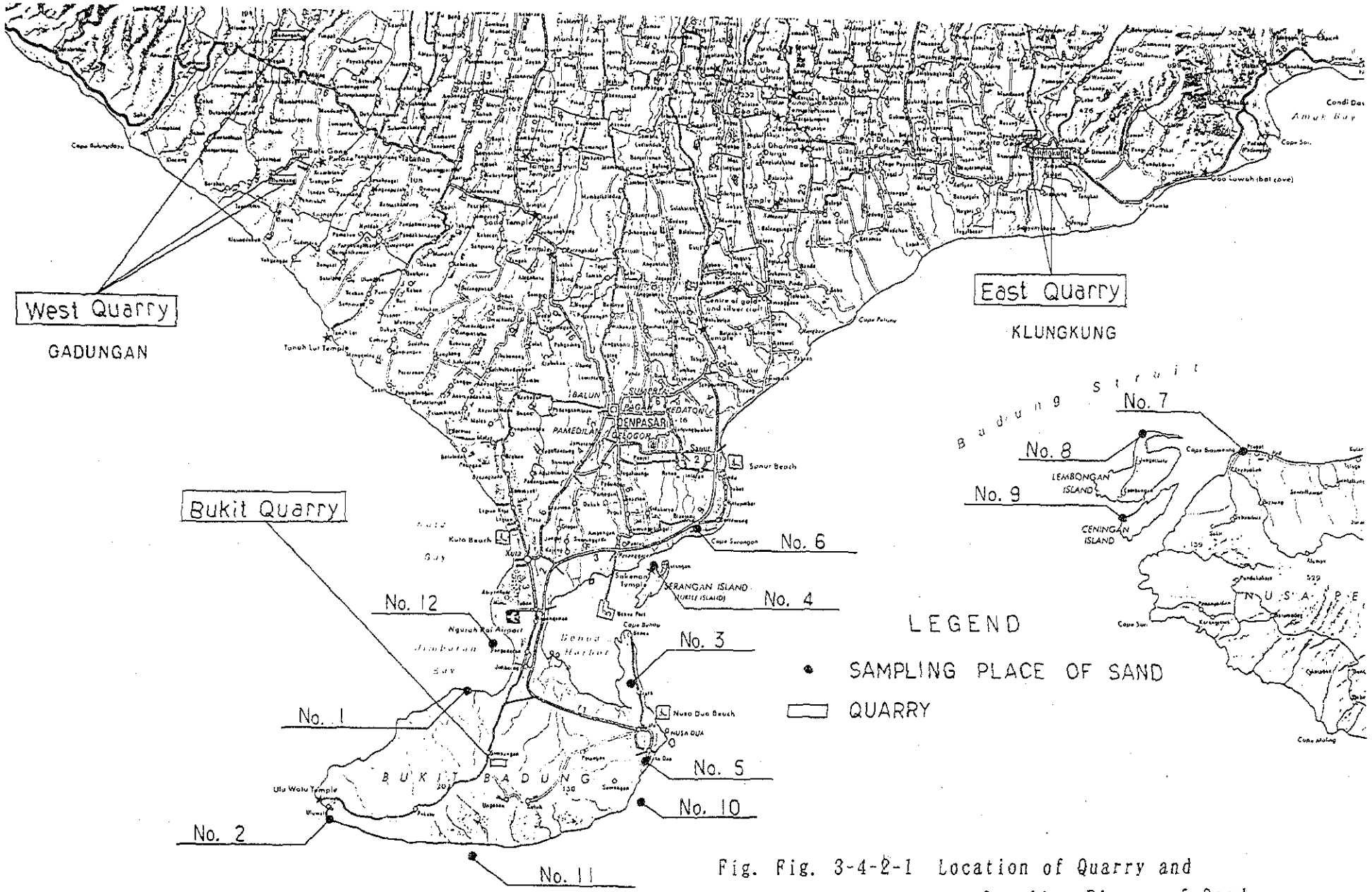


Fig. Fig. 3-4-2-1 Location of Quarry and Sampling Places of Sand

Table 3-4-3-1 Progress of Bali Beach Conservation Works

Area	Location No.	Type	Length or Volume	Amount (Rp)	Construction period	Remarks
Kuta	1.	off-shore groin	70 m	35.000.000	1984. 7. 24～1984. 12. 20	cylinder concrete blocks.
Nusa Dua	1.	groin	66 m	116.819.000	1986. 1. 3～1986. 3. 1	— do —
	— do —	Sand fill	15.000 m³	82.882.000	— do —	
	— do —	groin	30 m	100.335.000	1986. 12. 4～1987. 3. 19	cylinder concrete blocks.
	— do —	makeup by coral hill	96 m	27.600.000	1986. 12. 4～1987. 3. 19	
	— do —	Sand fill	10.000 m³	51.025.000	— do —	
— do —	2.	groin	10 m	3.185.000	1984. 7. 24～1984. 12. 20	cylinder concrete blocks.
— do —	3.	groin	60 m	11.733.000	1984. 7. 24～1984. 12. 20	sand bags.
— do —	4.	off-shore groin	65 m	75.965.000	1986. 1. 13～1986. 3. 1	cylinder concrete blocks.
	— do —	Sand bag	339 bags	938.000	— do —	
— do —	5.	off-shore groin	148 m	196.637.000	1986. 1. 3～1986. 3. 1	cylinder concrete blocks.
	— do —	Sand bags	960 bags	2.226.000	— do —	
	6.	off-shore groin	160 m	141.988.000	1987. 12. 2～1988. 2. 6	cylinder concrete blocks.
	— do —	Sand bags	4.000 bags	12.203.000	— do —	
	— do —	makeup by coral hill		18.616.000	— do —	
— do —	7.	groin	15 m	29.113.000	1986. 1. 3～1986. 3. 1	cylinder concrete blocks.
	— do —	Sand fill	10.000 m³	54.714.000	1986. 12. 4～1987. 3. 19	
	— do —	groin	15 m	56.037.000	— do —	cylinder concrete blocks.
	— do —	makeup by coral hill	74 m	6.249.000	— do —	
	— do —	groin	40 m	35.518.000	1987. 12. 2～1988. 2. 6	cylinder concrete blocks.
	— do —	makeup by coral hill		7.075.000	— do —	
	— do —	Sand bag	400 bags	1.193.000	— do —	
— do —	8.	groin	76 m	79.193.000	1986. 1. 3～1986. 3. 1	cylinder concrete blocks.
	— do —	groin	20 m	21.174.000	1986. 12. 4～1987. 3. 19	— do —
	— do —	groin	7 m	7.412.000	— do —	— do —
	— do —	makeup by coral hill	193 m	37.204.000	— do —	
Sanur	1.	off-shore groin	80 m	46.690.000	1986. 10. 2～1987. 2. 7	
	— do —	Sand fill	6.500 m³	39.583.000	— do —	
— do —	2.	off-shore groin	80 m	36.000.000	1986. 7. 5～1985. 11. 4	cylinder concrete blocks.
— do —	3.	groin	77 m	13.682.000	1986. 10. 2～1987. 2. 7	
— do —	4.	groin	60 m	19.985.000	1981. 7. 3～1981. 10. 31	cylinder concrete blocks.
— do —	5.	groin	60 m	32.597.000	1981. 3. 21～1981. 8. 20	— do —
	— do —	Revetment	35 m	27.403.000	— do —	coral

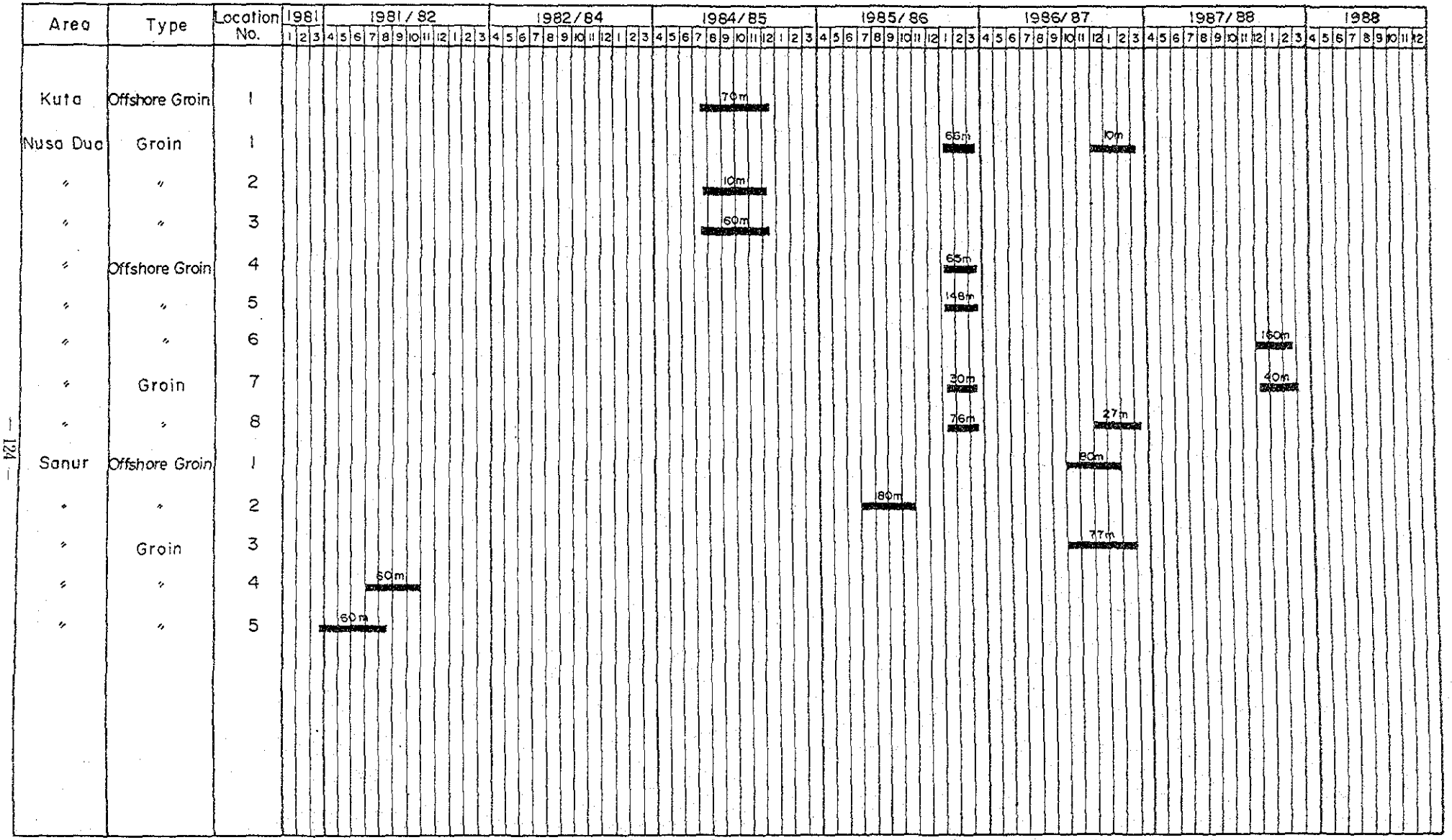


Fig. 3-4-3-1 Progress of Bali Beach Conservation Works

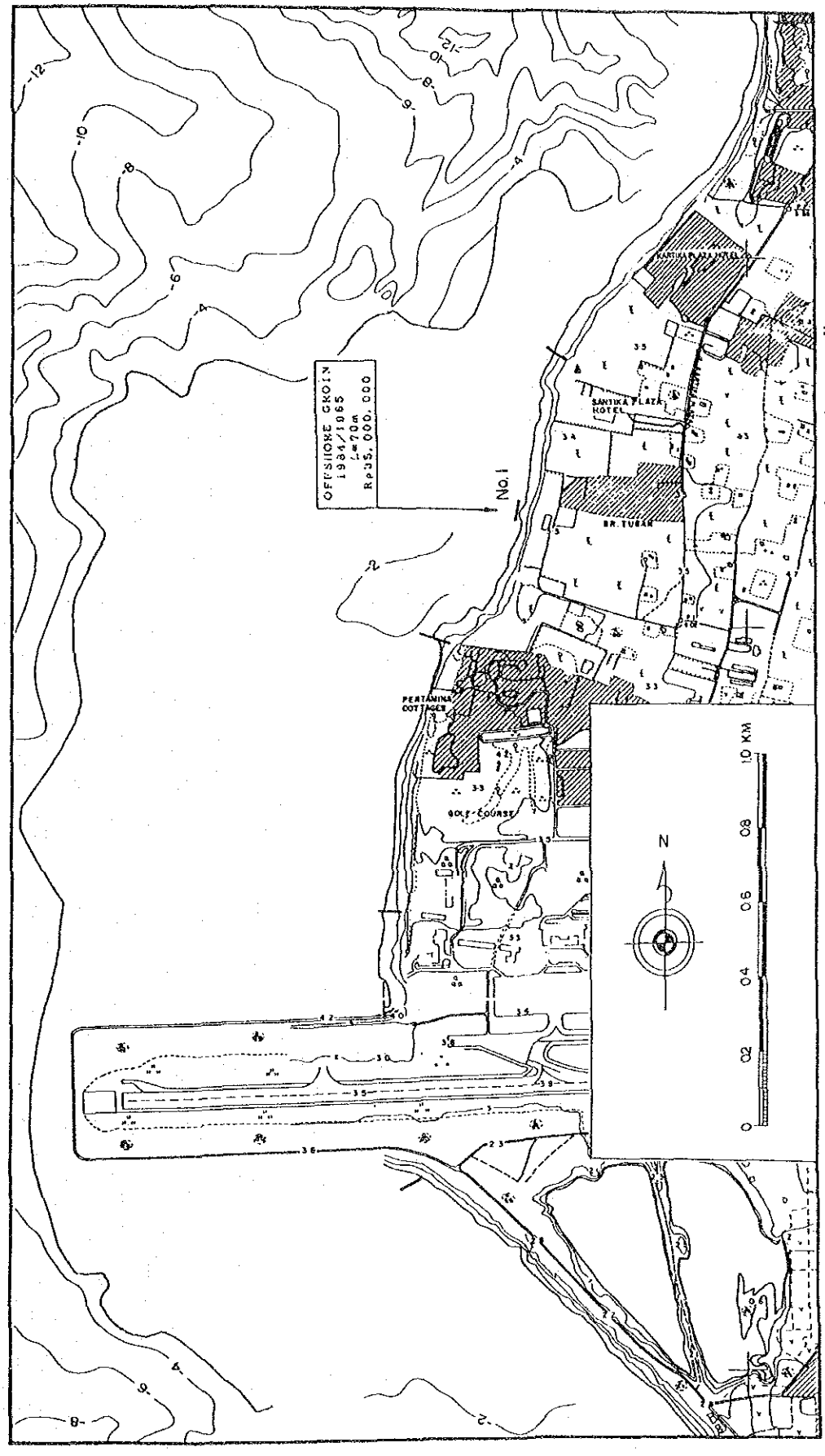


Fig. 3-4-3-2 Erosion Prevention Works at Kuta

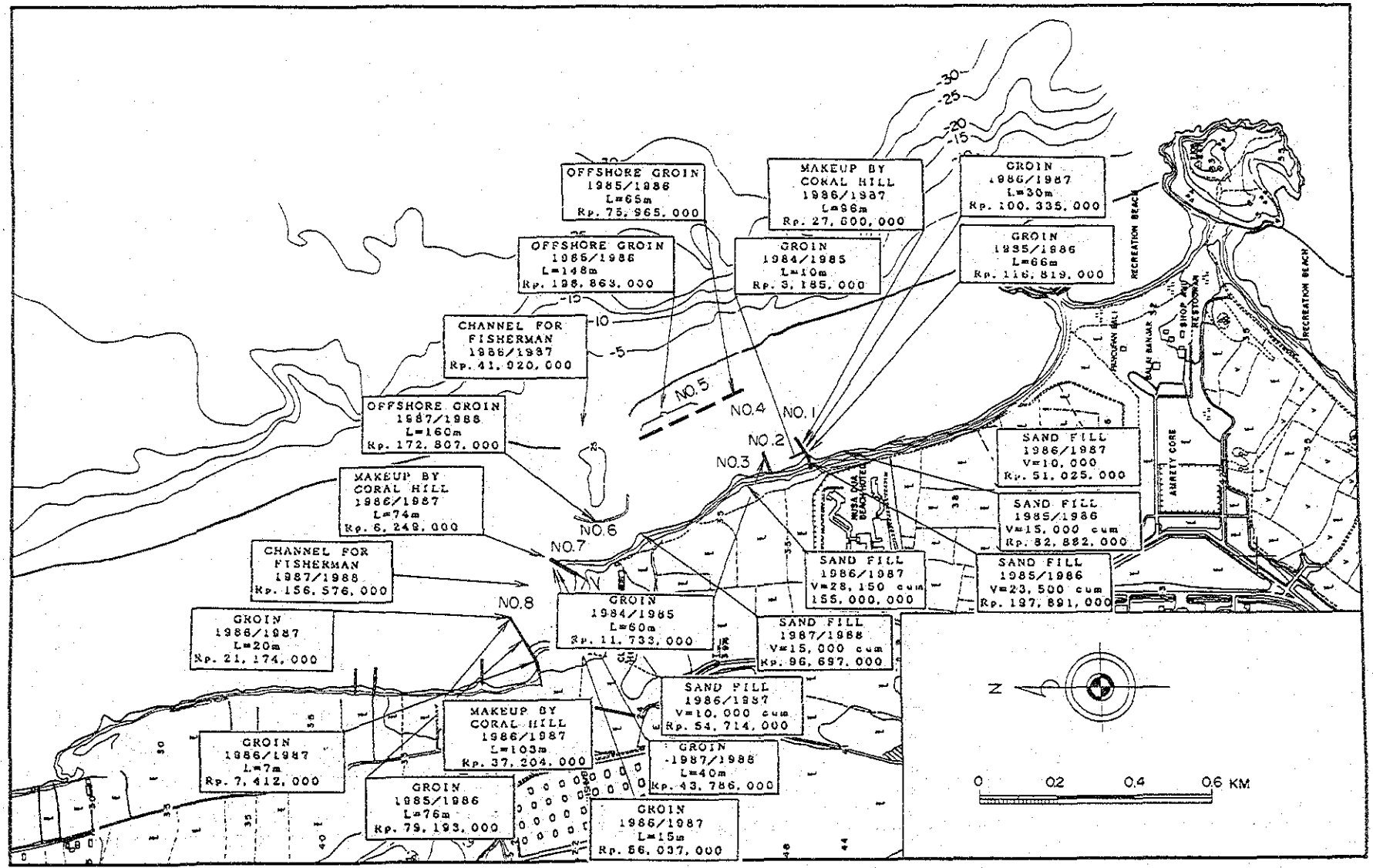


Fig. 3-4-3-3 Erosion Prevention Works at Nusa Dua

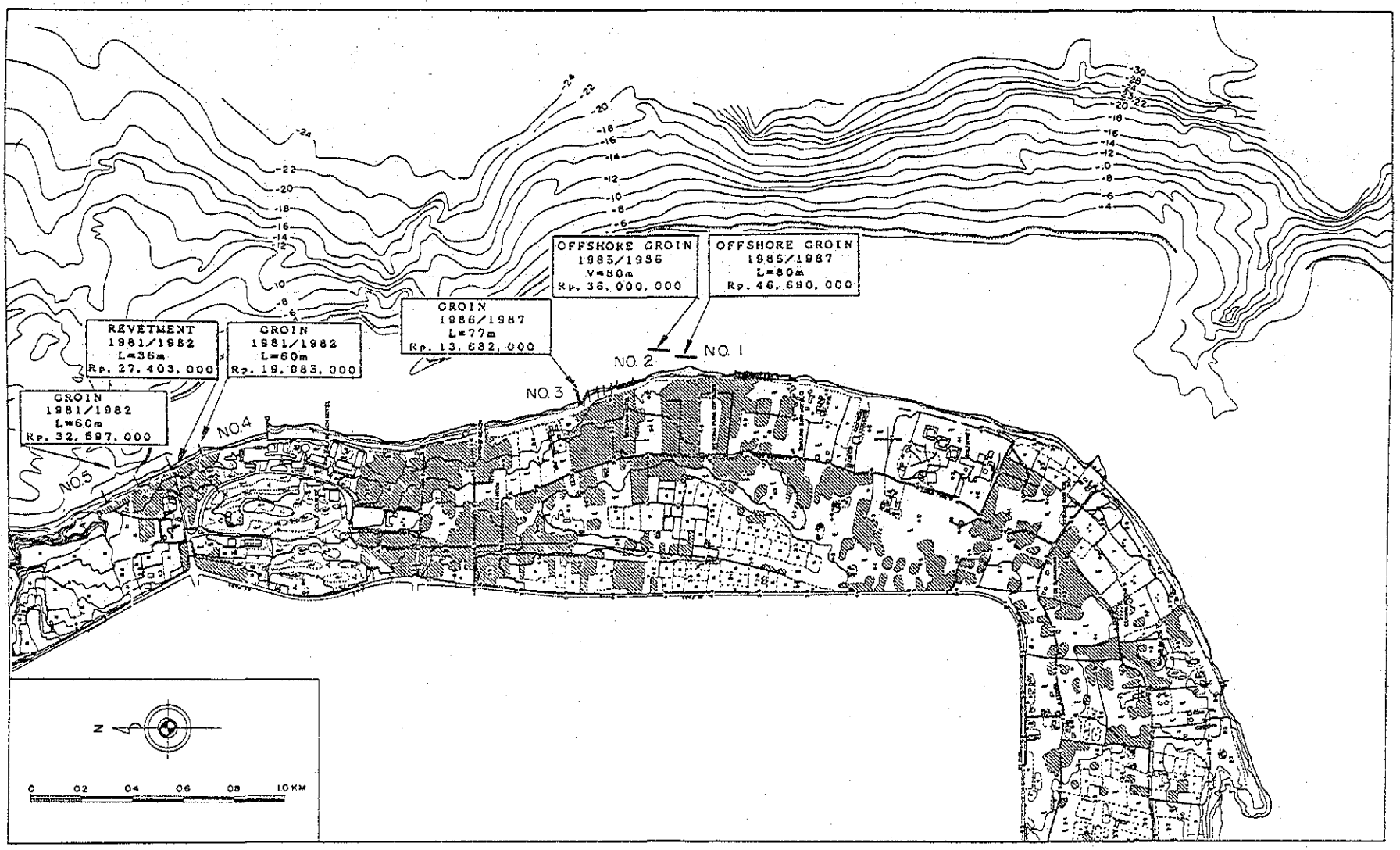


Fig. 3-4-3-4 Erosion Prevention Works at Sanur

3-4-4 Sand Quality

(1) Existing Sand Quality

The existing sand quality at the three beaches was studied at 150-meter intervals, and in each section, samples were taken at two points as shown in Fig. 2-5-2-8 to 2-5-2-13. The results of grain size analysis are shown in Table 2-5-2-1.

From these results, the qualities of sand at the three beaches are judged as follows.

1) The average grain size distributions of the coefficient of uniformity is 2.0 except at points No. 21, from No. 57 to No. 61, and at No. 93, 95 and 96.
2) The average grain size distribution of the coefficient of curvature is 1.0.
3) From the above, the grain size distribution is poor.

From the grain size analysis, the coarse sand distribution figures at the three sites are shown in Fig. 3-4-4-1 ～ 3 and summarized as follows:

1) At the Kuta beach area, despite some differences in the grain size, the beach is generally covered with fine-grained sand.
2) In the Nusa Dua beach area, B points consist of coarse sand on the whole, while at A points a fine sand is found mixed with coarse sand.
3) In the Sanur beach area, both A and B points show coarse sand and fine sand together, reaching as far as No. 105 Point, but, generally speaking, more than 50% of the total sand is coarse.

   The northern area beyond point No. 105 consists of fine sand.

(2) Sand for the Beach Sand Nourishment

The locations of samples are shown in Fig. 3-4-2-1 and the analysis results are shown in Fig. 3-4-4-4.

1) From the results of the analysis, points 2, 3, 5 and 7 have coarse sand and the other points have fine sand.

2) Points 3, 5 and 6 were selected for the sand by DPU in the past year for the beach sand nourishment.

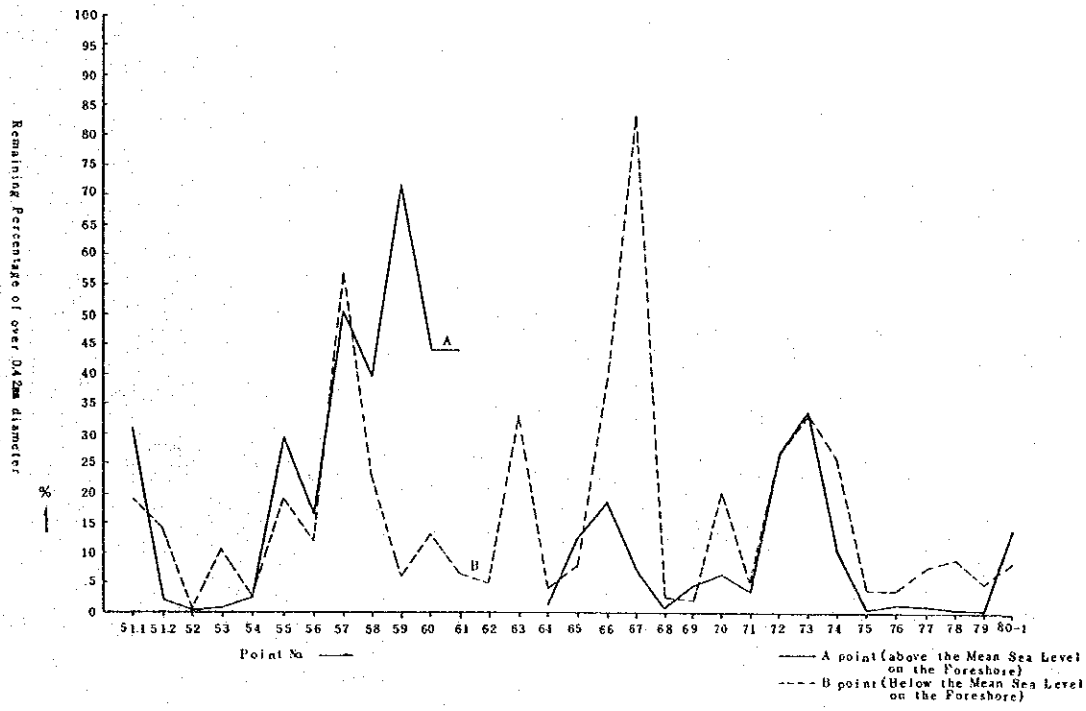


Fig. 3-4-4-1 Coarse and (above 0.42mm diameter) Distribution along the Coast Line at Kuta Beach

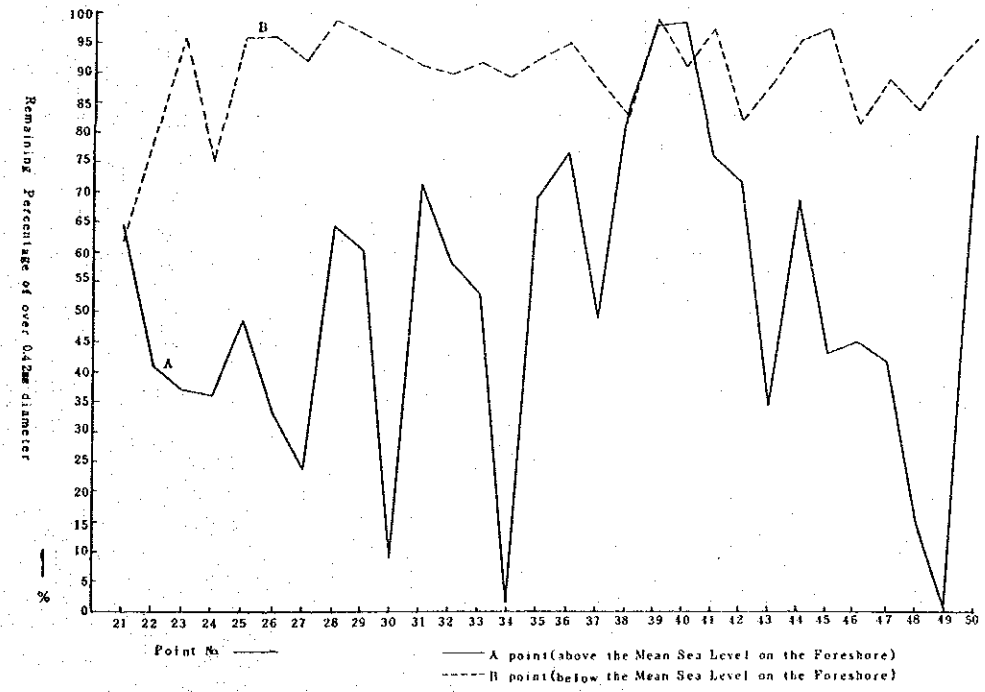


Fig. 3-4-4-2 Coarse and (above 0.42mm diameter) Distribution along the Coast Line at Nusa Dua Beach

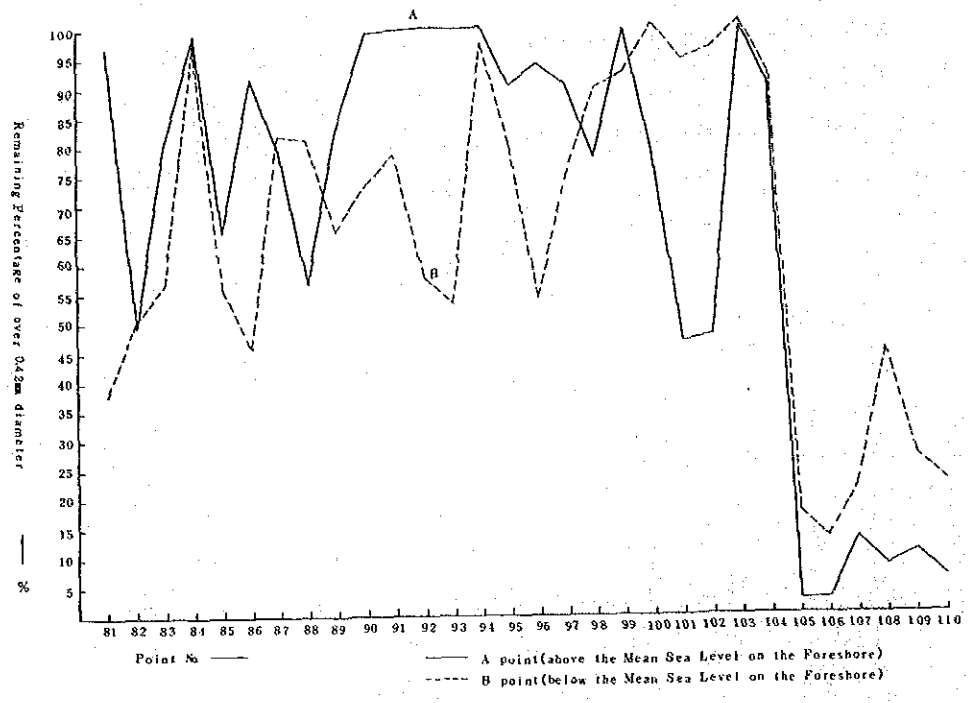


Fig. 3-4-4-3 Coarse and (above 0.42mm diameter) Distribution along the Coast Line at Sanur Beach

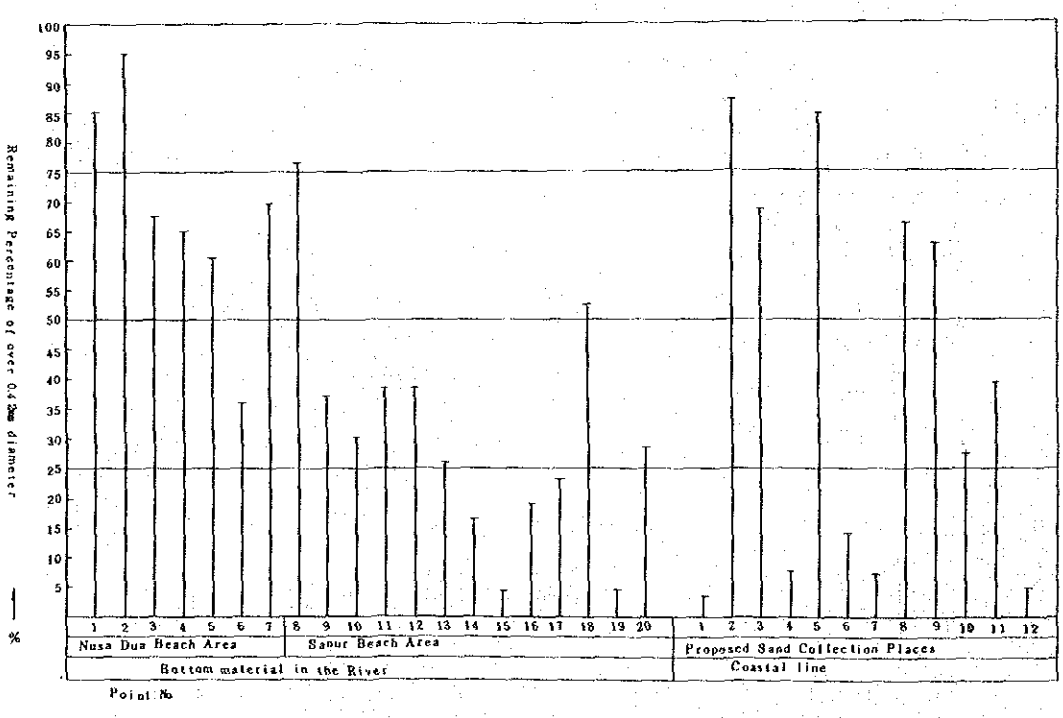


Fig. 3-4-4-4 Coarse Sand Distribution

CHAPTER 4

CAUSES OF SHORELINE EROSION

CHAPTER 4 CAUSES OF SHORELINE EROSION

4-1 General

It will be helpful to discuss in this section general causes of shoreline erosion and in the next section to refer to the specific sites. This section follows Shore Protection Manual (1984) by the Coastal Engineering Research Center of the U.S. Army.

Before embarking upon any method of coastal protection, it is important to identify and understand both the short- and long-term causes of coastal erosion. Failure to do this may result in the design and placement of shore protection measures which actually accelerate the process that the protection measure was intended to alleviate. Although the most serious incidents of coastal erosion occur during storms, there are many other causes, both natural and man-induced, which need to be examined.

Natural causes of erosion are those which occur as a result of the response of the beach to the effects of nature. Man-induced erosion occurs when human endeavors impact on the natural system. Much of the man-induced erosion is caused by a lack of understanding and can be successfully alleviated by good coastal zone management. However, in some cases coastal erosion can be due to construction projects that are of economic importance to man. When the need for such projects is compelling, the coastal engineer must understand the effects that the work will have on the natural system and then strive to greatly reduce or eliminate these effects through designs which work in harmony with nature.

(1) Natural Causes

a. Sea Level Rise. A long-term rise in sea level relative to the land exists in many areas of the world. This rise results in a slow, long-term recession of the shoreline, partly due to direct flooding and partly as a result of profile adjustment to the higher water level.

b. Variability in Sediment Supply to the Littoral Zone. Changes in

the world's weather pattern that cause droughts can result in a reduction in the occurrence of floods on rivers supplying sediment to the coastal zone.

c. Storm Waves and Offshore Currents. Steep waves from a coastal storm cause sand to be transported offshore with temporary storage in a bar or shoal. Later partial recovery of the beach may be made through natural transport of this material onshore by longer-period, flatter waves. But, in most cases, some material is permanently lost into the greater offshore depths by storm waves and strong offshore-oriented currents.

d. Wave and Surge Overwash. Overwash is a phenomen which occurs during periods of storm surge and severe wave action. Waves and overflowing water erode the beach and transport and deposit this material shoreward of the beach, or as an overwash fan on the bay side of low-lying barrier islands.

e. Deflation. The removal of loose material from a beach by wind action can be a significant cause of erosion. In many parts of the world, major natural dune fields exist well behind the active beach zone. These dunes can represent a large volume of beach sediment.

f. Longshore Sediment Transport. Sand is transported alongshore by waves breaking at an angle to the shore. If the sediment-carrying capacity of the longshore current generated by these waves exceeds the quantity of sediment naturally supplied to the beach, erosion of the beach results.

g. Sorting of Beach Sediment. Sorting of beach sediment by wave action results in the selective redistribution of sediment particles (sand, shell, and shingle) along a beach profile according to size or hydraulic properties. This mechanism is particularly important in designing beach nourishment projects because the selective loss of finer material to the offshore region and the retention of the coarse material in the surf zone

requires the placement of additional fill in order to balance this loss. Best results are usually achieved when the fill material is similar in grain-size distribution to the native beach material.

(2) Man-Induced Causes

a. Land Subsidence from Removal of Subsurface Resources. The removal of natural resources, such as gas, oil, coal, and groundwater underlying the coastal zone, may cause subsidence of the beach. This has the same effect as a sea level rise.

b. Interruption of Material in Transport. This factor is probably the most important cause of man-induced erosion. Improvement of inlets by both channel dredging and channel control and by harbor structures impounds littoral material. Often, the material is permanently lost from the downcoast beach regime either by the deposition of dredged material outside of the active littoral zone or the building of bars, shoals, and wider updrift beaches. This can be mitigated by sand-bypassing systems. Construction of protective works at the source of littoral material, such as an eroding cliff or bluff, can also result in disruption of supply. Realignment of the shoreline by the use of such structures as groins also interrupts the transport of littoral material.

c. Reduction of Sediment Supply to the Littoral Zone. In some areas the transport of sediment to the coast by rivers forms the major source of material to the littoral zone. Dams constructed on these rivers not only form sediment traps but also reduce peak flood flows, thereby reducing the sediment supply to the coast which results in coastal erosion.

d. Concentration of Wave Energy on Beaches. The building of coastal structures (such as vertical walls) either in the active beach zone or on the backshore can increase the amount of wave energy being dissipated by the beach material fronting the structure, resulting in an increase in the rate of erosion.

e. Increase in Water Level Variation. The deepening and widening of navigation inlets may adversely affect the tidal range within a harbor or bay, and may permit larger waves to enter the harbor area and adjacent beaches. An increase in tidal range will expose more of the harbor or bay beach face to the erosive effects of waves and cause a change in the beach profile.

f. Change of Natural Coastal Protection. The dredging of nearshore bars and shoals can change the pattern of energy dissipation on a beach face. If the change increases the wave energy acting on a given section of beach, erosion will likely result at that section. Onshore, the leveling of dunes, destruction of beach vegetation, paving of large backshore areas, and construction of boat channels on the backside of a narrow barrier island can further increase the overwash erosion and island breaching potential.

g. Removal of Material from the Beach. Excavation of beach material is undertaken in many parts of the world. This material is sometimes mined for the minerals it contains; in other places it is used for construction purposes (landfills, construction aggregate). For whatever purpose, it is a direct loss of the available supply of material for littoral transport.

4-2 Causes of Erosion at the Study Areas

It is evident that at Tanah Lot the vertical cliff on the island has been eroding due to the severe wave action. The rest of the sites (Kuta, Nusa Dua, and Sanur) consist of sandy beaches, and it is not straightforward to identify the causes of their erosion. A clue to the question is that until several decades ago the beaches had been fairly stable: neither eroding nor accreting. While we should have reservations about its arthenticity because the beach erosion may not have been as serious a concern in those days, it appears reasonable, with the lid data available on the nearshore topography and wave climate, to seek the causes from what has recently occurred

or changed.

On Kuta beach an airport runway was constructed in 1969 virtually as a huge groin. On Kuta and Sanur beaches coral stones have been actively dredged so that arriving waves are greater than in the past.

In the following, the areas are defined in Fig. 3-3-2-1, 4 and 7. The following statements reflects the results of the simulation in Chap. 5.2.

(1) Kuta

Kuta beach especially in area D has been seriously eroding. The direct cause is apparently the wave and surge overwash (Natural Cause d). The tracer tests indicate the northward longshore drift in area D during the study period. The incident-wave direction, mostly southwest, also suggests the long-term longshore drift in the north direction. The runway appears to trap sediment material which would be transported from A to B, C, ... (Natural Cause f, Man-Induced Cause b), whereas in area A no permanent tendency of accretion is observed possibly because of the reflected wave by the runway. In area B the slope is armored with some revetments and no waves are incident from the southwest except through diffraction, thereby reducing the sediment supply to area D due to the longshore drift. (Man-Induced Cause c). The circulating current due to diffraction behind the runway results in accretion in area B. The coral dredging has allowed higher waves to reach the beach (Man-Induced Cause f). Another possibility cited is that some beach material may be permanently lost into the greater offshore depths from area F where the reef is very narrow (Natural Cause c).

(2) Nasu Dua

On this beach except at area B the northward longshore drift is apparent from the fact that at the existing groins accretion is observed on the south side. The islands of Nusa Dua, whether or not connected with the beach, hinder the beach-material supply from the south (Natural Causes b and f) as a huge detached breakwater. Thanks to the beach fills conducted lately, the beach along its total stretch has rather accreted for these five years. However, the tracer tests and flow measurements show that some beach material is still

lost into the canyon behind the U-shaped groin which does trap a significant amount of sediment which would fall into the canyon (Natural Cause c).

(3) Sanur

The longshore drift is apparently southward in areas A and B and northward in D to H, judging from the accretion pattern on the groins and the results of the tracer tests and flow measurements. Areas C and D are eroding because of the negative sediment flow due to the longshore drift (Natural Cause f). During the study period a deposit of sand was observed along the boundary of areas C and D between the shoreline and the canyon mouth. This suggests some mechanism to induce a flow transporting the sediment material from somewhere else and make it settle down there. In conflict are the results of the flow measurements that show the flows away from the canyon. The results are also contrary to the results at Nusa Dua. At present it is not obvious whether each of these facts (deposition and flow directions) reflects the short-term or long-term tendency and further study is necessary. Area F is also eroding because the offshore breakwaters existing in area E trap the sediment which would be supplied into area F (Man-Induced Cause b). The same is the case for area H due to the heliport on the boundary between areas G and H (Man-Induced Cause b). The coral dredging has allowed higher waves to reach the beach (Man-Induced Cause f).

4-3 Remarks on the Longshore Drift in View of Beach-Material Origin

At the study sites of Kuta, Nusa Dua and Sanur, beach material is classified into three groups: magnetite (specific gravity - 5, black, volcanic origin), HCℓ-soluble material (specific gravity - 2.7, white, coral reef or coral limestone origin) and the rest (quartz, feldspar and so forth).

At Kuta little magnetite is found on the south but there is a lot of magnetite on the north of the airport runway and the content is greater at a greater distance from the runway. The beach was not as black as it is prior to the runway construction. The magnetite found on the north of the runway has been supplied from rivers to the north.

It may thus be concluded that on the north of the runway the net long-term drift of magnetite has been southward since the runway construction. The net long-term drift of the total beach material is, however, supposed to be northward as was discussed in the previous section.

At Sanur a similar situation is observed; magnetite is found little (0.1～2%) on the south but much (21 ～97%) on the north of the heliport in front of Hotel Bali-Beach. The magnetite comes from rivers to the north. This again suggests that on the north of the heliport the net long-term drift of magnetite is southward while that of the total material is northward.