SOPAC Cruise Report 126

March 1990

OFFSHORE SURVEY FOR CONSTRUCTION MATERIALS

NUKU'ALOFA AND VAVA'U

TONGA

9-30 August 1989

by
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Techsec

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*Contributed by: Commonwealth Fund for Technical Cooperation (CFTC)

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ABSTRACT

This survey was carried out to evaluate an alternative source for clean sands for the construction industry. Following a site survey, four holes were drilled in a sand basin north of Fafa Island, in water depths ranging between 9.2 and 12 m. Maximum penetration achieved was 3.8 m. Initial examination of the samples indicate the material drilled is good for landfill but too fine for use in the construction and building industry. A follow-up survey is planned in October/November 1989 to look at additional sand basins that lie in water depths ranging between 14 and 24 metres and lay northwest of Fafa.

Twelve navigation towers within a 16 km radius of Nuku'alofa were fixed using a Del Norte microwave digital distance measuring unit. Latitude/longitude of the towers were computed both by Fiji Hydrographic Unit and CCOP/SOPAC Data Management from data collected.

Recent studies by the Tongan Government geologists indicate an interim onshore sand deposit exists on Pangaimotu island with adequate reserves to supply the construction industry in Vava'u. A similar offshore drilling programme to that done in Nuku'alofa planned for Vava'u has been put on hold until a suitable platform can be arranged to support this operation.

PERSONNEL INVOLVED

Robert Smith Marine	Geologist (SOPAC)
Edward Saphore	Electronics Engineer (SOPAC)
Joe Mausio	Marine Mechanic (SOPAC)
Paul Schmidt	Driller (Western Samoa Observatory)
Robert Gatliff	Government Geologist (Tonga)
Saimone Relu	Government Geologist (Tonga)
Apai	Technical Assistant (Tonga)
Tevita Malolo	Surveyor (Tonga)

INTRODUCTION

At present there are only two sources of supply of material for the construction industry in Tongatapu. These are sands resulting from the production of aggregate from crushing quarried limestone and the removal of beach sands from beaches. Generally the material used from crushing contains too many fines hence is not a suitable source of material for block making. Beach sands presently used are in limited supply and as a result demand is far outstripping replenishment at the source level. An alternative source for clean sands is therefore sought offshore to provide material for the construction industry as well as landfill. For complete cruise log, see Appendix 1.

OBJECTIVES OF CRUISE

1) Determine volume and grades of sediment in two sand basin, A and C to the north of Fafa Island.

2) Make recommendations on the potential of sediment as constructional material.

EQUIPMENT AND METHODS

Bathymetry

A De 719E Raytheon precision echo sounder was used for profiling the seabed, and digital output logged on a TI 1000 laptop using inhouse developed software.

During the course of the survey tide data for reducing bathymetry to Lowest Astronomical Tide (LAT) being chart datum 0.0 metres was collected (see Appendix 2 for plots). Within the survey area, bar checks were done to check recorder calibration. Reduced depths (to LAT) in the survey area are expressed in metres unless indicated.

Navigation Control

Navigation control was with a Del Norte 520 digital distance measuring unit. Calibration was done prior to the start of the survey over a known range and the calibration factors recorded. The calibration factors then could be checked daily. The remote stations were surveyed with the assistance of Tevita Malolo of the survey department using a Sokkista EDM from known control points based on the Tongatapu Cadastral (see Appendix 3).

Grid	:	UTM Zone 1
Projection	:	Transverse Mercator
Spheroid	:	International
Unit of Measurement	:	Metres
System Accuracy	:	± 1 m

Appendix 4 contains all computations for calculating the trisponder remote co-ordinates in UTM metres.

Drilling

The drilling system used is a vibro airlift drill mounted on a locally supplied barge. Details of the drilling rig assembly and operation can be found in Smith (1989). Positioning of the boreholes was done using the Del Norte trisponder system. Depth of penetration was monitored by an echo sounder a (De 719E Raytheon) with the transducer being mounted at the top of the drill column.

RESULTS

Nuku'alofa Prospect

Figure 1 is a location map illustrating the prospect area ranging from 7 to 10 kilometres north of Nuku'alofa. Prior to taking the barge and drill assembly into sites A and C (Figure 2), a site survey was conducted to familiarize the author with the area under investigation. Figure 3 is a track plot of the lines run through basins A and C. A fix interval of 30 seconds was used for lines 1-6 and one minute for line 7.

Bathymetry

Figure 4 gives the bathymetry of the survey. Visual observations, plus interpretation of the seabed morphology from the bathymetric records were used to compile a seabed morphological map of the survey area. This is shown in Figure 5. Two type zones were identified, a sand rich zone, and a patch reef zone. Within the patch reef zone, coral heads were particularly abundant.

Drilling

Figure 5 illustrates the location of the four holes drilled in a north-south trending sand basin. Because of the deeper water depths encountered to the northwest, drilling was contained in the shallow portion of the basin. Appendix 5 contains the borehole statistics. Sample recovery was very good, with large volumes of samples recovered with little loss in particular the fines. From field observation the samples collected were generally medium to very fine sands with an abundance of large forams. Noticeably absent were shell, coral/rock and especially acropora fragments. Initial interpretation suggests that this material is good for fill but not for construction (Reidel, pers. comm.). No clean sands were observed. Water depths drilled in ranged from 12 m to 9.2 m.

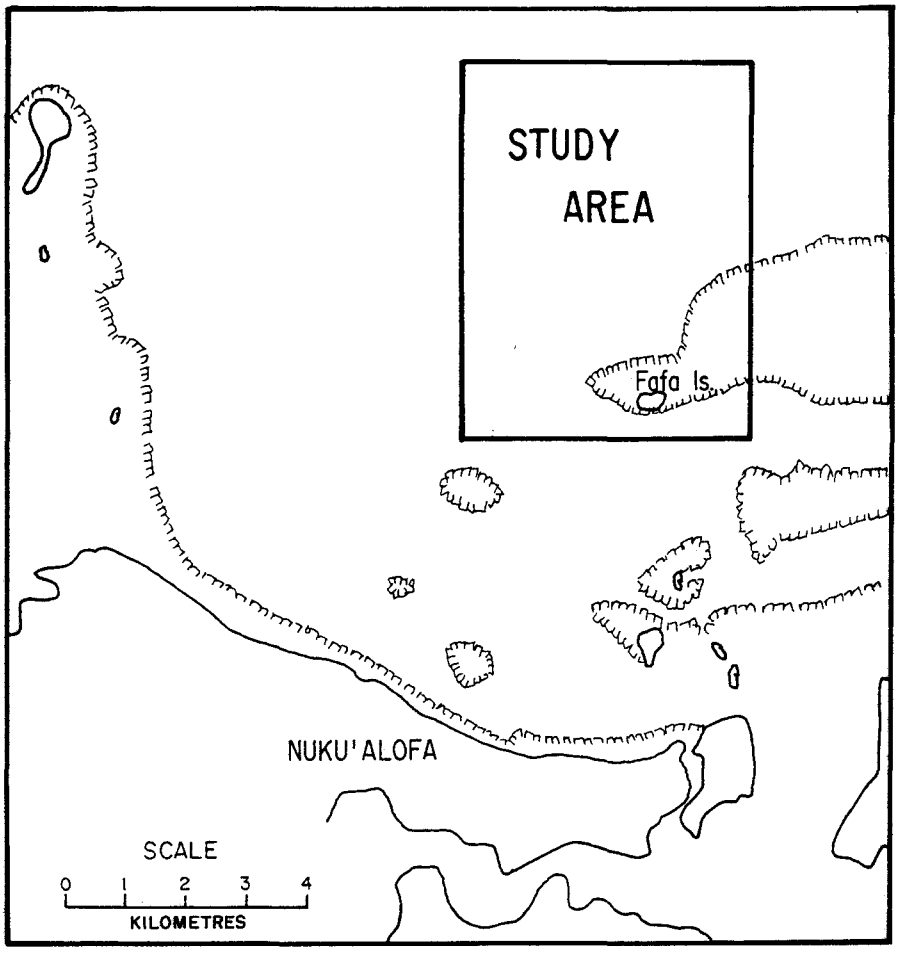


Figure 1. Location map.

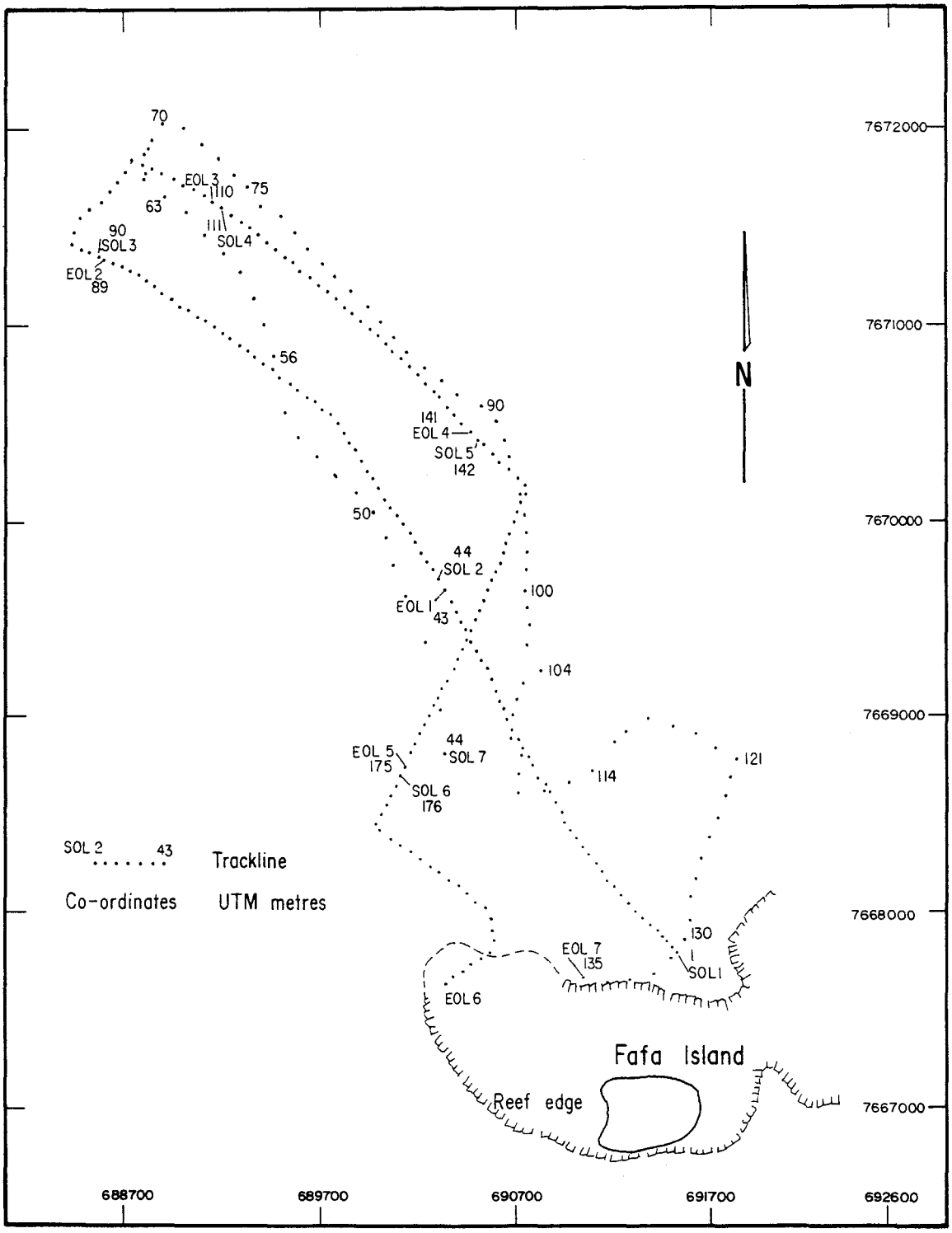


Figure 2. Track plot.

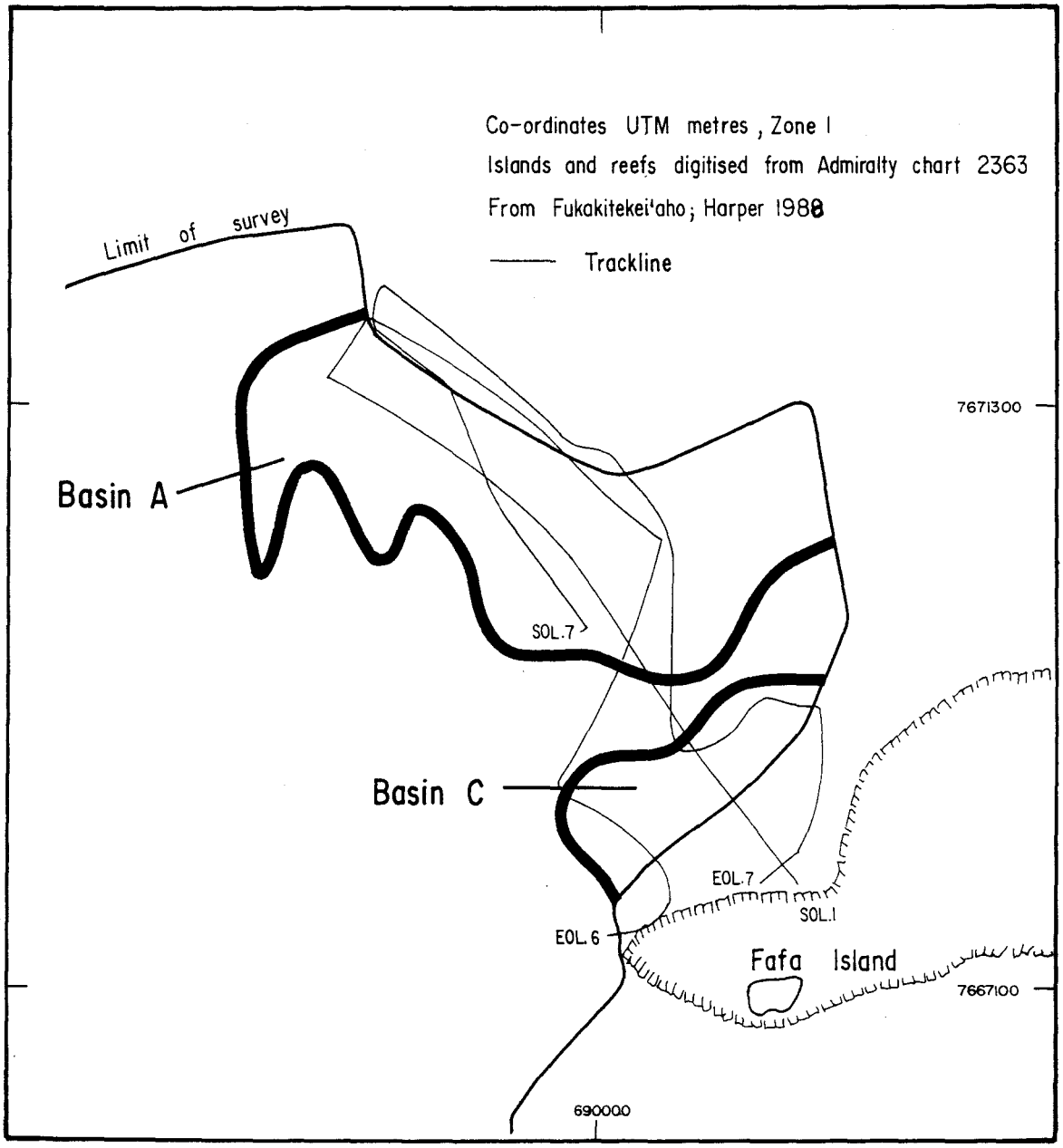


Figure 3. Location basin A and C.

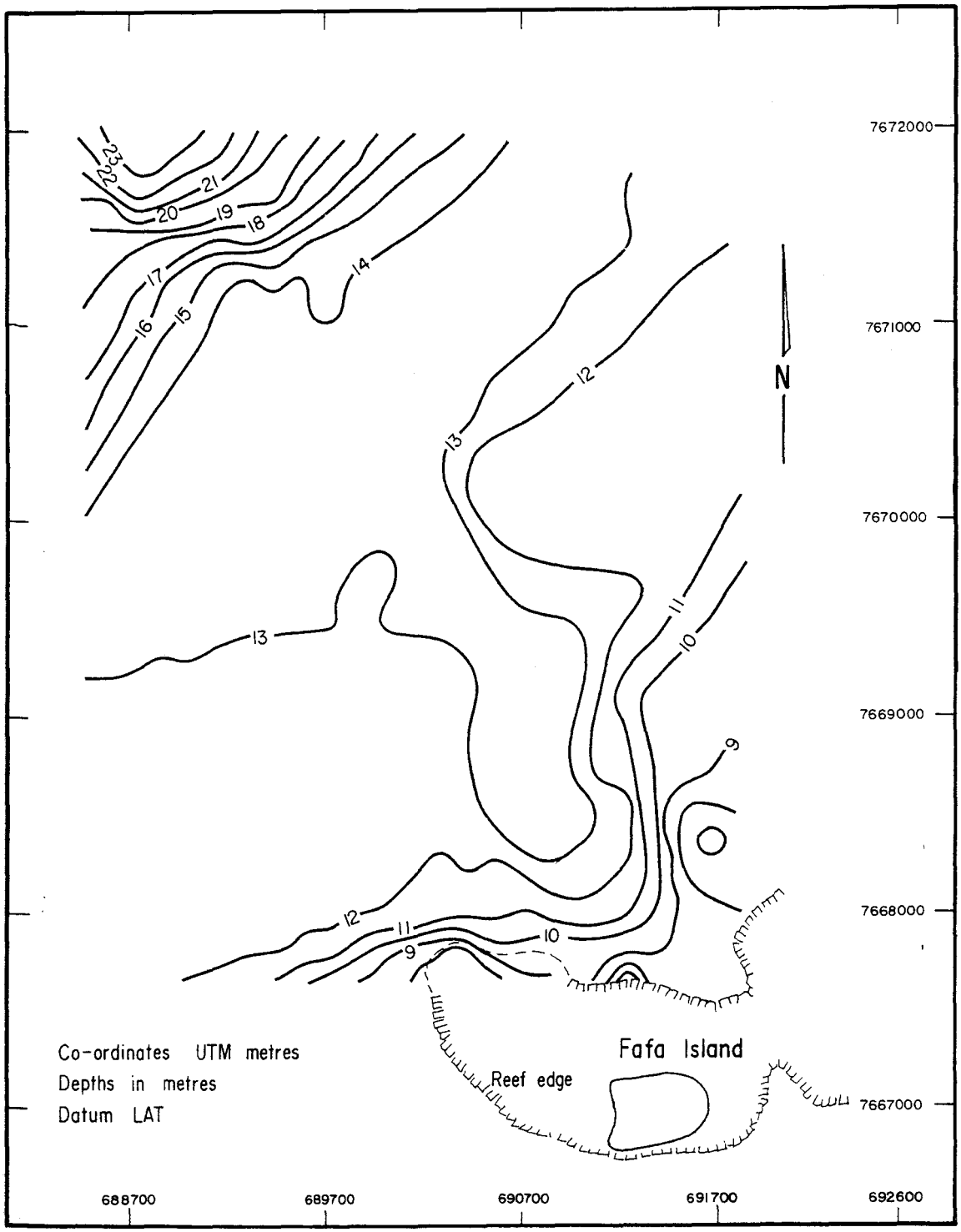


Figure 4. Bathymetry.

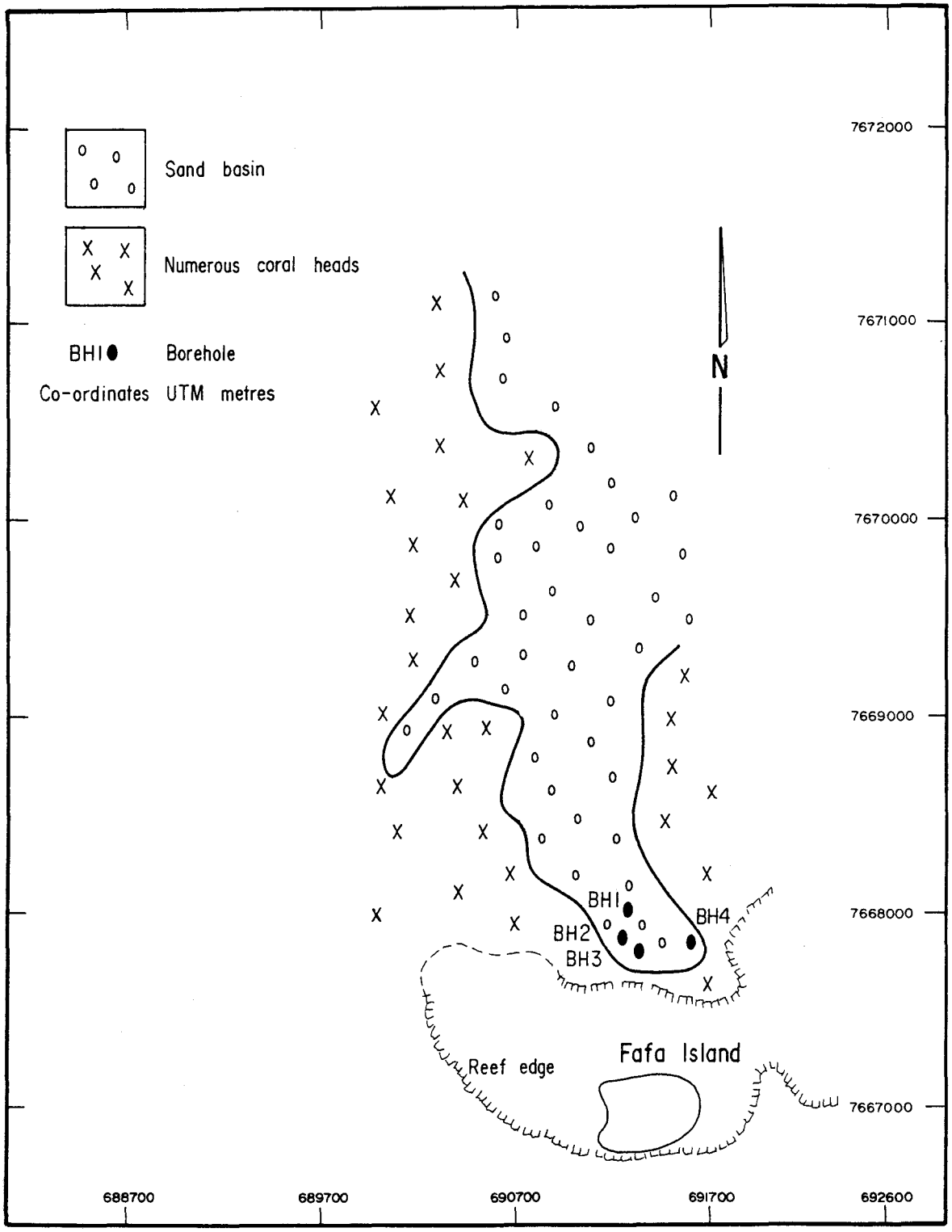


Figure 5. Seabed morphology/borehole location.

Navigation Towers

During the course of the survey navigation towers were positioned using the Del Norte trisponder system. Appendix 6 contains a listing of the tower positioned, their calculated UTM, and respective latitude longitude. Computation of the latitude/longitudes were provided by both the Hydrographic Office of the Fiji Marine Department as well as the Data Management section of the SOP AC Technical Secretariat for comparison and checking. Computed values showed discrepancies no greater than 1 second. The first 10 towers were positioned using the remotes, station 1 and station 2, at Faua Harbour and at the end of the seawall west of Fisheries respectively.

The remaining two towers Hakau Mama'o and Malinoa were positioned using station 3 Fafa rear lead on the 9 metre tower, and station 2 again at the end of the seawall. In addition to the towers, the channel marker buoy east of Hakau Mama'o was also positioned. On plotting the computed latitude/longitude values of the towers surveyed a constant discrepancy was noted. As the reason for the error in the plots is not yet known these values must be treated carefully until further checking can be done.

Vava'u Prospect

A quick overnight trip was made to Vava'u to check on the suitability of the barges locally available to mount a similar operation to that done in Nuku'alofa. Also an additional site inspection of the offshore area considered as a potential sand deposit was done.

Prior to the author's visit, the government geologist for the Tonga Lands and Survey Department had visited Vava'u and a review of onshore sand deposit was done. From that visit a new source of sand was located on Pangaimotu island, a beach adjacent to the King's Estate at Pangaimotu. Results of the survey of this area are with the Lands and Survey Department in Tonga. At present the sand for the construction industry is extracted from borrow pits on Tutuloa beach just north of Koloa island. The sand here appears to be finer than the sands at Pangaimotu.

Figures obtained from the Lands and Survey Department for tonnage sold by the government to local industry and the private sector, in 1988 a total of 3,339 tonnes, and to August 1989 only 549 tonnes had been sold.

CONCLUSIONS and RECOMMENDATIONS

The construction of a light weight (aluminium construction) self propelled portable barge system, to be permanently attached to the drill system is seen as a very important addition. It is evisaged such a barge would be able to be transhipped in one fullsize container. The flexibility of this system would allow us to work in member countries where no support barges are presently available.

Nuku'alofa

1) To resolve the sand basins off Fafa Island a detailed site survey (Figure 6) is proposed prior to drilling. It is therefore proposed to do both exercises in October/November.

2) The type of dredging operation needed will be reviewed based on the data collected from the survey, parameter being where the sand is and the water depth of the deposit.

Vava'u

1) No suitable platform is presently available in Vava'u to support a drilling operation. Alternatives are to tow the existing barge from Nuku'alofa to Vava'u which is not recommended as it is too expensive, and from a safety point of view, the barge in question is not oceangoing.

2) A site survey, to include bathymetry and high resolution seismic must be done first to define drilling targets. This could be accomplished during the mobilization of the drilling system.

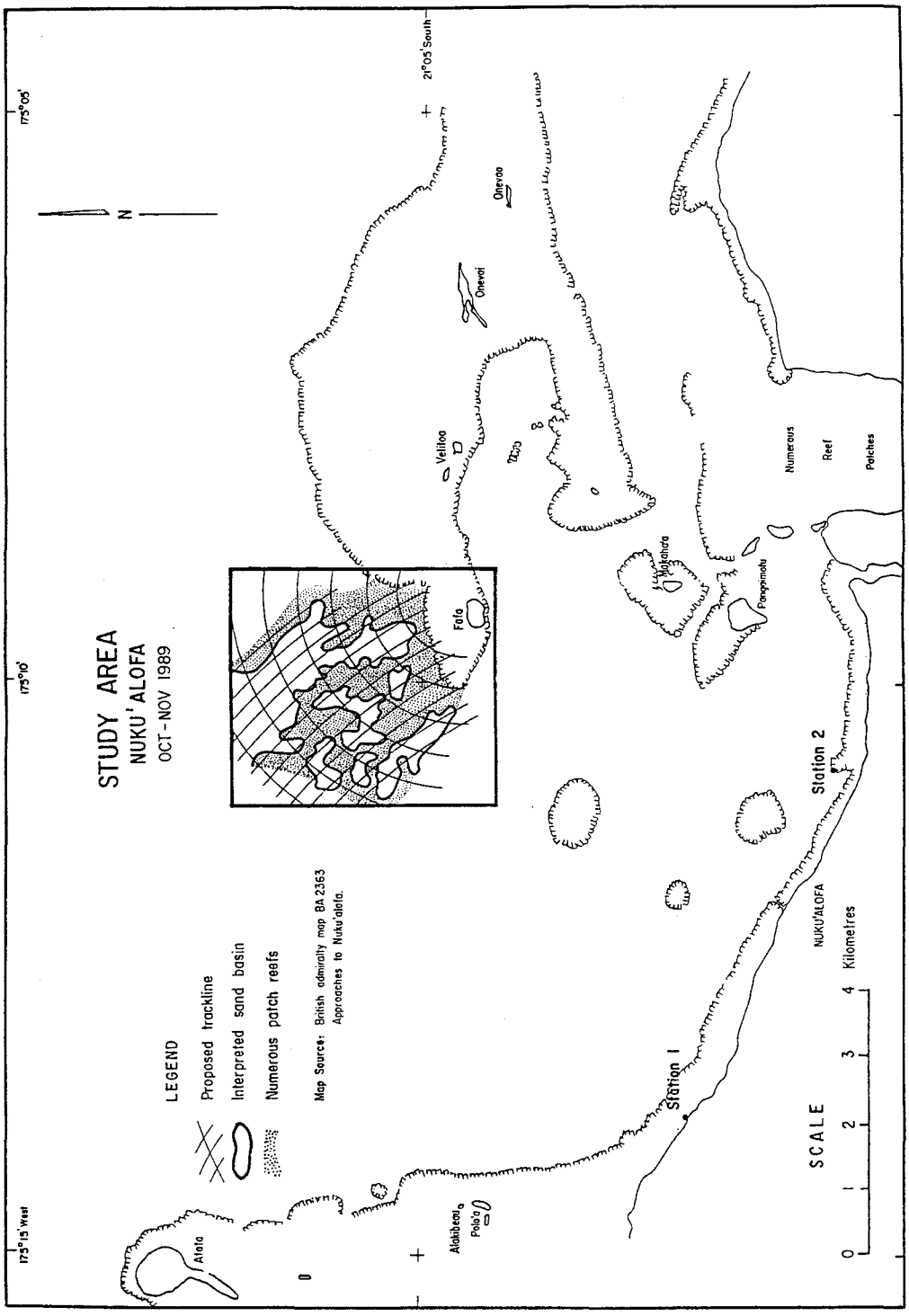


Figure 6. Proposed site survey.

REFERENCES

Kitekei'aho, T. and Harper, J.R. 1988. High-resolution seismic survey for lagoonal sand and gravel resources in Tongatapu, Kingdom of Tonga. *CCOP/SOPAC Technical Report 85*: 30 pages.

Smith, R. 1989. Vibro airlift development and trials, Laucala Bay, Fiji. *CCOP/SOPAC Preliminary Report 12*: 25 pages.

APPENDIX 1

CRUISE LOG

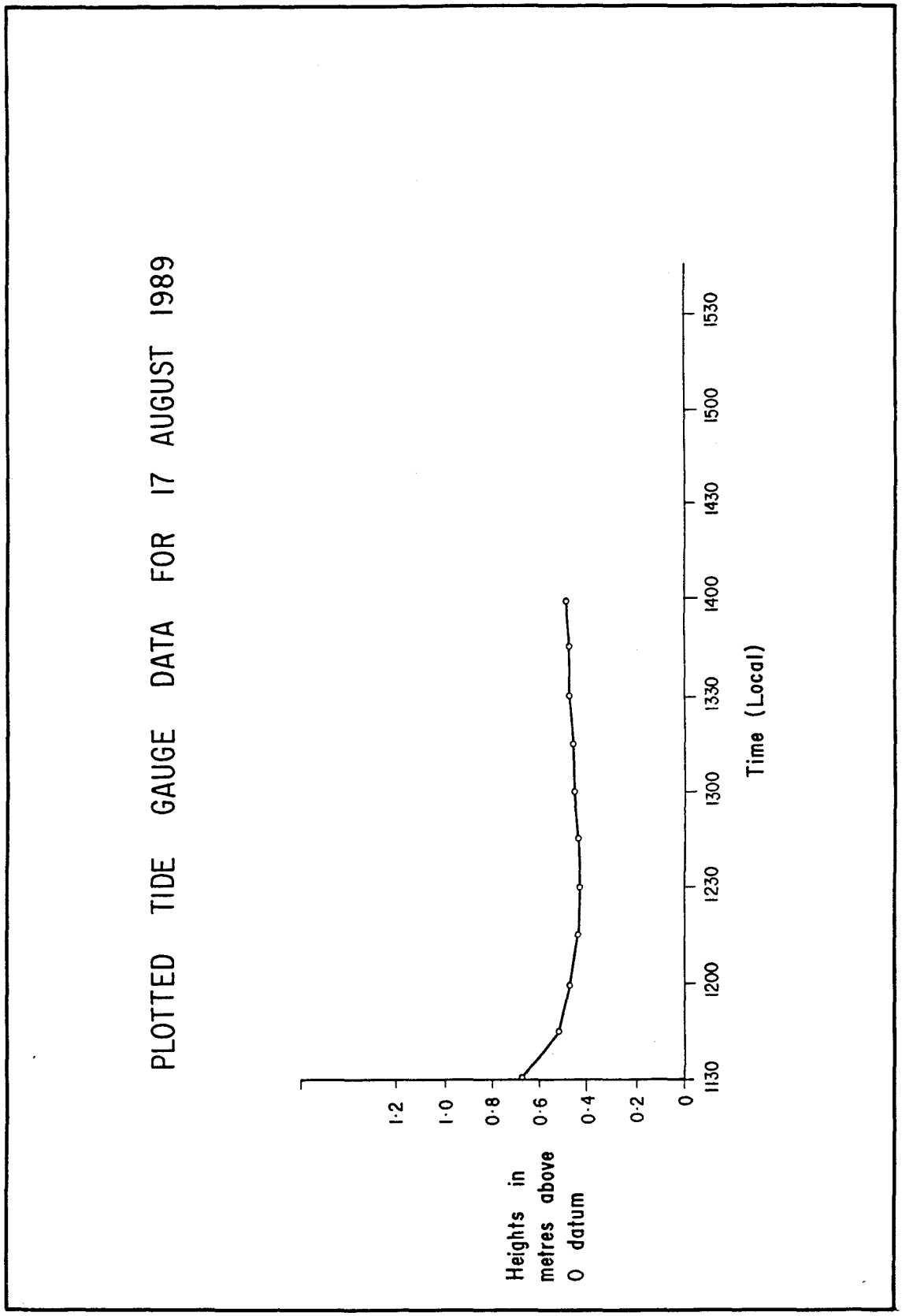
9th August	1315 hrs	Depart Suva for Tonga
	1800 hrs	Arrive Tonga, Nuku'alofa. Check in beach house.
10th August	0900 hrs	Meet with Robert Gatliff and discuss work programme; status of equipment; and location of barge. Barge not available until Tuesday 15th. Equipment may not be cleared until Monday.
		Check waverider buoy; condition not good. Check alternative vessels for moving the barge on location. In the afternoon check on shipping arrangements for moving equipment either to Vava'u or back to Suva. Check out Survey's new IBM PS/30 computer.
	1700 hrs	Return to beach house.
11th August	AM	Joe with Paul Schmidt's help prepare buoy for shipping back to Suva. Setup surveys computer prepare fax for Jim regarding work status and programme revision.
	1800 hrs	Return to the beach house.
12th August		Work on computer, processing data for drill programme.
13th August		SUNDAY
14th August	AM	Equipment cleared from main wharf with assistance from the Harbour Master's Office. Barge update, maybe available by Friday. Met Paul O'Brian of Reidel & Byrne consulting engineers. Paul is involved with the construction of navigational aids project and is using the barge for building the beacons.
14th August		Paul was unaware of our project and is very interested in our drilling programme.
		Organise fuel for the project through Fuka at British Petroleum.
	PM	Look for alternative remote locations for navigation control with Robert Gatliff and Apai (Technical Assistant with Survey). Saphore continued with the database project.

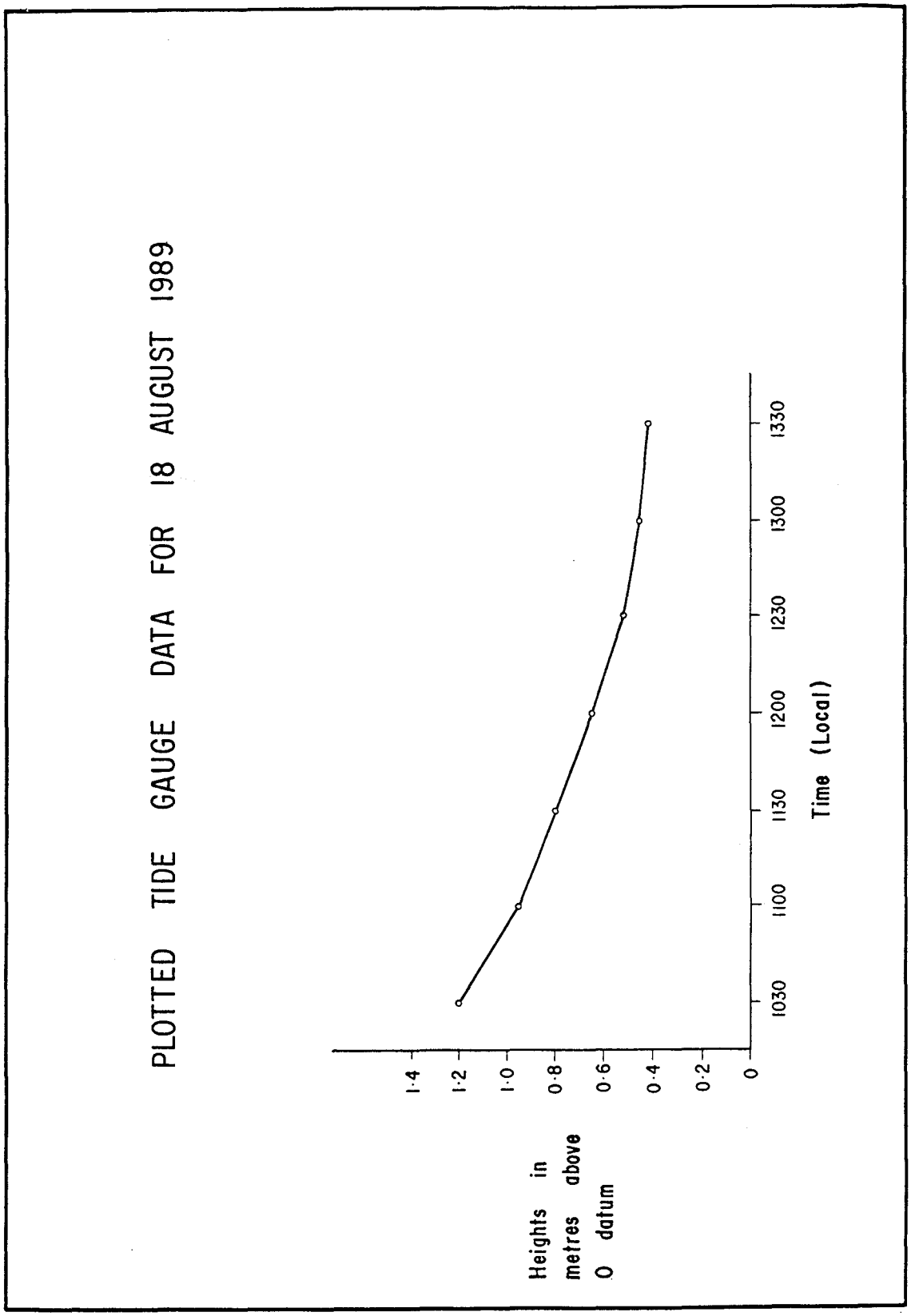
15th August	AM	Weather very wet with low visibility. Put batteries on charge at the beach house.
		Talk to surveyors about getting the remotes surveyed in known grid reference. Check on bookings for Joe and Robert at Air Pacific. Check with E.M. Jones Shipping agent to confirm future shipping arrangements.
	PM	Obtain fuel 200 litres diesel, 200 litres petrol, 41/2 stroke oil. Launch SOPAC boat and secure mooring. Rain ceased around 1300 hrs but still overcast. Drill equipment setup as much as possible before barge is available.
16th August		Triangulation survey with trisponders. Rain ceased operations in the afternoon. Reidel & Byrne provided detail maps on foreshore bench marks. Pacific Consultants (Japanese seawall project provided additional bench mark information). Barge update Friday should be available.
17th August	AM	Mobilise boat for survey. Survey lines 1 to 6. Weather was strong winds from the west, area surveyed very open long fetch. Had to stop survey because of rough water. Enroute to Faua Harbour (base) noticed on two occasions very strong currents running west to east ie. semi parallel and about 1 km south of Fafa Island reef. Turbulent zone was about 100 m to 200 m wide with very steep waves short period and very choppy, could be dangerous in a small boat. Further south of this zone a plume of, I guess, fine carbonate sediments appeared to create the illusion of a shallow sand spit some 1,000 m long with variable width up to 200 m wide.
	PM	Process data plot on isopach map which pointed to discrepancies in original data.
18th August	AM	Mobilise survey vessel; survey line seven. Complete bar checks, check calibration of instruments - all is okay. Barge arrived 1030 hours. Equipment needs to be offloaded. Ring HQ to give progress report.
19th August	0830	Survey in remote stations with Lands and Survey Department surveyor, Tevita Malolo.
	1400	Barge mobilisation started with removal of a small A-frame and wood/steel shed. Complete survey work up data and calculate coordinates for remotes in UTM metres.

	1900	Assembly of A-frame and drill started.
20th August		Sunday, process data, select drill sites based on data gathered. Weather overcast winds fresh to strong 10-15 knots and from the east.
21st August		Continue with the drill mobilisation. Weather strong easterly rough seas, some rain.
22nd August		Drill mobilisation with trial run in the small boat harbour. All systems working. Mount tranducer bracket and run vibro motors tomorrow. Wind now from the northeast 20 knots. Vavau ferry trip postponed 24 hours due to strong winds.
23rd August		Drill mobilisation complete, demonstrate unit to Robert Gatliff and Saimone Helu. Now waiting for clear weather.
24th August		Weather good. The *Unga* tows barge to drill site aea. Four holes drilled at the head of the major sand basin. Samples collected show a high mud content with a lot of large forams. No fragments of staghorn coral seen of the drill holes. Water depths proved to be deeper than desired which restricted penetration of drill because of hose length. Barge watchmen injured during the drilling of the last hole which required an emergency run to hospital. Completion of the drilling barge towed back to Faua Harbour.
25th August		Plot the drill hole locations and on analysis of immediate results, Robert Gatliff and Robert Smith decided that further drilling in the Fafa area was not necessary. Demobilisation of drill equipment started. Programme for the rest of the day was to fix the 12 navigation towers erected in the vicinity of Nuku'alofa for the Harbourmaster. Ten towers fixed, two remaining.
26th August		Fix the remaining two towers on Malinoa reef and Hakau Mamao reef.
28th August		Continue demobilisation of drilling system. Robert and Saimone leave for Vavau site inspection and barge availability for proposed drill programme.
29th August		Depart Vavau for Nuku'alofa.
30th August		Depart Nuku'alofa for Suva.

APPENDIX 2

TIDE GAUGE PWTS


PLOTTED TIDE GAUGE DATA FOR 17 AUGUST 1989
Heights in metres above 0 datum
1·2
1·0
0·8
0·6
0·4
0·2
0
1130
1200
1230
1300
1330
1400
1430
1500
1530
Time (Local)


PLOTTED TIDE GAUGE DATA FOR 18 AUGUST 1989
Heights in metres above 0 datum
1·4
1·2
1·0
0·8
0·6
0·4
0·2
0
1030
1100
1130
1200
1230
1300
1330
Time (Local)

APPENDIX 3

BENCHMARK DATA

TONGA CADASTRAL GRID
COORDINATES IN LINKS

	X (Easting)	Y (northing)
B33266	191747.460000	161259.990000
B45500	184046.570000	163414.720000
33266	953172.200000	801619.700000
45500	914891.250000	812330.780000
33261	953436.600000	801643.200000
33265	953486.300000	801622.900000
33263	953696.300000	801375.800000
34861	917550.450000	810599.360000
22957	913949.300000	813635.300000
60781	914386.910000	813134.680000
21194	920787.400000	809549.880000
31454	920039.380000	809713.200000
31353	919848.190000	809728.110000
31477	919568.600000	809730.570000
30362	919490.660000	809730.880000
45406	916461.870000	811103.030000
45407	916158.680000	811262.930000
45495	915609.400000	811765.370000
45496	915566.150000	811706.800000
B33261	191800.648751	161264.717398
B33265	191810.646784	161260.633685
B33263	191852.891966	161210.925104
B34861	184581.514938	163066.413729
B22957	183857.080274	163677.147482
B60781	183945.113201	163576.438821
B21194	185232.684644	162855.291683
B31454	185082.207186	162888.146520
B31353	185043.745931	162891.145963
B31477	184987.501446	162891.640882
B30362	184971.822433	162891.703257
B45406	184362.527855	163167.736060
B45407	184301.535837	163199.902830
B45495	184191.038511	163300.977635
B45496	184182.337997	163289.195248

Data Source : Masato Suzuki
(Pacific Consultants International) - Seawall Project

TONGA CADASTRAL GRID

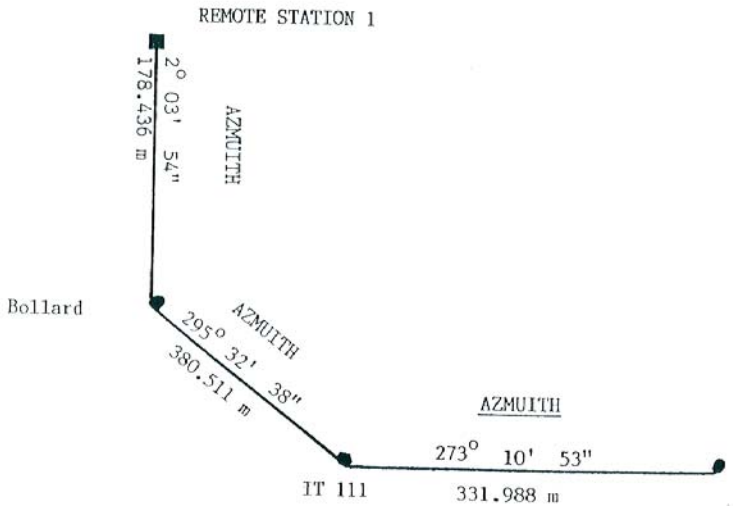
Universal Transverse mercator projection zone one. The false origin of the Tonga Cadastral Grid is the intersection of the UTM Northing of 17,500,000 metres with the Central Meridian of 177^{O} west longitude. To convert link co-ordinates to UTM co-ordinates multiply co-ordinates (in links) by 0.2011677 and add 500,000 to Eastings and 7,500,000 to Northings for final adjust co-ordinates.

Example

Benchmark #	Links		in UTM metres	
	E	N	E	N
4550	914891.25	812330.78	684046.56	7663414.7
45496	915566.15	811706.80	684182.33	7663289.1

APPENDIX 4

TRISPONDER LOCATIONS AND COMPUTATIONS



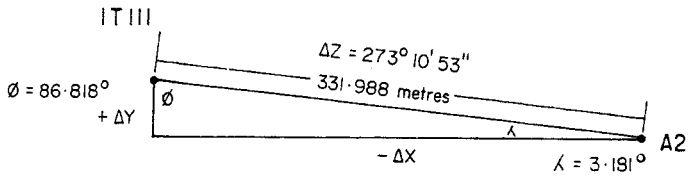
A2 Co-ordinates

Links = 800850.4N
941339.5E

UTM = 7661105.23 N
689367.10 E

SURVEY DATA FOR FIXING REMOTE STATION 1

CALCULATIONS FOR REMOTE STATION ONE CO-ORDINATES



A2 in Links
EASTING = 941339.5
NORTHING= 800850.4

A2 in UTM Metres
EASTING = 699367.10
NORTHING= 7661105.23

$-\Delta X$ = Sin 86.818 x 331.988
= .99845 x 331.988 m
= 331.476 m

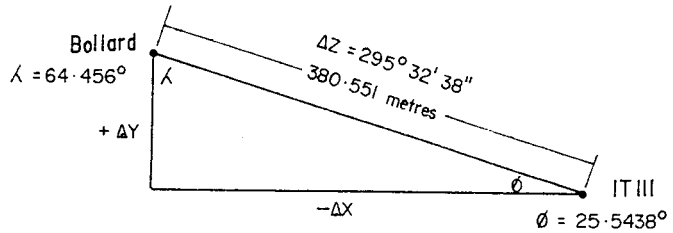
$+\Delta Y$ = Sin 3.181° x 331.988
= 0.5549 x 331.988
= 18.422 m

IT 111 Co-ordinates

EASTING = 689367.10 - 331.476
= 698035.624 m

NORTHING = 7661105.23 + 18.422
= 7661123.652 m

Bollard Co-ordinates



$-\Delta X$ = Sin 64.456 x 380.551 m
= .9022 x 380.551
= 343.353 m

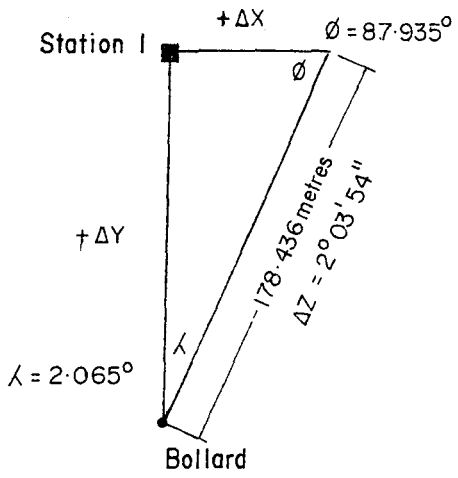
$+\Delta Y$ = Sin 25.5438 x 380.551
= 164.095 m

Bollard Co-ordinates -

EASTING = 689,035.624 - 343.353
= 688692.27 m

NORTHING = 7661123.652 + 164.093
= 7661287.747 m

REMOTE STATION ONE



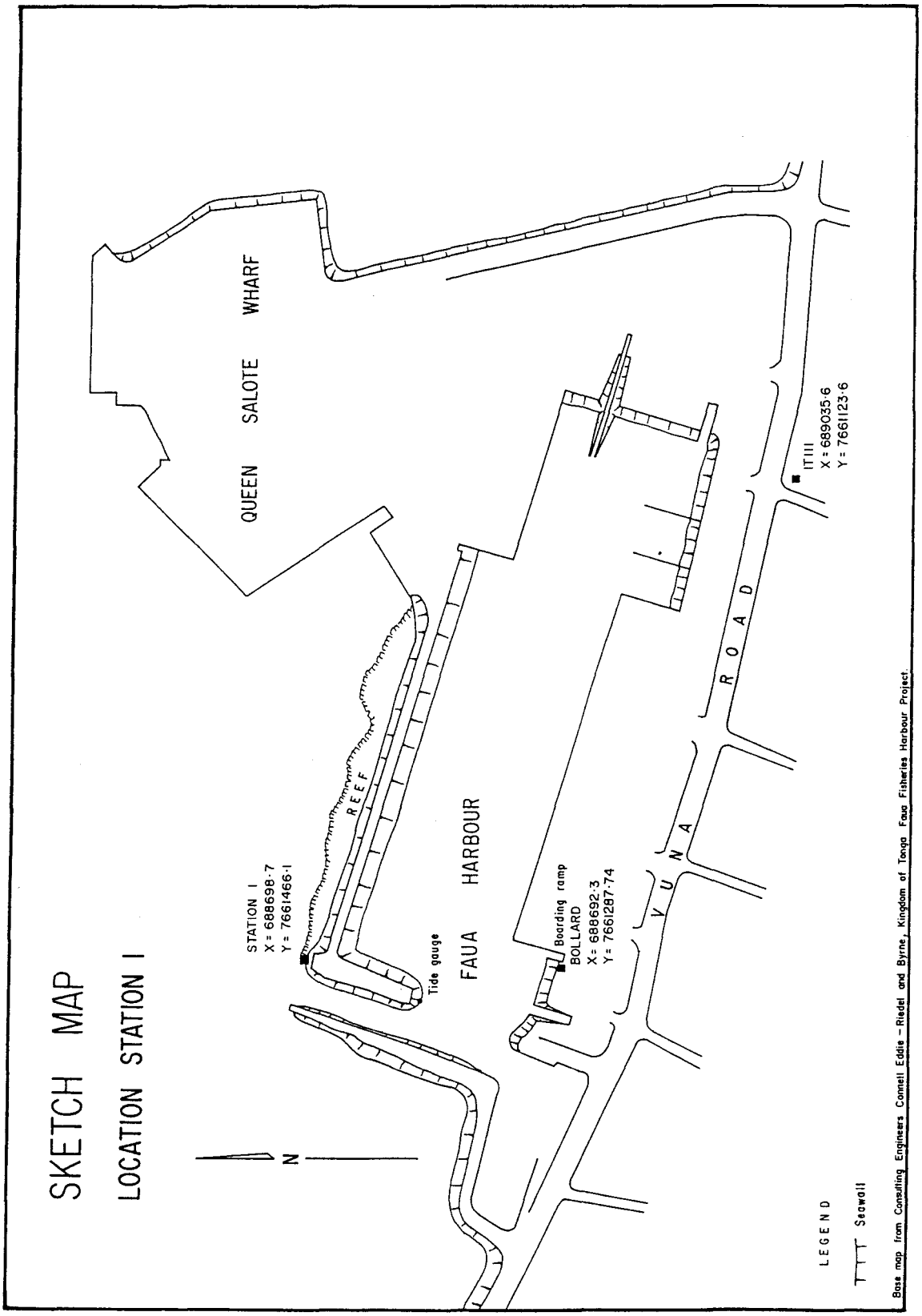
$+\Delta X$ = Sin 2.065 x 178.436
= 0.0363 x 178.436
= 6.429 m

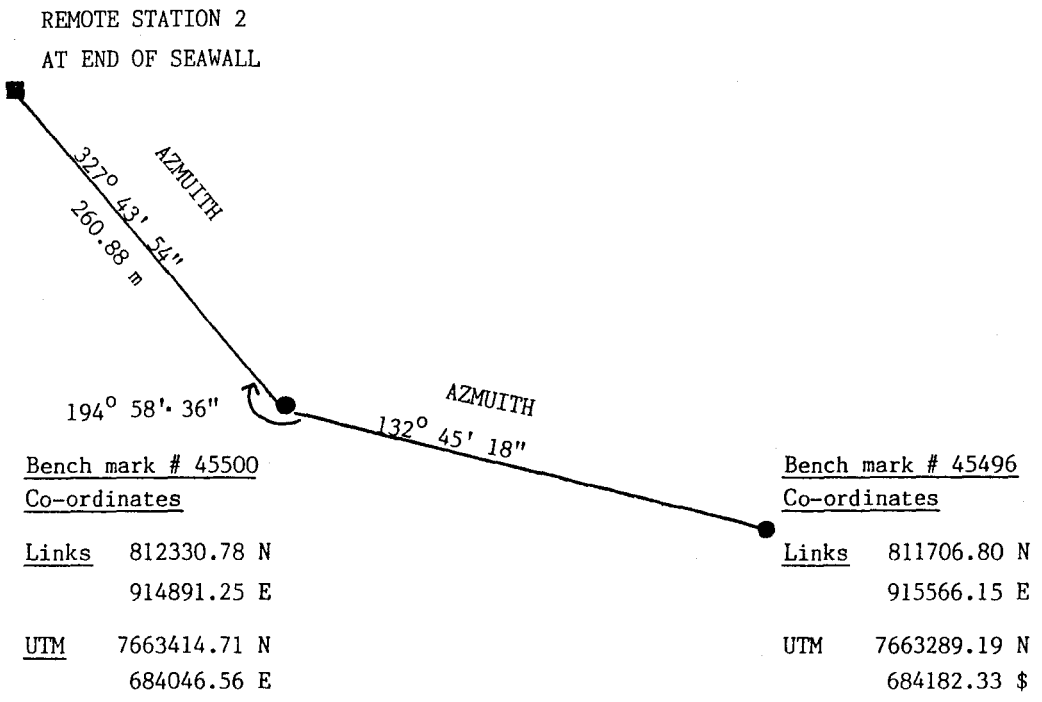
$+\Delta Y$ = Sin 87.935 x 178.436
= .9994 x 178.436
= 178.320 m

Co-ordinate Remote Station 1 in UTM metres

EASTING = 688692.27 + 6.429
= 688698.699 m

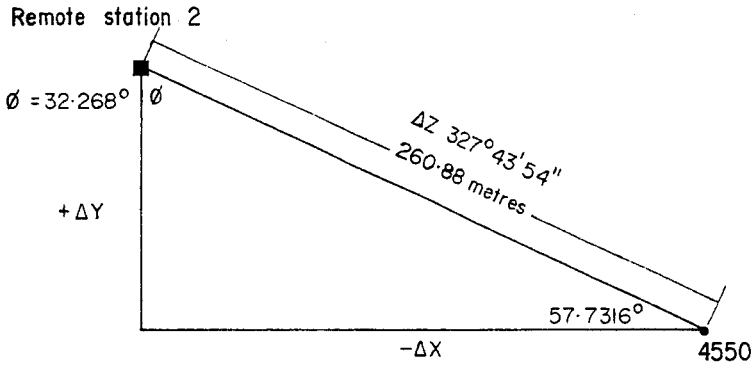
NORTHING = 7661287.747 + 178.320
= 7661466.067 m


SKETCH MAP
LOCATION STATION 1
N
STATION 1
X = 688698·7
Y = 7661466·1
REEF
Tide gauge
FAUA HARBOUR
Boarding ramp
BOLLARD
X = 688692·3
Y = 7661287·74
VUNA
ROAD
QUEEN SALOTE WHARF
IT111
X = 689035·6
Y = 7661123·6
LEGEND
Seawall
Base map from Consulting Engineers Connell Eddie – Riedel and Byrne, Kingdom of Tonga Faua Fisheries Harbour Project



SURVEY DATA FOR FIXING REMOTE STATION 2

CALCULATIONS FOR CO-ORDINATES REMOTE STATION 2



4550 in Links

EASTING = 914891.25
NORTHING = 812330.78

4550 in UTM metres

EASTING = 684046.56
NORTHING = 7663414.71

-ΔX

= Sin 32.268° x 260.88
-ΔX = .5338 x 260.88
= 139.2577 metres

+ΔY

= Sin 57.7316 x 260.88
= .84555 x 260.88
= 220.5887 metres

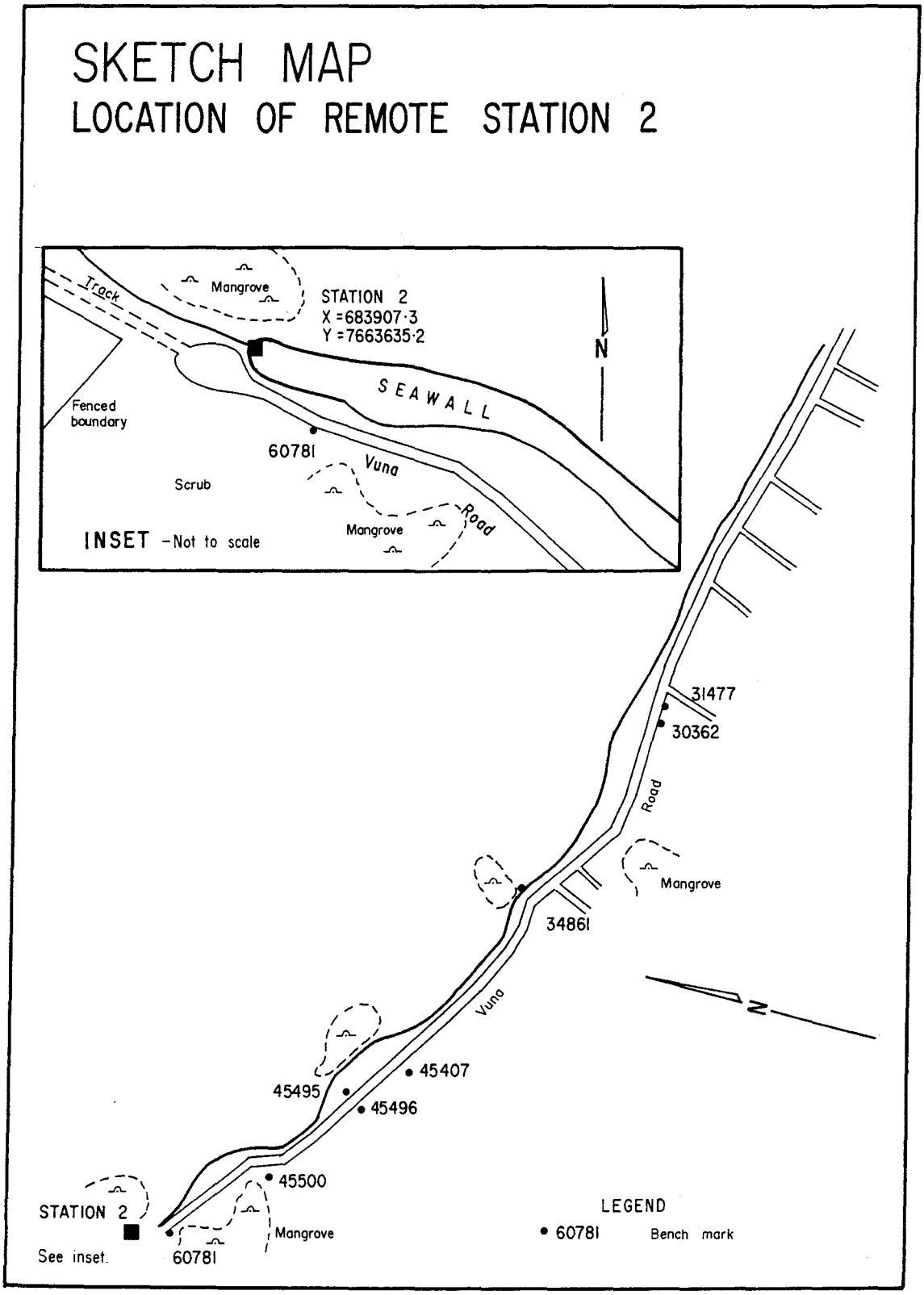
Co-ordinates Remote Station 2 in UTM metres

EASTING = 684046.56 - 139.2577
= 683907.3

NORTHING = 7663414.71 + 220.5887
= 7663635.29

Remote Station 2

EASTING = 683907.30
NORTHING = 7663635.29


SKETCH MAP
LOCATION OF REMOTE STATION 2
Track
Mangrove
STATION 2
X =683907·3
Y =7663635·2
N
SEAWALL
Fenced boundary
60781
Vuna
Scrub
Road
Mangrove
INSET -Not to scale
31477
30362
Road
Mangrove
34861
Vuna
45407
45495
45496
45500
STATION 2
See inset.
Mangrove
60781
LEGEND
60781 Bench mark

APPENDIX 5

BOREHOLE LOG

Borehole No.	Grid Reference	Water Depth	Sampling Interval
1	691283.8,7668001.0	10 metres	0-3 bulk sample
2	691256.2,7667877.0	12 metres	0 - 1.0 m 1 - 1.8 m 1.8 - 3.0 m
3	691346.8,7667810.5	12.2 metres	0 - 1.5 m 1-205m 2.1 - 3.2 m
4	691596.0,7667851.0	9.4 metres	0 - 1.5 m 1.5 - 2.5 m 2.5 - 3.5 m 3.3 - 3.8 m

APPENDIX 6

NAVIGATION TOWER AND COORDINATES

Navigational Aid Tower Title	Station 2 Range in metres	Station 1 Range in metres	UTM in metres x	UTM in metres y	Computed Latitude	Computed Longitude
Ulangalulu Tower (6 M)	4364.6	4085.6	687869.25	7665466.5	S21°06'08"	W175°11'28"
Monu Reef	4732.4	1427.3	688580.37	7662888.5	S21°07'31"	W175°11'03"
Valanga Uta	3444.9	2810.2	687339.9	7663926.0	S21°06'58"	W175°11'46"
Makaha'a Front Lead	8132.5	4148.8	692034.4	7663933.0	S21°06'55"	W175°09'03"
Makaha'a Rear Lead	7936.7	3987.5	691838.75	7663923.5	S21°06'56"	W175°09'10"
Makaha'a North	8185.1	4645.3	692021.2	7666912.5	S21°06'31"	W175°09'04"
Fafa Front Lead (3 M)	8585.9	6289.2	691843.19	7666912.5	S21°05'19"	W175°09'11"
Fafa Rear Lead (3 M)	8658.2	6675.6	691687.1	7667435.5	S21°05'02"	W175°09'17"
Tufaka Front Lead (6 M)	6534.6	11015.1	681302.18	7669628.5	S21°03'55"	W175°15'17"
Tufaka Rear Lead (9 M)	6328.4	10796.2	681450.8	7669467.5	S21°04'00"	W175°15'12"

Navigational Aid Tower Title	Station 2 Range in metres	Station 1 Range in metres	UTM in metres x	UTM in metres y	Computed Latitude	Computed Longitude
Malinoa	14006.3	6230.0	694197.8	7673137.0	S21°01'56"	W175°07'52"
Hakau Mama'o	13243.4	10069.6	686320.5	7676657.0	S21°00'04"	W175°12'26"
Buoy E. of Hakau	14178.6	9065.8	690143.6	7676369.0	S21°00'12"	W175°10'14"
Station One (Faua Harbour)			688698.7	7661466.1	S21°08'17"	W175°10'58"
Station Two (Seawall W of Fisheries)			683907.3	7663635.3	S21°07'09"	W175°13'45"
Station Three (Fafa Rear Lead)			691687.1	7667435.5	S21°05'02"	W175°09'17"

COORDINATES OF TOWER EXPRESSED IN UTM METRES BASED ON THE TONGA CADASTRAL GRID