(8) A supervising commission member advised the survey team on GPS operations and computations at I/21 located at Maungu in the middle of the survey area, and at Mombasa Base Camp (survey headquarters) respectively during August 27 - 29.

III-3 Computations and Adjustments

III-3-1 Outline

Satellite orbital data used for computations were based on broadcast ephemeris. Computations were performed by "Automatic Processing", a menu of Trimble program TRIVEC, and in the following sequence; after making computation on the geocentric coordinate system, the coordinates were transformed on to the reference ellipsoid WGS-84.

Taking three points (A, B, and C, for example) used for simultaneous observation, the approximate position of A was determined and, based on that position, coordinate difference, first between A and B, and then between B and C, were obtained. In Tab. 2, the three points for each triangle listed under the station name correspond, from the top downwards, to A, B, and C, respectively.

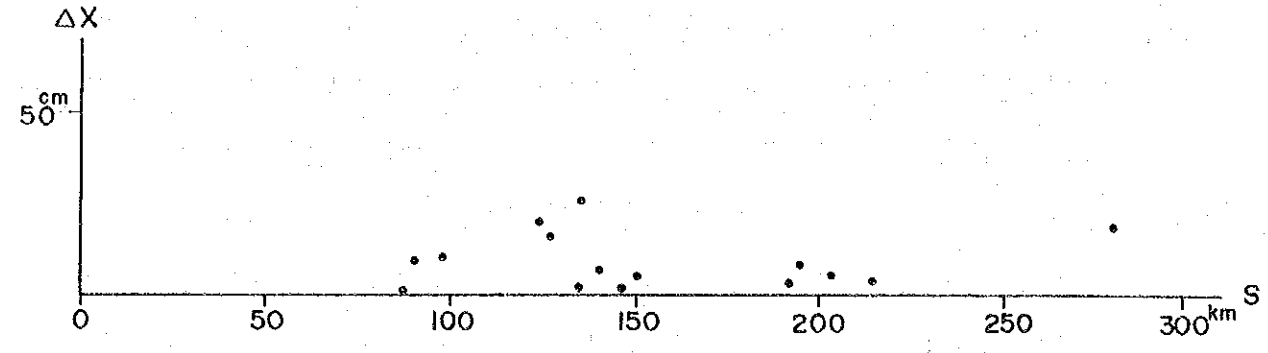
III-3-2 Closure of Coordinates

In addition to the above computations, coordinate difference between C and A is obtained to complete the circuit of A → B → C → A closing at A. By examining

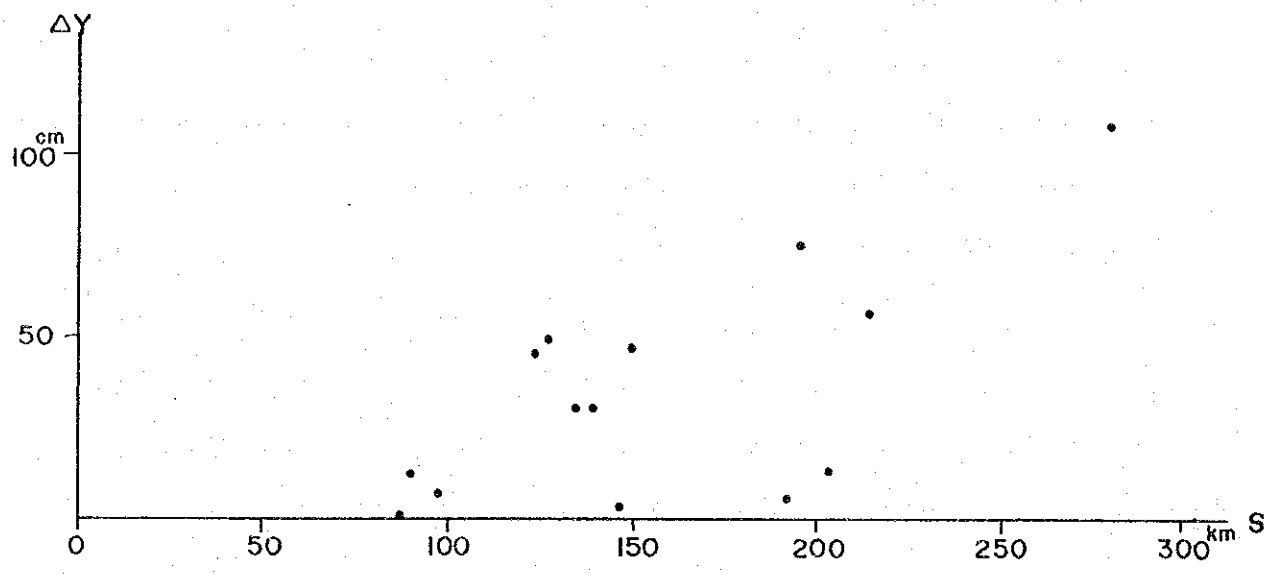
the closure of coordinates at A resulting from the above computations, the quality of observations for this set of points was judged (or if it was accurate enough for a given purpose was determined).

In Tab. 2 are listed combinations of the triangles and the closures. If the starting value at A turns out to be smaller than the closing value, it is shown as a + value, and similarly, if larger, it is shown as a - value. x and y are the latitude and the longitude component respectively on the reference ellipsoid WGS-84, h being the vertical component relative to the ellipsoid.

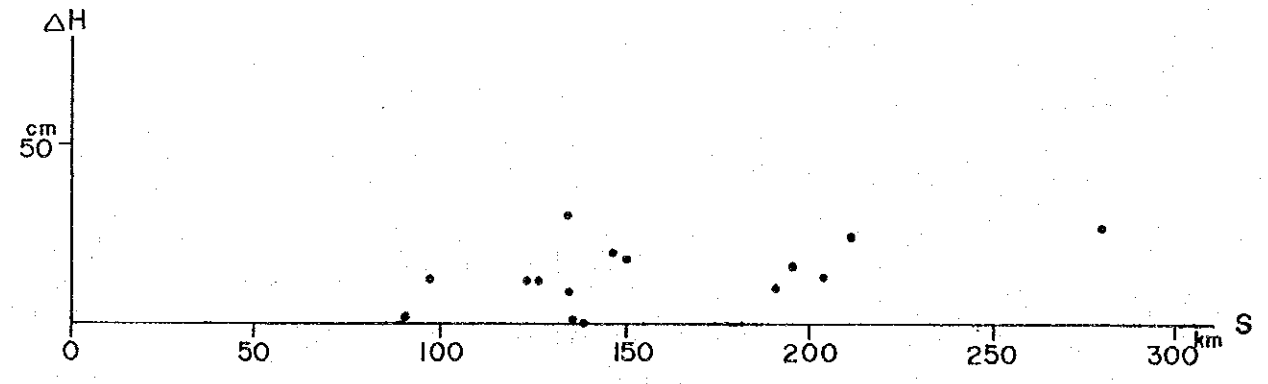
Δx, Δy, and Δh represent the closures for the respective components. The closures of these components as related to the sum of side lengths of the triangle (S) are graphically shown in Fig. 3 (a), (b) and (c). The figures are drawn based on the absolute values of the closures. Fig. 3(d) shows the closure vector ($\Delta s = \sqrt{\Delta x^2 + \Delta y^2 + \Delta h^2}$).



(a) ΔX



(b) ΔY



(c) ΔH

Fig. 3 Triangular Closures (1)

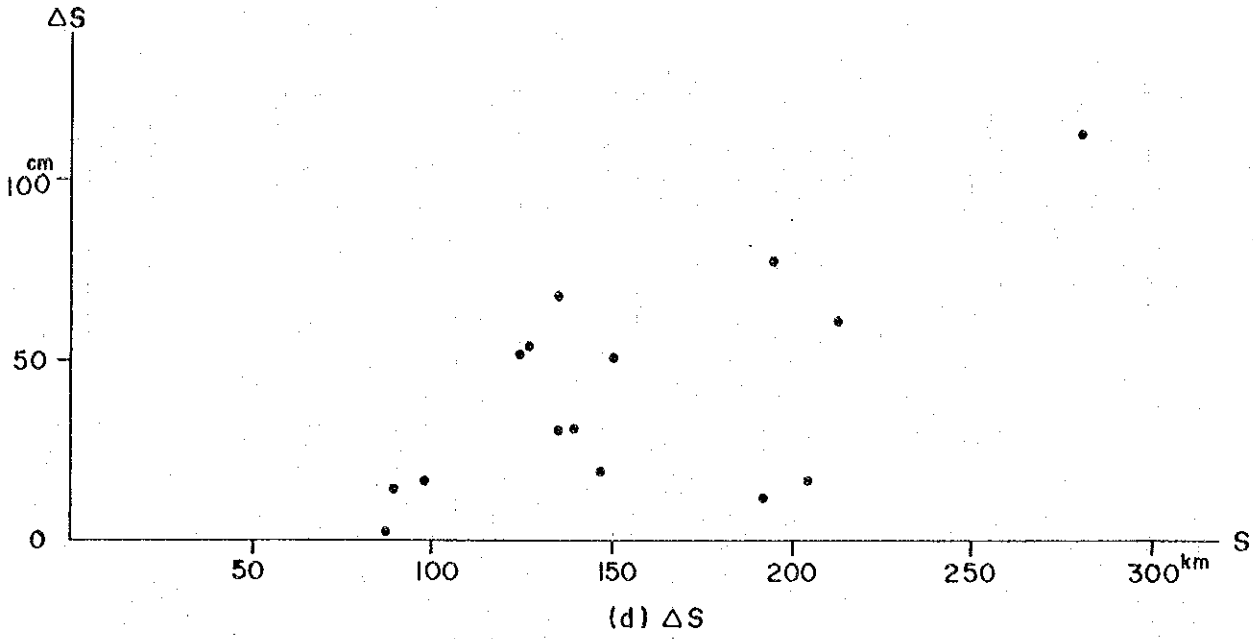


Fig. 3 Triangular Closures (2)

The computation results are summarized below.

	Range	Mean	
Total length (triangle)	87 km - 280 km	155 km	
Side length (a side)	21 km - 126 km	52 km	
Closure (absolute value)			÷3
Δx	1 cm - 26 cm	9 cm	3 cm
Δy	1 cm - 108 cm	37 cm	12 cm
Δh	0 cm - 30 cm	14 cm	5 cm

III-3-3 Accuracy of Side Length Measurements

In the course of computations, the standard deviations of side length measurements were obtained as shown in Tab. 3 and Fig. 4. The side lengths as surveyed ranged 21 km - 126 km with the mean of 52 km as stated above, their standard deviations being 0.000 m - 0.103 m with a mean value of 0.015 m.

Tab. 3. Side Length Measurement (1)

Number of triangle	Name of side	Side length	Standard deviation	Number of triangle	Name of side	Side length	Standard deivation
1	188PT1 - J-2	45,472.41^{m}	0.011^{m}	5'	190S2N - R-2	29,052.37^{m}	0.000^{m}
	J-2 - R-6	51,586.11	0.021		R-2 - I/21T	27,029.84	0.008
	R-6 - 188PT1	42,448.17	0.012		I/21T - 190S2N	30,897.11	0.007
2	R-6 - SKP49E	55,834.65	0.011	6	I/21T - 199ST1N	55,178.51	0.018
	SKP49E - J-3	39,166.21	0.010		196ST4N - 199ST1N	32,270.28	0.003
	J-3 - R-6	55,510.06	0.000		196ST4N - I/21T	47,874.83	0.014
3	195PT2 - 196ST4N	35,294.41	0.002	6'	I/21T - 199ST1N	55,178.35	0.009
	196ST4N - J-3	50,855.11	0.004		196ST4N - 199ST1N	32,270.26	0.002
	J-3 - 195PT2	38,193.17	0.011		196ST4N - I/21T	47,874.49	0.017
4	I/21T - 190S2N	30,897.40	0.006	7	200S8 - 199ST2N	26,883.85	0.005
	190S2N - J-2	86,078.14	0.007		199ST2N - 199ST1N	20,510.69	0.000
	I/21T - J-2	87,097.69	0.000		199ST1N - 200S8	43,035.90	0.005
5	191S2 - R-2	34,744.94	0.019	8	200S8 - 202S3	56,466.91	0.006
	R-2 - 190S2Z	29,052.90	0.000		202S3 - BM-1T	28,265.17	0.002
	190S2N - 191S2	33,335.11	0.011		BM-1T - 200S8	42,891.34	0.010

Tab. 3. Side Length Measurement (2)

Number of triangle	Name of side	Side length	Standard deviation	Number of triangle	Name of side	Side length	Standard deviation
9	SKP62 - 202S3	125,867.83^{m}	0.103^{m}				
	202S3 - 197S1	94,916.74	0.038				
	197S1 - SKP62	59,275.87	0.051				
10	197S1 - I/21T	71,354.91	0.007				
	I/21T - R-2	27,029.86	0.005				
	R-2 - 197S1	48,506.76	0.000				
11	192S6 - 198S8	54,470.02	0.014				
	198S8 - R-2	60,411.87	0.021				
	R-2 - 192S6	82,440.65	0.037				
12	SKP62 - 192S6	72,368.66	0.000				
	192S6 - 193S2	68,261.17	0.012				
	193S2 - SKP62	51,281.17	0.027				
13	197S1 - R9-47A	47,493.46	0.034				
	R9-47A - BM-1T	79,510.97	0.072				
	BM-1T - 197S1	87,618.16	0.024				

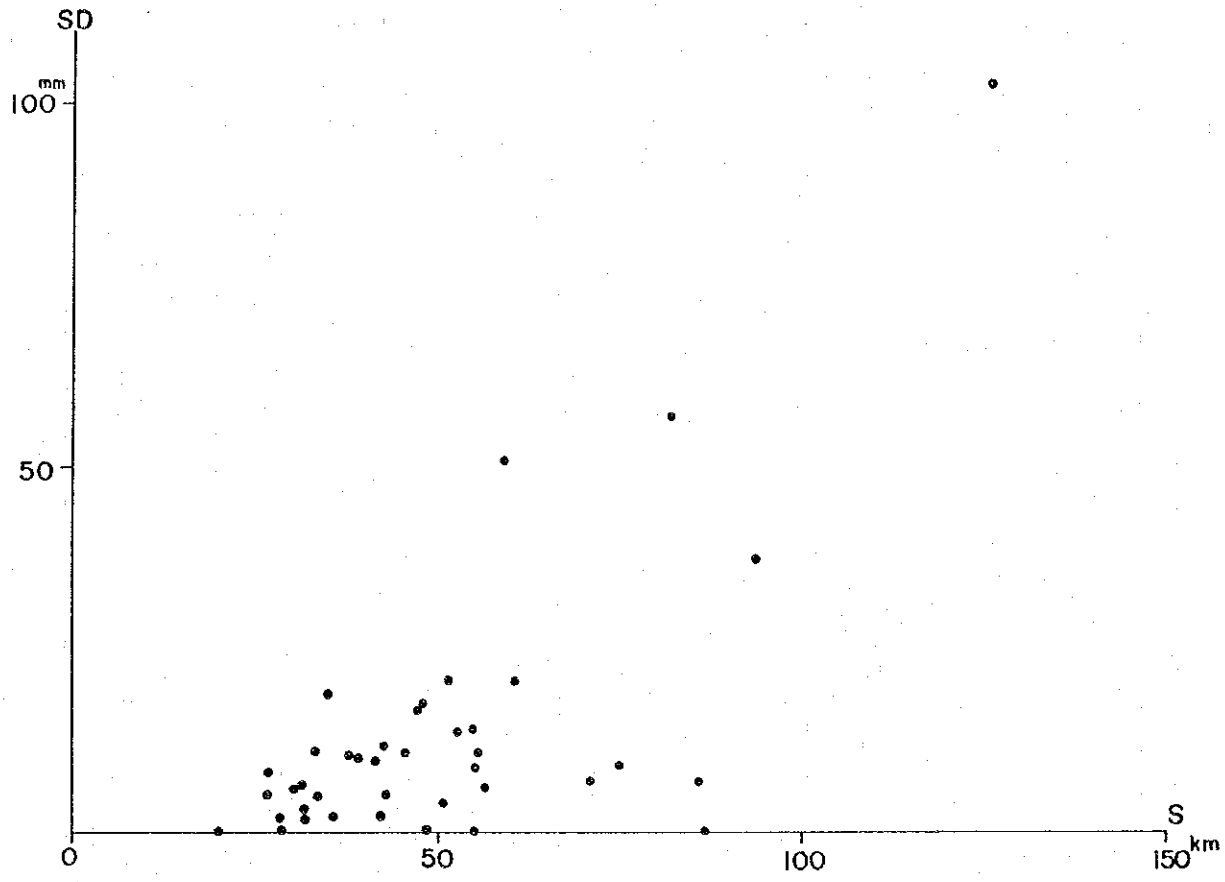


Fig. 4 Accuracy of Side Length Measurement

Since it was necessary to transorm the geodetic coordinates of te given points, which were based on Clarke 1880 Ellipsoid, to those of WGS-84, for transformation of the origin of coordinate system, the following value for x, y, and z, as tentatively obtained by Kenya for WGS-72 based on NNSS observations, were employed.

	m
x =	- 142.2567
y =	- 22.6533
z =	- 303.6667

The method discussed in this section as well as the previous section are considered reliable enough to serve as the geodetic control survey of the first order side length (30 km - 50 km).

III-3-4 Repeatability of Observations

As mentioned in III-2 (6), observations were made two times for the same side with two sets of results. The second measurements were obtained because of the satellite orbital adjustments after the first measurements. The first results were, therefore, not adopted but, for reference, the two sets of results partly taken from Tab. 3 are compared below.

For the time and dates of observations, refer to Tab. 2.

Of these, the last two columns were incidentally obtained in the course of measurement.

Name of side	First measurement (1)	Second measurement (2)	(1) - (2)
	m	m	m
190S2N - R-2	29,052.90	29,052.37	+0.53 (1/55,000)
I/21T - 199ST1N	55,178.51	55,178.35	+0.16 (1/340,000)
199ST1N - 196ST4N	32,270.28	32,270.26	+0.02 (1/1,610,000)
196ST4N - I/21T	47,874.83	47,874.49	+0.44 (1/110,000)
I/21T - 190S2N	30,897.40	30,897.11	+0.29 (1/110,000)
R-2 - I/21T	27,029.86	27,029.84	+0.02 (1/1,350,000)

III-3-5 Computations of Coordinates

All coordinate computations were performed in reference to WGS-84, the reference ellipsoid of the satellites. It was known that the coordinate values could change within a triangle depending on the sequence of computations due to computation programs, but the changes were negligible for our purpose and, therefore, the values obtained in the sequent of A → B → C, as discussed in III-3 (1), alone were adopted. Closures obtainable by further computation of C → A are not considered at this stage.

In the next step, coordinates of the proposed points were computed from the coordinates of the starting points and closing points provided as given points. In this process, the closures of coordinates between the given points were distributed in proportion to the numbers of sides surveyed. The alignments of the points for computations of the proposed points are given in Fig. 5 and Tab. 4.

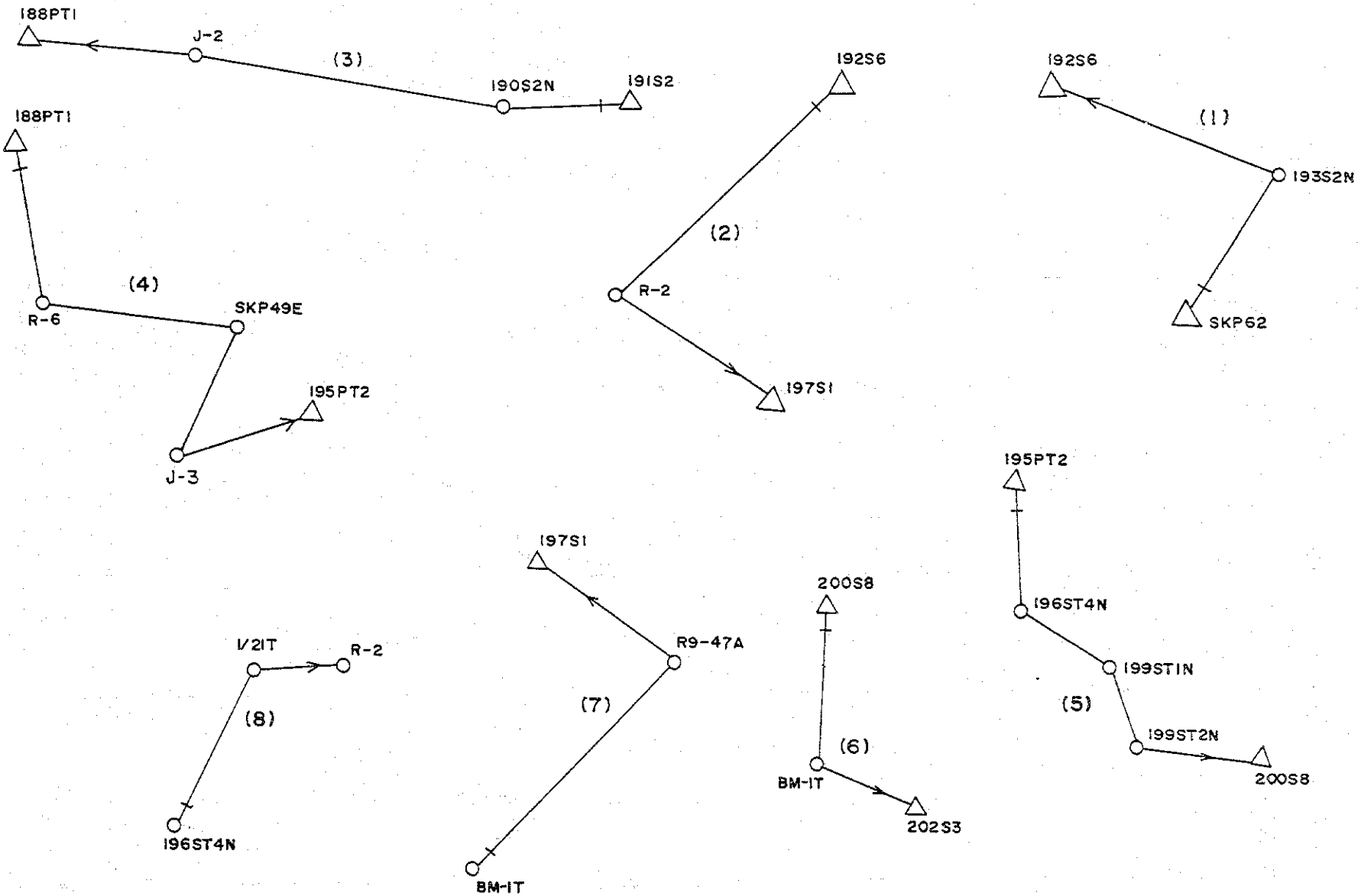


Fig. 5 Alignment of Points for Computation of Horizontal Coordinates

Tab. 4. Computation of Horizontal Coordinates

Route	Route length	Number of intermediate points	Closure of horizontal coordinates			Closure ratio
			Δx	Δy	$\sqrt{(\Delta x)^2+(\Delta y)^2}$	
(1) SKP62 - 192S6	km 119.5	1	sec -0.0188	sec +0.0137	cm 70	1/170,700
(2) 192S6 - 197S1	130.9	1	+0.0030	+0.0231	70	1/187,000
(3) 191S2 - 188PT1	164.8	2	-0.0316	+0.0671	223	1/73,900
(4) 188PT1 - 195PT2	175.6	3	+0.0096	-0.0834	252	1/69,600
(5) 195PT2 - 200S8	114.9	3	+0.0240	+0.0423	146	1/78,600
(6) 200S8 - 202S3	71.1	1	+0.0150	-0.0003	45	1/158,000
(7)* BM-1T - 197S1	127.0	1	-0.0042	-0.0051	20	1/635,000
(8)* 196ST4N - R-2	74.9	1	+0.0256	+0.0569	187	1/40,000

* : Closure as the secondary route.

BM-17 in Route (7), R-2 and 196ST4N in Route (8) were computed from Routes (6), (2), and (5), respectively, as given factors.

Provisional results of the coordinate computations as above based on WGS-84 as the reference ellipsoid are shown in Tab. 5. In that table, the upper group of horizontal coordinate values were obtained by conversion from the official final result table whereas the lower group was computed from the actual observations. These coordinates were transformed eventually to Clarke 1880, the reference ellipsoid in Kenya. (Tabs. 9 and 10)

III-3-6 Computations of Elevations

Since elevations obtained from GPS observations are based on WGS-84, they were converted to those based on the geoid.

All of the given points for elevations were obtained by direct leveling. With respect to the proposed points, by assuming the differences between relative height between given points on the reference ellipsoid and that on the geoid to be identical with the differences in elevation between the surfaces of that ellipsoid and the geoid, the difference between the two surfaces at the unknown point was computed by interpolation or extrapolation for correction.

In Fig. 6, for example, where A and B are given and C is unknown, and their elevations based on the reference

Tab. 5. Coordinates of Control Points on WGS-84

Station No.	WGS 84		
	Latitude	Longitude	H
SKP 49	3° 24' 54." 6218 (S)	38° 17' 32." 7252 (E)	m
SKP 62	3 37 47. 1051 (S)	39 51 18. 6599 (E)	74.29
191 S 2	3 16 51. 7028 (S)	39 10 18. 7736 (E)	477.08
192 S 6	3 02 59. 5797 (S)	39 33 11. 8510 (E)	174.33
197 S 1	3 47 44. 3228 (S)	39 20 52. 0144 (E)	292.01
198 S 8	3 31 26. 7317 (S)	39 32 13. 4995 (E)	350.69
200 S 8	4 10 23. 5996 (S)	39 11 19. 3583 (E)	327.23
202 S 3	4 39 13. 9607 (S)	39 21 37. 4526 (E)	34.45
188 PT 1	3 00 25. 1588 (S)	37 43 51. 2013 (E)	1258.54
195 PT 2	3 38 09. 8536 (S)	38 27 28. 0830 (E)	980.43
SKP 49 (E)	3 26 10. 5597 (S)	38 17 34. 0499 (E)	1684.67
196 ST 4 N	3 56 27. 3802 (S)	38 33 06. 0455 (E)	642.47
199 ST 1 N	4 03 04. 1547 (S)	38 49 14. 5691 (E)	483.02
199 ST 2 N	4 11 11. 5613 (S)	38 56 49. 0157 (E)	374.09
190 S 2 N	3 18 21. 8432 (S)	38 52 22. 7555 (E)	438.91
193 S 2	3 15 29. 6142 (S)	40 07 52. 9542 (E)	40.74
J - 2	3 04 13. 2430 (S)	38 08 05. 8981 (E)	676.67
J - 3	3 45 08. 5495 (S)	38 08 02. 8425 (E)	803.90
R - 2	3 32 20. 9114 (S)	38 59 36. 9964 (E)	403.75
R - 6	3 23 08. 4296 (S)	37 47 34. 8429 (E)	930.13
I/21T	3 33 25. 6834 (S)	38 45 03. 6845 (E)	555.99
BM-1T	4 33 20. 8710 (S)	39 07 30. 6631 (E)	77.89
R9 - 47A	4 05 00. 3476 (S)	39 39 54. 7702 (E)	40.32

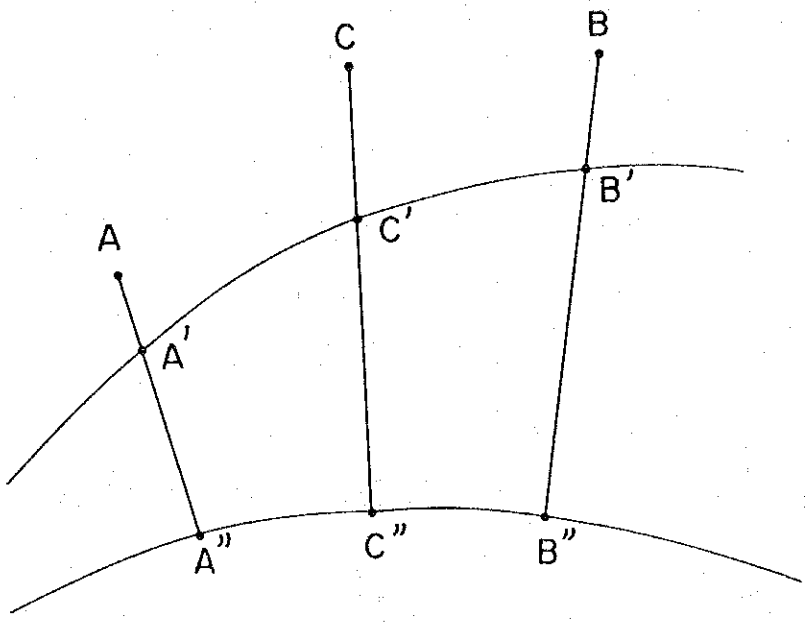


Fig. 6 Computation of Elevation

ellipsoid are expressed as AA", BB", and CC", and these same elevations, when based on the geoid, as AA', BB', and CC', then the difference in elevation between the ellipsoid and geoid defined as

$$(AA" - AA') - (BB" - BB')$$

is distributed in proportion to A"C" and C"B" to arrive at the difference in elevation between the surfaces of the ellipsoid and geoid at C, as

$$\{(AA" - AA') - (BB" - BB')\} \times \frac{A"C"}{A"B"},$$

which is added to derive the elevation of C based on geoid CC'

$$C'C" = A'A" + \{(AA" - AA') - (BB" - BB')\} \times \frac{A"C"}{A"B"}$$

$$CC' = CC" - C'C".$$

Considering that AA" - BB" and AA" - CC" are actually observed, the above equation is modified as follows:

$$CC' = AA' + (CC" - AA") + \{(AA" - BB") - (AA' - BB')\} \times \frac{A"C"}{A"B"}.$$

The elevation computations were performed in the sequence as shown in Fig. 7. In the figure, a circuit closure was made for Route (1) with SKP62 as fixed, and the closure then was distributed in proportion to the number of sides. Based on the R-2 value thus obtained, a closure was made for Route (2). The elevations thus averaged were fixed for consecutive adjustments of other routes.

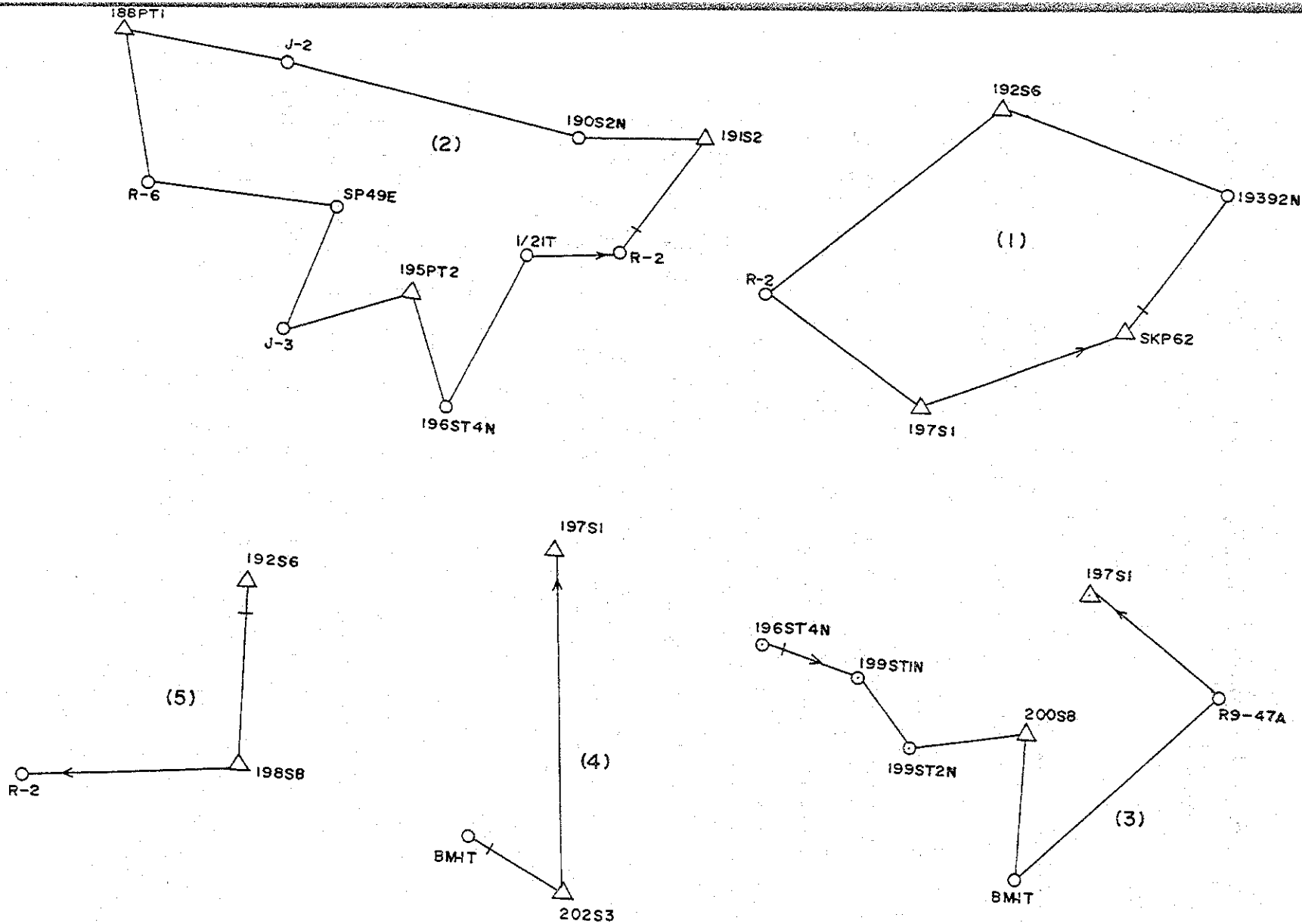


Fig. 7 Alignment of Points for Computation of Elevation

Closures of elevations in GPS observations are shown in Tab. 6. The elevations on the reference ellipsoid after correction of closure errors are given on the right hand side of Tab. 5.

Tab. 6. Closure of Elevation

	Route name	Route length	Number of sides	Closure
(1)	SKP62 - SKP62	309.7 km	5	46 cm
(2)	R-2 - R-2	485.4	11	163
(3)	196ST4N - 197S1	249.5	6	22
(4)	BM-1T - 197S1	123.1	2	9
(5)	192S6 - R-2	112.8	2	4

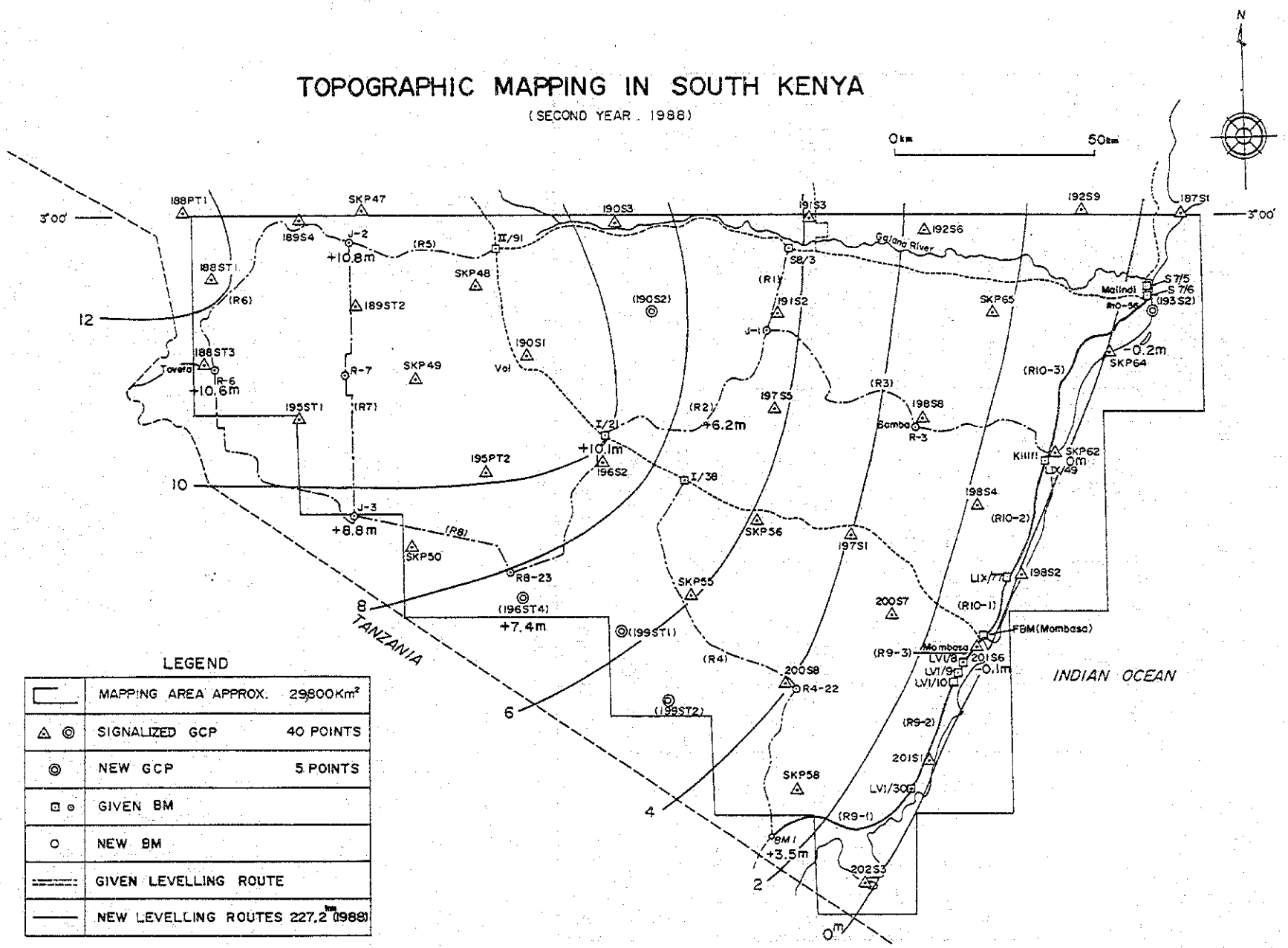
With respect to those elevations surveyed by direct leveling, the geoid-based elevations and the ellipsoid-based elevations as obtained by GPS observation are compared in Tab. 7.

The ellipsoid-based elevation of SKP62 is an approximate value derived from GPS point positioning. From Tab. 7, assuming that the geoidal surface and ellipsoidal surface at SKP62 are coincident to each other, the geoidal height at other points are calculated, which are shown in the right hand-side column of Tab. 7 and their geographical distribution is shown in Fig. 8.

Tab. 7. Elevations of Given Points

Point name	From ellipsoid (1)	From geoid (2)	Geoidal height (1)-(2)	Relative geoidal height
	m	m	m	m
SKP62	74.29	45.78	+28.51	0
193S2	40.74	12.43	+28.31	-0.20
R-2	403.75	369.00	+34.75	+6.24
J-2	676.67	637.32	+39.35	+10.84
R-6	930.13	891.05	+39.08	+10.57
J-3	803.90	766.55	+37.35	+8.84
196ST4N	642.47	606.57	+35.90	+7.39
I/21T	555.99	517.35	+38.64	+10.13
R9-47A	40.32	11.94	+28.38	-0.13
BM-1T	77.89	45.92	+31.97	+3.46

* Fixed point



LEGEND

	MAPPING AREA APPROX.	29800Km²
△ ◎	SIGNALIZED GCP	40 POINTS
◎	NEW GCP	5 POINTS
⊡ ⊙	GIVEN BM	
○	NEW BM	
═══	GIVEN LEVELLING ROUTE	
———	NEW LEVELLING ROUTES 227.2 km (1988)	

Fig. 8 Relative Geoidal Map

By referring to the distributions of geoidal height, geoid-based elevations for the proposed points were calculated by interpolating or extrapolating for the following combinations of given points and proposed points.

For checking, 3 to 4 sets of combinations for each point were averaged for a mean value which then was applied as the geoid-based elevation for that point, as shown in Tab. 8.

III-3-7 Preliminary results

The results from III-3-5 and III-3-6 above are listed in Tab. 9 as preliminay results. They were meant to serve as given factors for aerial triangulation. But actually applied were only those computed from triangles 5' and 6' except for 191S2, because there was no way of computing the coordinates of 191S2 other than using triangle 5. They were based on:

Reference ellipsoid:	Clarke 1880
Geodetic coordinate system:	New Are 1960
Datum of elevation:	Mean sea level at Mombasa Bay

At the same time, computations were performed for other unknown points that were necessitated or incidentally came in the course of computations of the proposed points. The results of such computations are given in Tab. 10. Tab. 11 shows the UTM coordinates and meridian convergences of the newly defined (proposed) points.

Tab. 8. Computation of Geoidal Height (1)

Proposed point	Given points	Geoidal Height
		m
197S1	R-2 - R9-47a	31.40
	SKP62 - 196ST4N	31.49
	I/21T - R9-47A	32.33
	J-2 - R9-47A	30.81
	Mean	31.51
SKP49E	R-6 - I/21T	38.85
	J-2 - J-3	38.34
	J-3 - 196ST4N	38.02
	Mean	38.40
192S6	J-2 - 193S2	31.56
	196ST4N - R-2	33.27
	BM-1T - 197S1	31.04
	Mean	31.96
200S8	R-2 - BM-1T	32.97
	196ST4N - R9-47A	31.53
	197S1 - BM-1T	31.75
	Mean	32.08
195PT2	J-3 - I/21T	38.03
	J-2 - 196ST4N	38.01
	SKP49E - 196ST4N	37.25
	Mean	37.76
190S2N	SKP49E - 192S6	35.47
	J-2 - SKP62	34.83
	R9-74A - R-2	36.56
	J-2 - R-2	35.85
	Mean	35.68

Tab. 8. Computation of Geoidal Height (2)

Proposed point	Given points	Geoidal Height
188PT1	J-3 - R-6	40.25 m
	190S2 - J-2	41.38
	J-3 - J-2	39.58
	SKP49E - R-6	39.21
	Mean	40.11
199ST1N	200S8 - 196ST4N	34.47
	196ST4N - BM-1T	34.85
	197S1 - 196ST4N	34.69
	195PT2 - BM-1T	35.17
	Mean	34.80
199ST2N	196ST4N - BM-1T	33.92
	196ST4N - 200S8	33.56
	R9-47A - 200S8	34.23
	199ST1 - BM-1T	33.88
	Mean	33.90
202S3	R9-47A - BM-1T	31.52
	200S8 - BM-1T	31.94
	199ST2N - BM-1T	30.88
	Mean	31.45
191S2	190S2N - 193S2	33.84
	R-2 - 192S6	33.51
	190S2N - SKP62	33.67
	Mean	33.67
198S8	R-2 - SKP62	30.88
	192S6 - 197S1	31.70
	191S2 - SKP62	30.74
	197S1 - 193S2	30.43
	Mean	30.94

Tab. 9. Preliminary Results of Proposed Points

Station No.	CLARKE 1880		
	Latitude	Longitude	H
	° ' "	° ' "	m
190S2N	3 18 13. 1910 (S)	38 52 19. 8810 (E)	403.23
193S2	3 15 20. 9485 (S)	40 07 49. 9913 (E)	12.43*
196ST4N	3 56 18. 9387 (S)	38 33 03. 1922 (E)	606.57*
199ST1N	4 02 55. 7505 (S)	38 49 11. 6964 (E)	448.22
199ST2N	4 11 03. 2025 (S)	38 56 46. 1336 (E)	340.19
R-2	3 32 12. 3370 (S)	38 59 34. 1128 (E)	369.00*
SKP49	3 24 46. 0069 (S)**	38 17 29. 8922 (E)**	2206.99
188PT1	3 00 16. 4060 (S)**	37 43 48. 4089 (E)**	1218.43
195PT2	3 38 01. 3108 (S)**	38 27 25. 2373 (E)**	942.67
202S3	4 39 05. 7588 (S)**	39 21 34. 5398 (E)**	3.00

* By direct leveling. ** By official record.

Tab. 10. Preliminary Results of Other Points

Station No.	CLARKE 1880		
	Latitude	Longitude	H
	° ' "	° ' "	m
SKP49E	3 26 01. 9511 (S)	38 17 31. 2166 (E)	1636.27
191S2	3 16 43. 0430 (S)**	39 10 15. 8781 (E)**	443.41
192S6	3 02 50. 8435 (S)**	39 33 08. 9291 (E)**	142.37
197S1	3 47 35. 8346 (S)**	39 20 49. 1051 (E)**	260.50
198S8	3 31 18. 1536 (S)**	39 32 10. 5776 (E)**	319.75
200S8	4 10 15. 2370 (S)**	39 11 16. 4592 (E)**	295.15
J-2	3 04 04. 5112 (S)	38 08 03. 0765 (E)	637.32*
J-3	3 45 00. 0443 (S)	38 08 00. 0194 (E)	766.55*
R-6	3 22 59. 8020 (S)	37 47 32. 0451 (E)	891.05*
I/21T	3 33 17. 1146 (S)	38 45 00. 8180 (E)	517.35*
BM-1T	4 33 12. 6356 (S)	39 07 27. 7672 (E)	45.92*
R9-47A	4 04 51. 9560 (S)	39 39 51. 8377 (E)	11.94*
SKP62	3 37 38. 5626 (S)**	39 51 15. 7154 (E)**	45.78*

* By direct leveling. ** By official record.

Tab. 11. UTM Coordinates of Proposed Points

Point name	UTM Coordinates (Zone 37)		Meridian convergence
	N	E	
SKP49E	9620 456.892 m	421 354.942 m	-0° 2' 32." 6713
196ST4N	9564 686.776	450 140.780	-0 1 51. 0565
199ST1N	9552 515.272	480 010.411	-0 0 45. 7746
199ST2N	9537 551.743	494 023.403	-0 0 14. 1452
190S2N	9634 874.507	485 801.068	-0 0 26. 5157
193S2	9640 093.043	625 610.943	+0 3 51. 1824
J-2	9660 891.767	403 788.578	-0 2 46. 8298
J-3	9585 495.577	403 762.024	-0 3 24. 0730
R-2	9609 112.734	499 201.334	-0 0 1. 5970
R-6	9625 992.702	365 826.319	-0 4 16. 6334
I/21T	9607 120.241	472 259.080	-0 0 55. 7513
BM-1T	9496 734.801	513 797.219	+0 0 35. 5483
R9-47A	9548 919.372	573 747.763	+0 2 50. 2310

III-3-8 Checking of Given Points

Tab. 4 shows the closures of the given points. However, in the process of measurement, there were cases where two given points were directly connected (measured). The discrepancy in their relative position between the measured and official values are listed in Tab. 12.

Tab. 12. Closure between Given Points

Side name	Side length	Horizontal closure			Closure ratio
		Δx	Δy	$\sqrt{\Delta x^2+\Delta y^2}$	
SKP62-197S1	59 277.614 m	-47.7 cm	+1.5 cm	47.7 cm	1/124,000
SKP62-192S6	72 368.796	-56.5	-37.4	67.8	1/107,000
198S8-192S6	52 469.993	+29.3	+2.4	29.4	1/178,000
202S3-200S8	56 466.862	-46.9	+6.4	47.3	1/119,000
202S3-197S1	94 916.246	-33.1	-9.4	34.4	1/276,000

From Tabls. 4 and 12, it was found that the relative positions of the control points used for survey were found to be sufficiently accurate as required.

IV. Minor Order Leveling

IV-1 Outline

With respect to the existing first order leveling routes along the coastal roads (Routes A14 and B8) on the Indian Ocean where most of the existing bench marks could not be recovered (Fig. 9), leveling was carried out using levels, staves, and staff stands, followed by pricking, to determine the elevations required for aerial triangulation and plotting.

Planned: Minor order leveling 200 km (including cross-sea leveling at 2 locations)

Implemented: Minor order leveling 245.1 km (including cross-sea leveling at 2 locations, check measurement, connections to triangulation points)

IV-2 Observations

IV-2-1 Outline

(1) The accuracy of the minor order leveling was 50 mm $\sqrt{S}$ as specified in S/W, where S is distance (one way) in kilometers.

(2) The leveling routes were connected to the existing bench marks. The observations were made two-way using staff stands.

(3) Trigonometric cross-sea leveling was conducted across Kilindini Harbor in Mombasa and Kilifi Creek. The outline of the surveys as conducted is shown in Fig. 10.

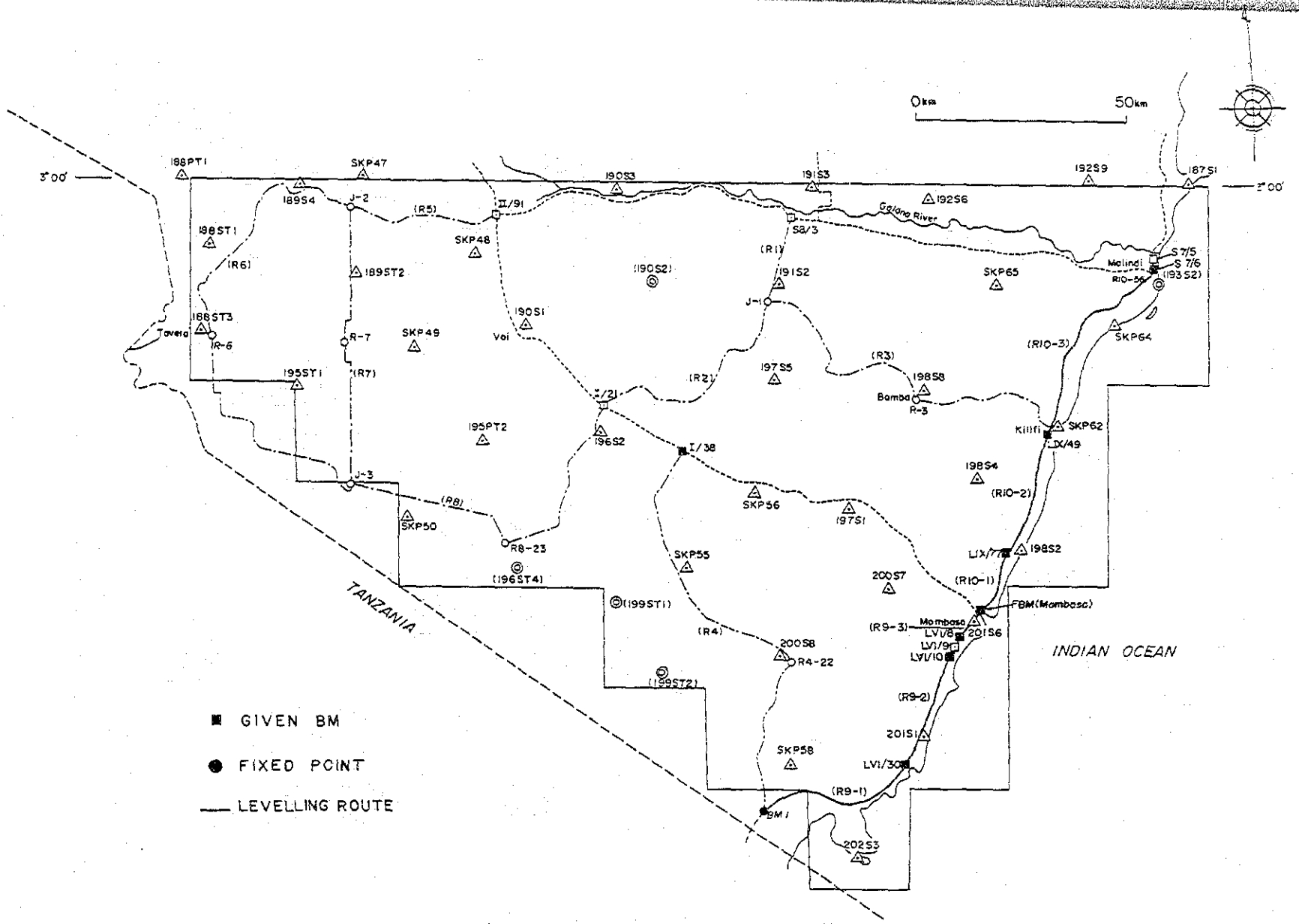


Fig. 9 Leveling Route Map

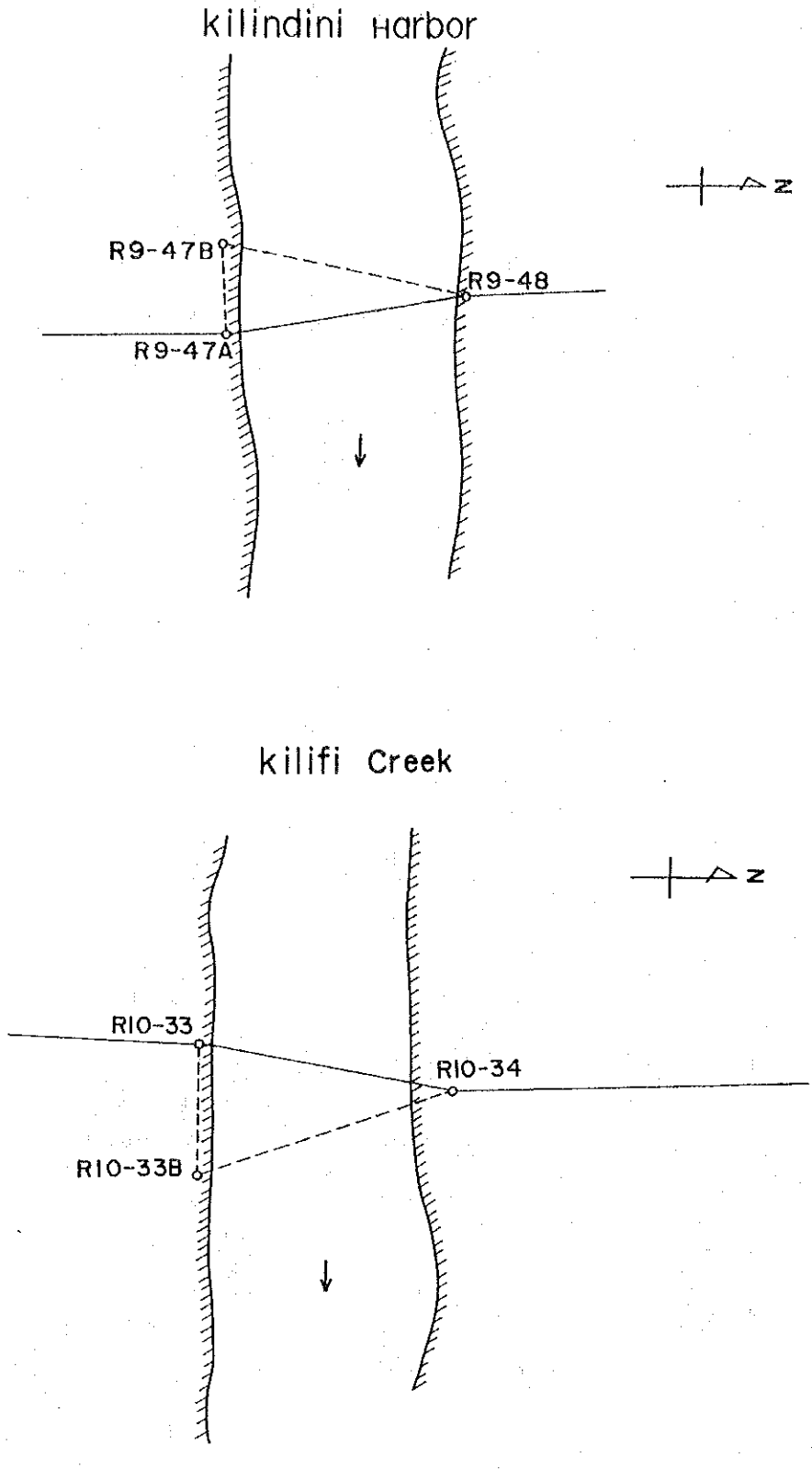


Fig. 10 Trigonometric Cross-sea Leveling

IV-2-2 Lengths of Leveling Routes and Numbers of Monuments

Leveling was executed along the route between BM-1 and S7-6 dividing it into two routes, R9 and R10. Each route was further divided as shown below, taking the existing points into consideration. In addition to these two routes, connections were made to the geodetic control points, 193S2, SKP62, and 196ST4N, covering a total of 12.8 km. And a check measurement was made for the sections between existing bench marks LVI/8 and LVI/10, and between S7-5 and S7-6 (5.1 km in total). Including all those, the total distance covered by the leveling amounted to 245.1 km. Furthermore, there was some additional leveling performed for the connection to BM-1T, R-6, and I/21T. The table below summarizes the foregoing.

Route number	BM number	Route length (km)	Number of * monuments
R9-1	BM-1, R9-1 ... R9-25, LVI/30	50.9	25
R9-2	LVI/30, R9-26 ... R9-41, LVI/10	32.8	16
R9-3	LVI/8, R9-42 ... R9-48, FBM	14.0	7
R10-1	FBM, R10-1 ... R10-10, LIX/77	21.0	10
R10-2	LIX/77, R10-11 ... R10-34, LIX/49	42.6	24
R10-3	LIX/49, R10-35 ... R10-56, S7-6	65.9	34
	R10-56-193S2 (Vertical positioning)	5.3	
	LIX/49-SKP62 (")	1.1	
	R8-23-196ST4N (")	6.4	
	LVI/8-LVI/9 (Check measurement)	1.7	
	LVI/9-LVI/10 (")	1.7	
	S7-5-S7-6 (")	1.7	
Total		245.1	116

* Excluding starting and ending points and auxiliary points for cross-sea leveling, R9-47B and R10-33B.

IV-2-3 Monumentation

Monumentation was made approximately every two kilometers as was done during the first year. Since all the leveling routes dealt with this time were paved, rivets instead of timber piles were driven into the road surfaces for temporary marking.

Existing ground features were used for the same purpose whenever there were appropriate ones available. For example, there were traverse points on some sections of the routes and whenever possible, their monuments were riveted on the side for marking. (See Photo 3-6))

Besides, permanent monuments were set up approximately every 10 km, including auxiliary bench marks for cross-sea leveling. (See Photo 3-7))

Their types and numbers are shown below.

a.	Riveted on the pave road surface	66 points
b.	Riveted on a structural object on the ground or a rock outcrop	13
c.	Riveted on the side of a traverse monument	15
d.	Permanently monumented (including two auxiliary BMs for cross-sea leveling)	14
	Total	108

The descriptions of points were prepared for their identification.

IV-2-4 Instruments used for Observations

a. Level — Nikon AS automatic level,
Carl Zeiss Ni2 automatic level

b. Staff — Metal staves

c. Staff stand — Steel stands

d. Theodolite — Wild T2 (cross-sea leveling)

e. Electro-optical distance meter
Wild DI-3000 (cross-sea leveling)

f. Radio-telephone (Cross-sea leveling)

IV-3 Computations and Adjustments

IV-3-1 Check Measurement

Check measurements were made by comparing relative heights of existing first order bench marks, namely, a measured relative height, and that computed from the final result table (official record), to see if the difference between these two relative heights was within 50 mm $\sqrt{S}$ (S = distance between points) allowed for the present surveying. And if the differences were within that range of tolerance, their values on the final result table were adopted as given. The measurements of the following three sets, as shown in the following table, were found to meet the above accuracy requirement, and, therefore,

S7-6, LVI/8, and LVI/10

were adopted as given factors.

Section	Relative height (m) (official)	Relative height (m) (measured)	Difference (mm)	Distance (km)	Tolerance (mm)
LVI/8-LVI/9	-1.595	-1.591	-4	1.7	65
LVI/9-LVI/10	-0.475	-0.473	-2	1.7	65
S7-5 - S7-6	-10.416	-10.424	+8	1.7	65

With respect to LIX/49, LIX/77, FBM, and LVI/30, check measurements were not made due to the absence of bench marks in their neighborhood. But as can be seen from the next section, it was found by leveling that the closures of the following sections,

I/38-LVI/30, LVI/30-LVI/10, LVI/8-FBM,
FBM-LIX/77, LIX/77-LIX/49, LIX/49-S7-6,

were within the required limit of tolerance so that the final results of the above four points also were adopted as given factors.

There are 10 existing bench marks between R10-51 and R10-56 (LIX/28 - LIX/23, LIX/19, LIX/18, LIX/16, LIX/11), but check measurements found that none of them met the required tolerance as given factors, and, therefore, they were treated as new points and assigned new elevations by the present survey.

IV-3-2 Closures and Tolerances

Closures for the respective route sections are as follows.

Route name	Section	Closure (mm)	Tolerance (mm)	Remarks	Distance (km)
R4+R9-1	I/38-LVI/30	57	683	Including 135.8 km (I/38 - BM-1) done in the first year	186.7
R9-2	LVI/30-LVI/10	26	286		32.8
R9-3	LVI/8-FBM	13	187		14.0
R10-1	FBM-LIX/77	68	229		21.0
R10-2	LIX/77-LIX/49	61	326		42.6
R10-3	LIX/49-S7-6	29	406		65.9
	R10-56 - 193S2	3 (Discrepancy between two way observations)	115	(Vertical positioning)	5.3
	LIX/49 - SKP62	3 (")	52	(")	1.1
	R8-23 - 196ST4N	1 (")	126	(")	6.4

As the closures in Sections R10-1 and R10-2 are nearly the same with opposite signs, the total closure through these two sections turns out very small (7 mm). The closure of each section, however, is within the tolerance, it was decided to regard the official value of LIX/77 as given.

Since the terminal point in R4, i.e. BM-1, dealt with during the first year was a fixed point with unknown values, it was connected to R9-1 and closed to LVI/30 for computation in the present survey.

To review the accuracies of the leveling performed during the first year, closures for the respective routes are listed below as reference.

Section	Closure (mm)	Tolerance (mm)	Distance (km)	Remarks
R1+R2	-98	504	102.0	
R1+R3	-274	594	141.4	
R2+R3	-362	669	179.2	
R5+R6+R8	-337	870	303.2	
R5+R7+R8	-342	745	222.6	
R6+R7	+235	778	242.6	

IV-3-3 Closure Errors in Cross-sea Leveling

Cross-sea levelings across Kilindini Harbor and Kilifi Creek were conducted at Likoni and Kilifi. The method was trigonometric leveling using two units of Wild T2 theodolites and a Wild DI-3000 electro-optical distance meter. The cross-sea distances were 540 m at Likoni and 470 m at Kilifi, respectively.

Observations were conducted with stations set up as shown in Fig. 10. They are also shown schematically in Fig. 11, where Station A is set on one side of the sea and Stations B and C on the other side, and vertical angle measurements were made by two pairs of simultaneous observations between A and B (and between A and C) and in the meantime their distances were measured.

B and C were about 10 meters apart on the same side and the relative height between them was measured by direct leveling. Observation results with respect to AB and AC were checked and their closure errors were found to be 2 mm and 3 mm respectively as shown in the table below and their mean values were adopted to represent the relative heights of R9-47A - R9-48 and R10-33A - R10-34, respectively.

Closure in Cross-sea Leveling

Place and Section	Distance	Relative height	Closure
Kilindini Harbor	m	m	m
R9-47A → R9-47B (Direct leveling)	7.00	-0.148	+0.002
R9-47B → R9-48 (Trigonometric leveling)	539.22	-0.576	(0.039)*
R9-48 → R9-47A (")	538.54	Average +0.726	
Kilifi Creek	m	m	m
R10-33A → R10-33B (Direct leveling)	8.30	-0.011	+0.003
R10-33B → R10-34 (Trigonometric leveling)	470.72	-0.676	(0.033)*
R10-34 → R10-33A (")	469.06	+0.684	
		Average +0.686	

* Note: Figures enclosed by parentheses in the column of Closure stand for tolerance (= 50 mm $\sqrt{S}$: S being distance).

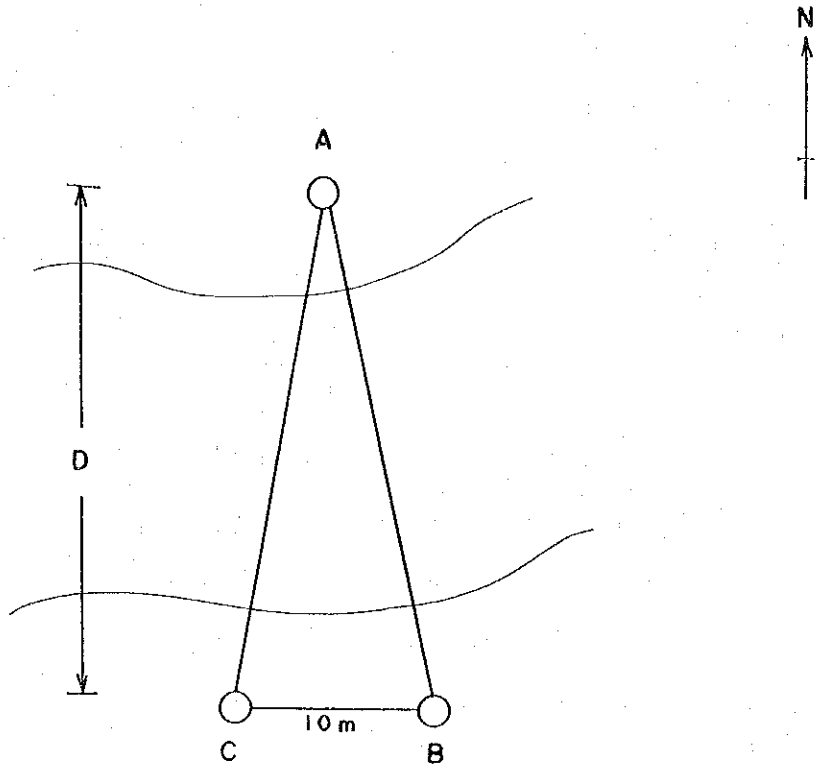


Fig. 11 Schematic Configuration of Cross-sea Leveling

IV-3-4 Preliminary Results

Elevations of the bench marks were obtained distributing closures between the known points in proportion to the distances between points on the route.

The results are shown in Tab. 13. The survey results of R4 obtained during the first year were added to the table.

Monumentation was classified into the following 5 types.

A: Riveted on the paved road surface

B: Riveted on a stable ground feature

C: Riveted on the side of a traverse point

D: Permanent monument

E: A timber pile or a nailed stub

The traverse points that are classified as Type C are listed below by their identification numbers.

Tab. 13. Preliminary Results of BMs (1)

BM number		Elevation	Monumentation type					BM number		Elevation	Monumentation type				
			A	B	C	D	E				A	B	C	D	E
R4															
BM-1	10	m 45.799				o		R4-22	422	m 252.083		o			
R4-1	401	71.839		o				-23	423	251.916		o			
-2	402	63.977		o				-24	424	270.499		o			
-3	403	65.606		o				-25	425	245.128					o
-4	404	74.886		o				-26	426	246.150					o
-5	405	102.819					o	-27	427	249.611		o			
-6	406	118.350		o				-28	428	260.973					o
-7	407	132.067		o				-29	429	275.015		o			
-8	408	111.768		o				-30	430	291.382					o
-9	409	151.961		o				-31	431	286.045					o
-10	410	126.942		o				-32	432	289.608					o
-11	411	118.790		o				-33	433	286.866					o
-12	412	131.770		o				-34	434	288.706					o
-13	413	125.774		o				-35	435	309.208		o			
-14	414	127.576		o				-36	436	324.535					o
-15	415	154.989		o				-37	437	312.497		o			
-16	416	164.033		o				-38	438	330.597		o			
-17	417	147.606		o				-39	439	329.419					o
-18	418	177.123		o				-40	440	336.319					o
-19	419	206.678		o				-41	441	345.534					o
-20	420	203.732		o				-42	442	366.806		o			
-21	421	228.322		o				-43	443	366.614		o			

Tab. 13. Preliminary Results of BMs (2)

BM number		Elevation	Monumentation type					BM number		Elevation	Monumentation type				
			A	B	C	D	E				A	B	C	D	E
R4-44	444	373.598					o	R9-1							
-45	445	416.109					o	LVI/30	3000	4.8980				o	
-46	446	403.063					o	R9-25	925	16.768	o				
-47	447	381.911					o	-24	924	15.980	o				
-48	448	386.332					o	-23	923	20.278				o	
-49	449	392.558					o	-22	922	17.526	o				
-50	450	394.378		o				-21	921	11.430				o	
-51	451	394.432					o	-20	920	10.075	o				
-52	452	397.238					o	-19	919	12.237	o				
-53	453	412.147		o				-18	918	7.040		o			
-54	454	409.796					o	-17	917	5.112	o				
-55	455	420.912					o	-16	916	12.351	o				
-56	456	428.852					o	-15	915	13.134	o				
-57	457	418.918					o	-14	914	15.595				o	
-58	458	400.942					o	-13	913	22.138	o				
-59	459	398.390					o	-12	912	20.992	o				
-60	460	409.887					o	-11	911	27.068				o	
-61	461	411.201					o	-10	910	29.053	o				
-62	462	407.542					o	-9	909	57.643	o				
-63	463	427.088					o	-8	980	58.822				o	
-64	464	439.488		o				-7	907	80.486	o				
I/38	3800	441.1230				o		-6	906	59.252	o				
								-5	905	31.031		o			

Tab. 13. Preliminary Results of BMs (3)

BM number		Elevation	Monumentation type					BM number		Elevation	Monumentation type				
			A	B	C	D	E				A	B	C	D	E
R9-4	904	42.818	o					LVI/10	1010	21.0770				o	
-3	903	47.219				o		R9-3							
-2	902	61.900	o					LVI/8	8	23.1470				o	
-1	901	76.287	o					R9-42	942	22.549	o				
BM-1	10	45.799				o		-43	943	21.544	o				
R9-2								-44	944	15.202	o				
LVI/30	3000	4.8980				o		-45	945	11.738		o			
R9-26	926	10.547	o					-46	946	14.089		o			
-27	927	7.458	o					-47A	947	11.943				o	
-28	928	5.019				o		-48	948	11.218				o	
-29	929	11.332	o					FBM	1000	21.0410				o	
-30	930	18.164	o					R10-1							
-31	931	20.229		o				FBM	1000	21.0410				o	
-32	932	25.965	o					R10-1	1001	17.692	o				
-33	933	28.636	o					-2	1002	16.820	o				
-34	934	28.021				o		-3	1003	15.493	o				
-35	935	27.562	o					-4	1004	21.889		o			
-36	936	18.086	o					-5	1005	15.121		o			
-37	937	8.114		o				-6	1006	9.535		o			
-38	938	26.358		o				-7	1007	14.896			201 TT4		
-39	939	30.933	o					-8	1008	7.688	o				
-40	940	29.126	o					-9	1009	13.134	o				
-41	941	35.258		o				-10	1010	14.912	o				

Tab. 13. Preliminary Results of BMs (4)

BM number		Elevation	Monumentation type					BM number		Elevation	Monumentation type				
			A	B	C	D	E				A	B	C	D	E
LIX/77	77	2.3640				o		R10-31	1031	25.971	o				
R10-2								-32	1032	24.602	o				
LIX/77	77	2.3640				o		-33A	1033	18.789				o	
R10-11	1011	22.364			198 TT6			-34	1034	18.104				o	
-12	1012	20.356	o					LIX/49	49	15.8660				o	
-13	1013	19.561	o					R10-3							
-14	1014	19.456	o					LIX/49	49	15.8660				o	
-15	1015	21.690			198 TT12			R10-35	1035	27.338			198 TT32		
-16	1016	22.730	o					-36	1036	19.816	o				
-17	1017	22.454	o					-37	1037	15.692	o				
-18	1018	25.654		o				-38	1038	13.215			198 TT37		
-19	1019	24.965			198 TT18			-39	1039	15.259	o				
-20	1020	26.119			198 TT19			-49	1040	13.058	o				
-21	1021	19.157	o					-41	1041	15.036	o				
-22	1022	22.765			198 TT21			-42	1042	16.982			198 TT42		
-23	1023	31.253		o				-43	1043	18.726	o				
-24	1024	32.133	o					-44	1044	12.565	o				
-25	1025	26.172	o					-45	1045	17.398	o				
-26	1026	39.949			KIBA -ON1			-46	1046	22.678			193 TT3		
-27	1027	53.219	o					-47	1047	21.364	o				
-28	1028	9.037	o					-48	1048	24.798	o				
-29	1029	46.366			198 TT20			-49	1049	17.883	o				
-30	1030	17.789	o					-50	1050	16.127			192 TT7		

Tab. 13. Preliminary Results of BMs (5)

BM number		Elevation	Monumentation type					BM number		Elevation	Monumentation type				
			A	B	C	D	E				A	B	C	D	E
R10-51	1051	10.330	o												
LIX/28	28	8.828				o									
/27	27	3.210				o									
/26	26	3.319				o									
/25	25	6.252				o									
/24	24	3.872				o									
/23	23	6.622				o									
R10-59	1059	16.377	o												
-60	1060	14.662	o												
LIX/19	19	17.910				o									
/18	18	20.555				o									
/16	16	19.288				o									
R10-52	1052	20.634			193 TT14										
-53	1053	27.789			193 TT15										
-54	1054	31.439	o												
-55	1055	23.229	o												
LIX/11	11	18.790				o									
R10-56	1056	9.892	o												
S7-6	706	16.550				o									

V. Map Symbols, etc.

At a meeting with SK held prior to the start of the second year work, items to be covered during the second year and thereafter data requirements were discussed.

V-1 Map Symbols and their Applications

The Uniform Map Symbols for East Africa is applied as the standard symbols for mapping in Kenya with some modifications to suit the local conditions.

The present mapping is partly based on the map symbols and their applications as agreed between Kenya and Japan (March 1981) and applied for the Topographic Mapping Project for East Kenya undertaken by JICA during 1975 to 1980.

The following were discussed in connection with the map symbols and their applications to be applied for field verification and subsequent work operations:

(1) Roads:

To be based on the symbols applied to East Kenya mapping by JICA.

(2) Embankments, edges, revetments:

To be shown if they are longer than 1 cm on the map.

(3) Water pipelines, oil pipelines:

To be shown by solid lines regardless of whether they are on the ground or underground. But not to be shown if they are under the road. Oil pipelines are shown only on the compiled manuscripts.

(4) Power lines, telephone lines:

All main lines to be shown in principle.

(5) Elevated railways:

To be shown if they have pillars by the symbol for elevated structures and, if not, by the symbol for bridges.

(6) Cuts, fills:

To be shown those of 250 m or longer and 5 m or higher.

(7) Bench marks:

To be shown only when confirmed in the field. Elevation to be rounded to meter and figures to be followed up with notation BM.

(8) Fish snares:

To be shown only if they are permanent.

(9) Principal point of photograph:

The one used for plotting to be shown on the map in three figures (Ex. 001).

(10) Hydroplane airports:

To be shown when confirmed in the field.

(11) Rivers:

To be shown if they measure 5 mm or longer on the map in principle and if they measure 1 cm or longer on the map over the flat land.

(12) Plantations:

To be shown with the initial letter of the plant name if not specified.

(13) Wells, springs, water holes, boreholes:

To be shown by new symbols.

(14) Airfields:

To be included in "Grass" if it is unpaved.

(15) Small buildings:

To be shown as around or square depending on their shape.

(16) Cemetery:

No symbol to be used but to be annotated with "Cém".

(17) Registered land:

To be shown by boundaries and reference numbers.

(18) Boundary of private site:

Not to be shown.

(19) Bridges:

To be shown for all bridges that are confirmed in the field regardless of their sizes.

(20) Railway:

To be shown with level crossing identified by LC.

(21) Magnetic declination:

To be shown by rounding to minute. The epoch shall be Jan. 1, 1991.

(22) Administrative boundaries:

To override the sub-district boundary where they overlap with others.

V-2 Data Collection

Data on the following items were requested and some were made available prior to the survey and others after the survey. There are some others expected to be delivered to the team when it returns to Kenya for the next year's work.

Road classifications

Water pipelines, oil pipelines

Power lines, telephone lines

Administrative boundaries, forest boundaries, cadastral boundaries and numbers

Administrative names, geographical names, sheet names, sheet numbers

VI. Field Verification

VI-1 Outline

Field verification is conducted for on-site verification of aerial photo interpreted items and other items related to the symbols and other map representations required for topographic mapping, with its findings incorporated into the aerial photos and other related data to provide necessary information for plotting and compilation.

The field verification for the second year covered some 26,800 km^2 out of 29,800 km^2 planned to be surveyed for topographic mapping, excepting 3,000 km^3 for which aerial photographs were not made available in time. (See Fig. 12)

That remaining area will be covered by the field completion scheduled for the third year based on the compiled manuscripts plotted and compiled by using aerial photographs without field verification.

VI-2 Planning and Preparations

Prior to the departure for Kenya, reconnaissance study was made in Japan to collect following information to prepare for the field verification.

(1) Listing of data items that need to be provided by SK, based on the study of the symbols.

(2) Adjustment of inconsistencies and questions concerning data and information made available.

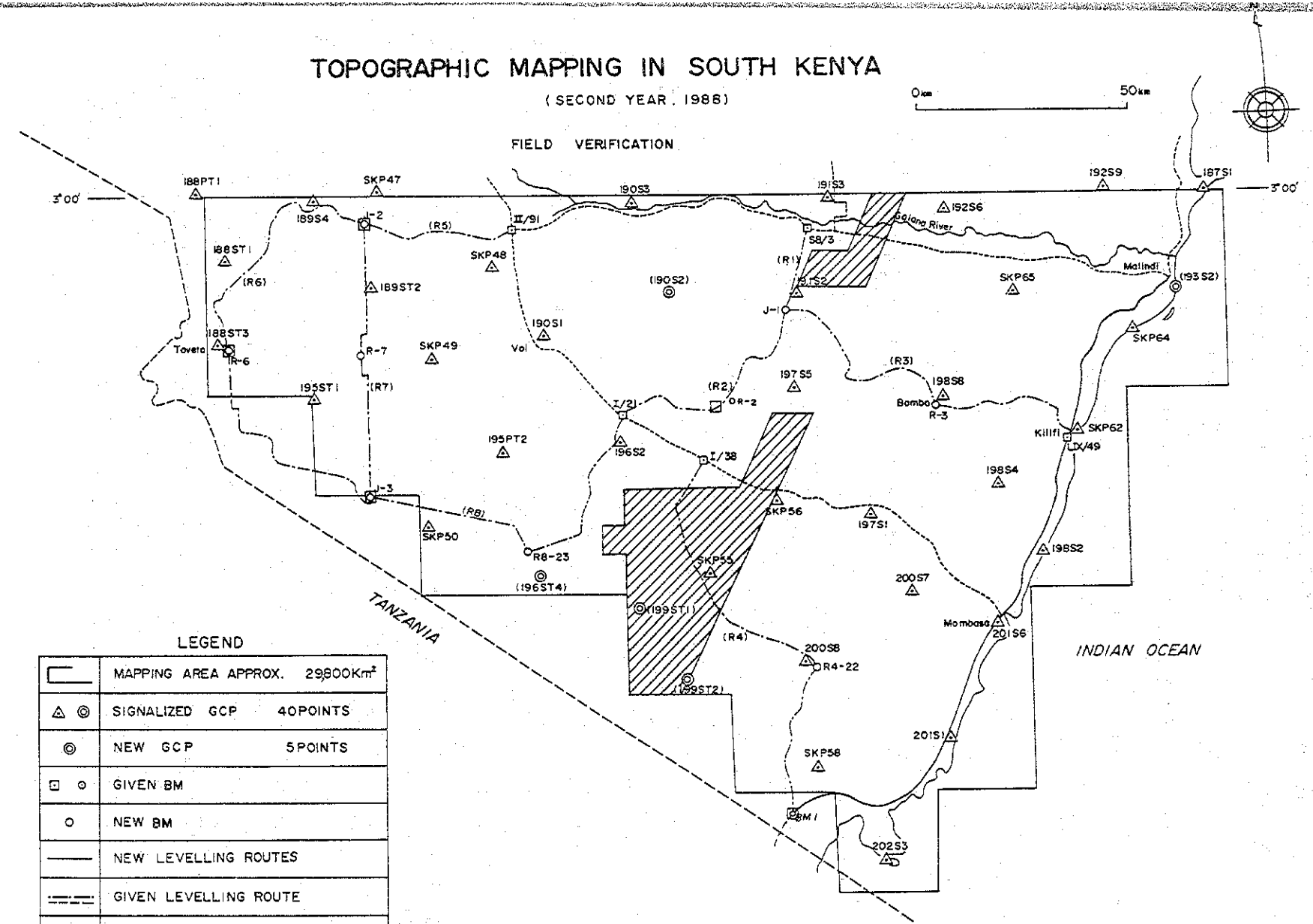


Fig. 12 Area for Field Verification

(3) By aerial photo interpretation, compilation of keys for interpretation, identification of items that are difficult for interpretation, and determination of the range and area to be covered by the field verification.

(4) Preparation of twice enlarged aerial photos for use in the field.

VI-3 Items of Field Verification

The following items were surveyed and verified in the field according to the map symbols and their application rules.

(1) Results of reconnaissance study and keys for aerial photo interpretation.

(2) Features that are difficult to interpret from photos.

(3) Roads, railways, buildings (including antiquiites, ruins), pipelines, control points, special districts, rivers, vegetation, topography, and other items necessary for application of the symbols.

(4) Collection of data and information on names necessary for annotations, and their verification.

(5) Place names. This was done by SK counterparts. The survey was conducted in a most efficient manner using old maps with relevant names on and the Information on Geographic Names. Starting with the examination of relevant names in the old maps and other data, and making corrections as necessary before proceeding to identifying

new geographical names and other names that require annotation, the survey was carried out most efficiently.

The collected data and information on geographical names were to be turned back to JST upon inspection of SK.

VI-4 Adjustment and Map Matching

VI-4-1 Adjustment

Field survey findings were incorporated onto the enlarged aerial photos according to the symbols and the work procedure by taking plotting and compilation into consideration.

VI-4-2 Matching

Due attention was paid to the matching of the sheets in the project area with those in the adjacent areas covered by the existing maps so as to fully study the edges of them. As for such areas where matching was difficult due to changes over years, it was agreed with SK that no attempt should be made for artificial modification as long as there was justification not to do so.

VI-4-3 Accuracy Control

Based on the findings of the field verification, the followings were checked and the accuracy control table was prepared.

a. Presence of any blank space,

b. Presence of anything left out and quality of adjustments,

c. Quality of delineations of such features as are difficult to interpret from aerial photograph,

d. Quality of representations of names, geographical or otherwise,

e. Quality of matching of adjacent aerial photos,

f. Presence of any discrepancies among aerial photos and other data.

VII. Aerial Photography

VII-1 Outline

Of the total study area of 29,800 km^2 planned to be photographed for 1 : 50,000 scale topographic mapping, some 3,000 km^2 that was left over from the first year was flown for photographing at 1 : 60,000 using a super-wide angle camera (Fig. 13).

Planned	14 courses	780 km (flight distance)
Implemented	13 courses	760 km (flight distance)

PHOTOMAP, the contractor for the first year, was contracted again for aerial photography for the second year.

The same technical specifications as for the first year were applied. (See The Report of the First Year's Work for the Topographic Mapping of South Kenya in the Republic of Kenya, March 1988 JICA or Attachment 3, Exhibit A.)

The contracted periods were 10 days from August 10 to 19, 1988, and 15 days from February 13 to 27, 1989. But there was no single shot taken during the first period and all photographs were taken during the latter period. The amount of work done was a little over 2% less than contracted, but it was decided that the amount was enough not to seriously affect the subsequent work, the flying was terminated.

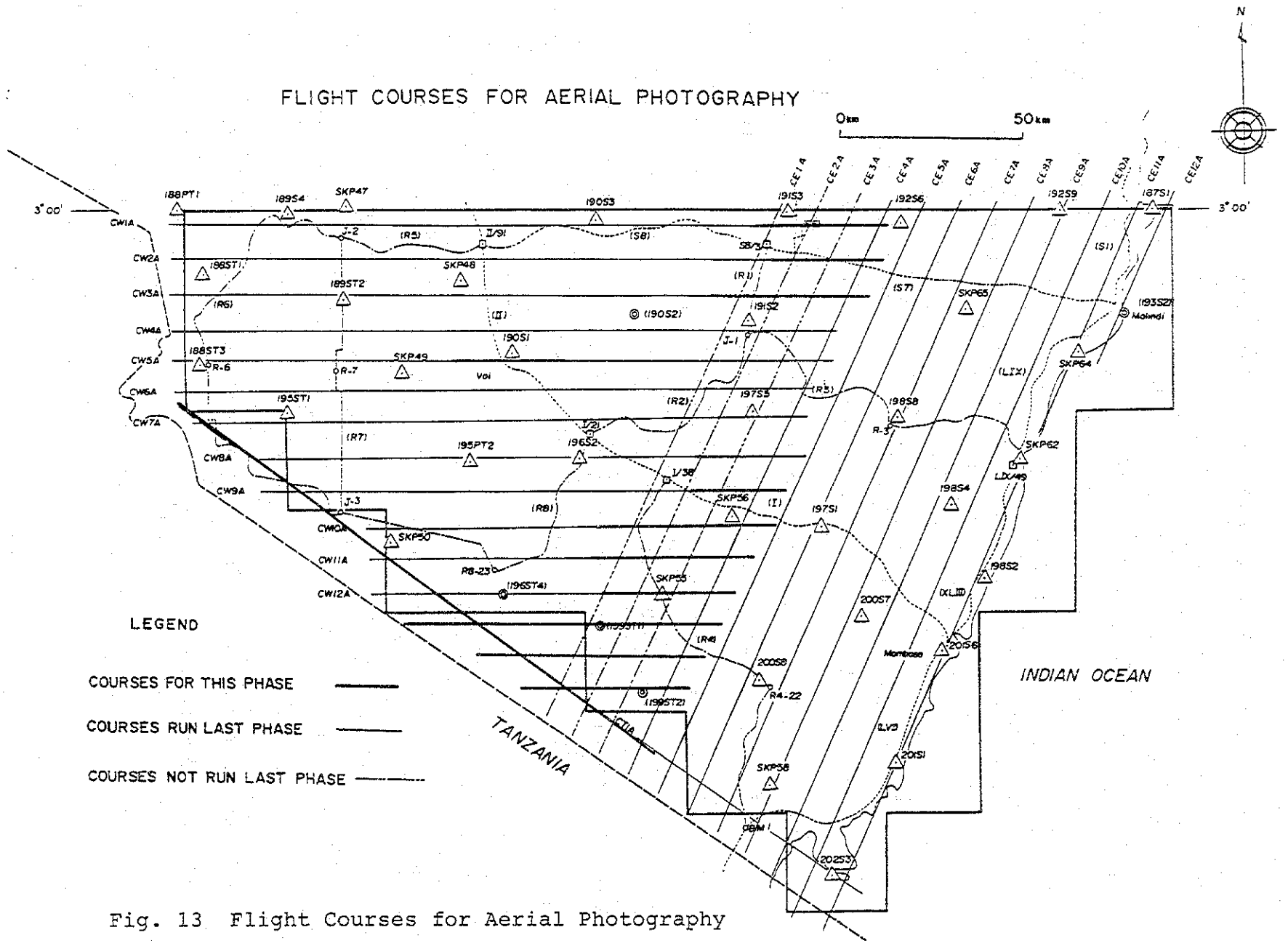


Fig. 13 Flight Courses for Aerial Photography

VII-2 Execution

(1) Flight-plan:

As specified in S/W, aerial photography was taken with a super-wide angle camera at 1 : 60,000 scale.

Flight courses and directions were:

Area	Number of courses	Datum height
Central part	13	1,000 m
Along Tanzanian border (Tie course)	1	500 m

with 60% for forward overlaps and 30% for sidelaps as standards.

(2) Bases

Malindi Airport (Aug. 10 - 19, 1988)

Malindi Airport (Feb. 13 - 27, 1989)

(3) Aircraft and aerial camera

Aircraft : Cessna 404 Twin Engine Turbo Charged

Aerial camera : Wild RC-10/88 mm lens cone

(4) Navigation system

Teledye Ryan Doppler

Sperry C-12 Compass System

(5) Film and printing paper

Film : Kodak double X Panchromatic Aerographic type 2405

Printing paper : Kodabrome 11RC

(6) Photo taking

a. First flight:

During the scheduled 10-day period of Aug. 10 - 19, 1988, no photographs were taken due to the unfavorable weather conditions with the aircraft based at Malindi Airport.

b. Second flight:

Photographs were taken during the scheduled 15-day period of Feb. 13 - 27, 1989, with the aircraft based at Malindi Airport.

A report on the photographic flight operations and the results is annexed to this report as Attachment 4, the Flight Records.

The number of days flown for photographing and the number of flights were as follows.

Number of days flown for photographing	: 15 days
Number of flights	: 4 (successful flights only)
Flight hours	: 5 hours 42 minutes

(7) Results

The final results of aerial photography were as follows. (See Attachment 4, Tab. 14, Fig. 13)

Number of film rolls taken	: 1 roll
Number of courses (total)	: 13 courses
Number of photographs taken	: 179 frames

(8) Photo inspector

Hideto Hosoda, engineer

Tab. 14. Number of Photographs

Course number	Photo number	Number of frames
W1	2216 - 2222	7
W2	2241 - 2247	7
W3	2252 - 2262	11
W5	2305 - 2310	6
W8	2314 - 2321	8
W9	2486 - 2478	9
W10	2489 - 2503	15
W11	2507 - 2524	18
W12	2526 - 2538	13
W13	2571 - 2588	18
W14	2593 - 2607	15
W15	2614 - 2623	10
T	2117 - 2155	39
Total		176

VII-3 Processing and Adjustment

VII-3-1 Inspection of Developed Films

Developed films were checked to see whether:

a. The tones of photo images are uniform and contrasts are adequate,

b. Emulsion and other chemicals are totally removed, and

c. There are any distorted images due to inadequate drying.

VII-3-2 Inspection by Contact Prints

By using contract prints followings were checked.

a. Overlaps, sidelaps

b. Clouds, shadows of clouds, irregularities in film development

c. Deviation of flight lines from the plan

d. Halation

e. Mists, smokes

f. Scratches on film

VII-3-3 Annotations of film

Annotations of the film were made in the following manner according to the specifications as agreed with SK.

Annotations include the Roll Number on the header of each roll, imprints of JICA SOUTH KENYA MAPPING 1 : 60,000 FEB. 1988, followed by Course Number and Photo Number, on the first and last photos, and, on the rest of photos, only of Course Number and Photo Number.

The index map was compiled, on the basis of the 1 : 250,000 map, in the following manner.

Course Numbers were given consecutively from north to south, and Photo Numbers from west to east. When the same course was flown more than twice, they were identified by A, B, C, and so on, starting from west, added at the end of that Course Number.

VII-3-4 Photo Processing

a. Photo processing of aerial photographs was carried out by the contractor including film development and preparation of contact prints for the checking purpose.

b. The amount of photo processing done was as follows.

Number of film rolls	: 1 roll
Number of courses covered	: 13 courses
Number of photo frames	: 179 (See Tab. 14 for the numbers of frames for the respective courses)
Contact printing	: 2 sets each
* Contact printing	: 1 set each (for aerial triangulation)
* Twice enlargement	: 2 sets each (for field verification)
* Positives	: 1 set each (for aerial triangulation and plotting)

Note: * indicates work done in Japan.

VII-3-5 Photo Inspection

Photo inspection was performed by Hideto Hosoda, engineer.

VIII. Aerial Triangulation

VIII-1 Outline

Coordinates of the pass points and the control points to be used for plotting were measured by a stereocomparator, and by block adjustment computations based on independent models, analytical aerial triangulation was executed to obtain orientation elements as well as the coordinates of pass points.

According to the original plan, adjustment computations were to be performed for the entire study area as one block. But actually due to the delay in the aerial photography scheduled for this year and out of consideration for the plotting and compilation work to follow, computations were made by partly splitting up the study area. The area to be covered accordingly was made to correspond to that of plotting and compilation scheduled for this year (Fig. 14). For the remainder, computations were performed as the relevant aerial photographs were made available, together with the rest of study area previously covered. (Total number of models being 755.)

The results of aerial triangulation covering, though partly, the area planned for plotting for this year are as follows.

(1) Specifications

Photo scale : 1:60,000 (Flight altitude above ground: 5,300 m)

Number of courses : 19

Number of models : 332

Control points : Horizontal 48, elevation 165

Adjustment computations: Independent model method (PAT M 43 Program)

(2) Major instruments used

Pricking device : PUG 4 (Wild)

Stereocomparator : Stecometer (Zeiss Jena)

Computer : FACOM-M340 (Fujitsu)

(3) Aerial camera

Aerial camera : Wild RC10

Focal length 88 mm

Lens 8.8 SAG II

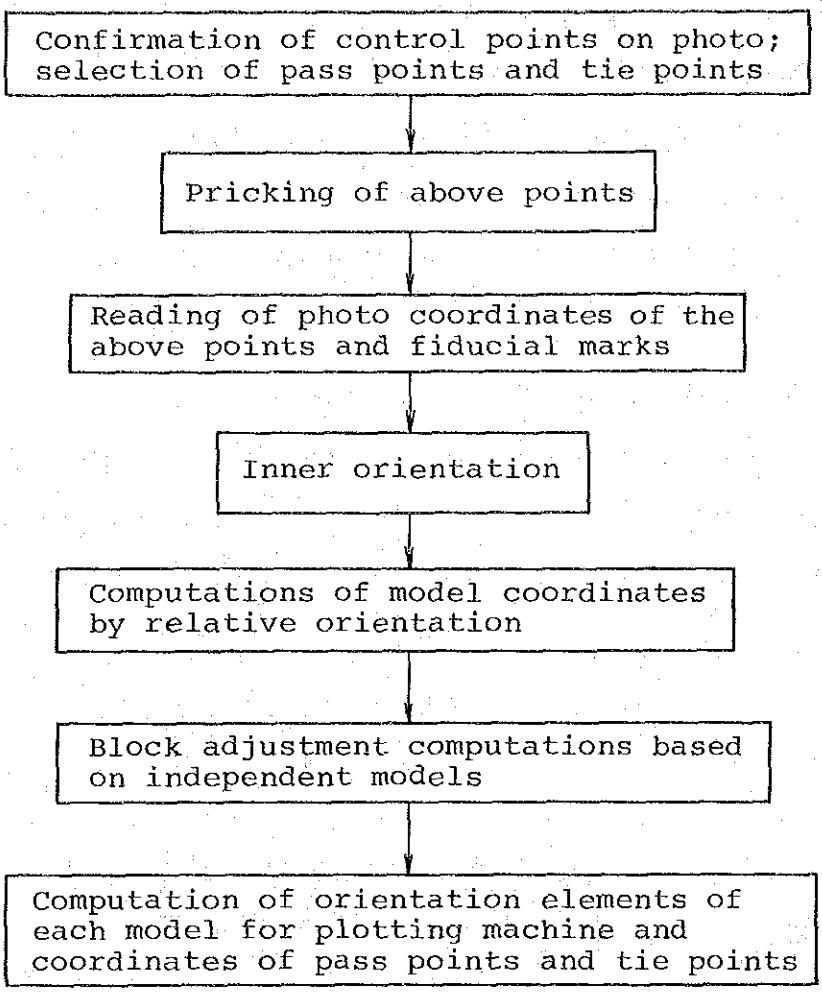
Distortions

Radius	0	10	20	30	40	50	60	70	80	90	100
Distortion	0	-2	-3	-4	-4	-4	-4	-1	1	3	4

Radius	110	120	130	140	145	Grade
Distortion	3	2	-1	0	0	μ

VIII-2 Work Procedure

The work was carried out in the following procedures.



VIII-3 Point Selection

Point selection was made on contact prints with respect to pass points and tie points. Considering that the block adjustment computations were based on the independent model method, 6 pass points for each model, and one tie point for each model at where flight courses overlap were selected.

The locations of the pass points and tie points were indicated on the contact prints surrounded by a red circle of approximately 7 mm in diameter.

For transfer of the points to film positives, PUG 4 was employed as a pricking device. The points were indicated on the positives surrounded by a red circle of about 7 mm in diameter.

Transfer of the points including the control points whose locations were determined by pricking was performed stereoscopically with a pricking device by referring to the pricked photos, description of pricked control points and bench marks.

VIII-4 Measurement of Photo Coordinates

For measurement of photo coordinates of fiducial marks, geodetic control points, pass points, and tie points, the stereocomparator was used to take measurements in terms of μ.

The above measurements were performed twice independently.

VIII-5 Inner Orientation

The residuals of fiducial marks were transformed to the coordinate system having the center of photo projection as the origin, and the measured value of each fiducial mark was computed by the Helmert's transformation.

The standard deviations and maximums of the residuals of the fiducial marks are as follows.

SD	Maximum	Remarks
13.3 μ	20.0 μ	Tolerance by specifications Max. 30 μ

VIII-6 Relative Orientation

Relative orientation was made using all the points contained in the models, and corrections were made for atmospheric refraction.

VIII-7 Adjustment Computations

Adjustment computations were performed using the PATM 43 Program, which is based on the independent model method, taking the entire study area in one block, whereby the horizontal and vertical elements were treated simultaneously. In this process, the points originally established for aerial triangulation on the aerial photos for topographic mapping of East Kenya but covering the same area as for the present study were transferred to the present photos and applied as control points. There were 23 such points each for horizontal and vertical. They are included in the control points listed below.

Adjustment computations were made including all the control points.

Standard deviations and maximum of control point residuals and tie point discrepancies resulting from aerial triangulation are as follows.

Residuals of Control Points

Number of courses & models	Number of control points		Residual of control points (planimetry)		Residual of control points (elevation)		Remarks
	Planimetry	Elevation	SD	Maximum	SD	Maximum	
19 courses 332 models	48	165	m 0.92	m 2.03 (0.38‰)	m 0.38	m 1.63 (0.31‰)	Specified tolerance of flight height ratio Planimetry 1.4‰ Elevation 1.4‰

Discrepancies of Pass and Tie Points

Planimetry		Elevation		Remarks
SD	Maximum	SD	Maximum	
m 0.38	m 0.96 (0.18‰)	m 0.22	m 0.71 (0.13‰)	Specified tolerance of flight height ratio Planimetry 0.8‰ Elevation 0.8‰

The results as shown above are good enough to meet the tolerance requirements set forth in the work specifications, and it is attributable to the good distribution of the geodetic control points, implementation of aerial photography as planned, and use of the independent model program for aerial triangulation, among others.

IX. Plotting

IX-1 Outline

Based on the results of aerial triangulation and field verification, topographic features necessary for mapping were measured and delineated by a plotting machine to produce restitution manuscripts. The area planned for this year's plotting is shown as hatched in Fig. 14.

IX-2 Specifications

Plotting scale	: 1:50,000
Area	: 11,475 km^2
Number of sheets	: 15
Contour lines	: Intermediate 20 m, index line 200 m, half interval auxiliary line 10 m (on flat land)
Projection	: UTM
Neat line	: 15' east west × 15' north south
Sheet allocation	: Sheet numbers and names as shown in Fig. 15.
Map sheet material	: Polyester base #500

IX-3 Instruments Employed

Plotting machine	: Stereo-plotter A-8 (Wild), Metrograph (Zeiss),etc.
Coordinategraph	: XP1100 (Daini-Seikosha)

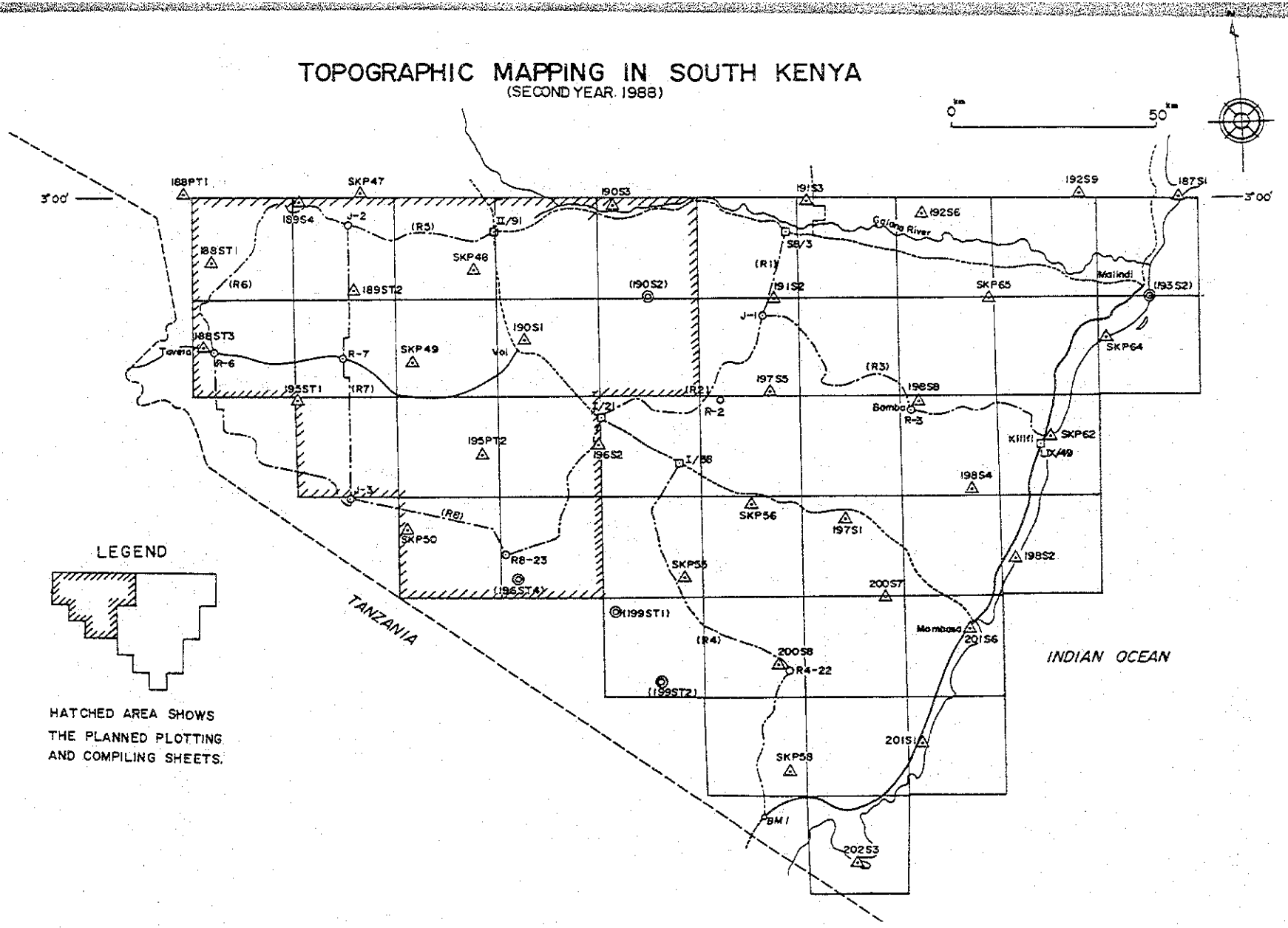


Fig. 14 Area for Plotting and Compilation in the Second Year

IX-4 Plotting of Control Points

Neat lines, grid lines, longitude/latitude lines, control points, existing geodetic control points (provided by SK) as well as pass points and tie points were plotted by co-ordinategraph, with plotting errors not to exceed 0.2 mm on the map.

IX-5 Orientation

(1) Relative orientation was performed by using 6 pass points, with residual parallax not to exceed 0.02 mm on the contact film positives.

(2) Absolute orientation was made using pass point and tie point results from aerial triangulation as well as control points (including pricked points), pricked bench marks, with tolerances of 0.3 mm or less for planimetry on the map and 5 m or less for elevation.

The results of absolute orientation were entered in the record of plotting.

IX-6 Restitution

(1) Operators of plotting work were duly briefed on the map symbols, their application rules, specific method of detail plotting, matching method, in accordance with the specifications of detail plotting as set forth in the operation manual for plotting work so as to ensure the uniformity among operators.

(2) Detail plotting involved measurement and delineation of linear features, such as roads, rivers, railways, and housing, vegetation, contour lines, in that order, based on the map symbol rule as agreed between JST and SK, and on the field verified photos.

(3) The colors used for plotting are as follows.

Black : Double line roads, railways, buildings, linear features, vegetation symbols.

Red : Passes, indication symbols for specialized features, enclosures, small objects, revetments.

Green : Vegetation boundaries, garden paths.

Orange : Contour lines

Purple : Coast lines, rivers, lakes and ponds, fish nurseries, salt fields, riparian plants.

(4) Buildings were delineated truly in principle without generalization but in concentrated areas such as urban cities they were generalized to the extent not to affect the opaqueness of lines.

(5) Contour lines were delineated in such a manner as to maintain accuracy and not to affect terrain features.

(6) With respect to the Tsavo National Park, steep slopes cultivated way up to the top and dried up rivers, attention was paid so as to represent most adequately the topographic and other geographic features of the areas in which they were located.

(7) Contour lines were drawn by paying due attention so as to have them represent the topography to the best possible extent. Distorted lands were surveyed separately for elevations so as to consummate the contour lines.

(8) The spot heights were measured two times independently and their mean values in meters were adopted. The density of spot height measurement was varied depending on the topography and distribution of control points. They were further screened at the time of compilation.

The locations of the spot heights were pricked on the control point data map and the restitution manuscripts, and measurement values were entered in the control point data map.

Measurements of spot heights were taken at such places, in principle, as:

a. Major mountain tops, cols
b. Major intersections of roads
c. Knick points of slopes
d. Points typical of the area
e. Bottom of a depression
f. Points necessary for identification of the topography

IX-7 Checking

Upon completion of the plotting work, the restitution manuscripts were compared with the field-verified aerial photos and the collected data to check the conformity with the map symbols, fill information that was left out, and

correct errors. The questions that arose in the course were referred to the field completion for conformation.

IX-8 Products

The plotting work produced followings:

Restitution manuscript ... Planimetry sheet, contour line sheet

Control point data map

X. Compilation

X-1 Outline

Based on the restitution manuscripts, by incorporating the findings of the field verification and the research of existing data, map representations were compiled into the compiled manuscripts. The area covered was the same as for the restitution manuscripts. (See Fig. 14)

X-2 Specifications

Compilation scale	: 1:50,000
Area	: 11,475 km^2
Number of sheets	: 15
Neat lines	: 15' × 15' (UTM 37 ZONE)

Paper:

The following types of paper were used for the compilation work. They were selected for their stable quality.

Compiled manuscripts ... Polyester base #500

Data maps ... Polyester base #300

Plotting:

Neat lines and control points were plotted by coordinatograph. Errors were kept less than 0.3 mm for a neat line and less than 0.4 mm for a diagonal line.

X-3 Compilation Work

(1) The compilation manuscripts were prepared in accordance with the map symbols as agreed between JST and SK. In order to maintain the uniformity of map representations,

a manual was prepared to ensure technical people involved comply with the same work rules.

(2) Compilation was made by the overlay method. Planimetry and contour lines were compiled on the same sheet with annotations separately on the annotation sheet. To facilitate the subsequent work of scribing, four types of data maps were separately prepared: the road data map, vegetation map, water/sea surface data map, and the control point data map.

(3) Material paper for the compiled manuscripts was stable polyester base #500.

Tick marks were entered on the neat lines at every 5' of longitudes and latitudes and UTM grid ticks every 1 km.

(4) The sheet names and sheet numbers were applied as provided by SK. (Fig. 15)

(5) The color classifications for compiled manuscripts are as follows.

Black : Double line roads, railways, buildings, spot heights, vegetation symbols, linear features, contour figures.

Red : Passes, administrative boundaries, small objects, enclosures, sub-symbols.

Green : Vegetation boundaries, parks.

Brown : Contour lines

Purple : Sea and rivers, lakes and other water bodies, fish nurseries, salt fields.

TOPOGRAPHIC MAPPING IN SOUTH KENYA
(SECOND YEAR. 1988)

SCALE 1 : 1, 000, 000

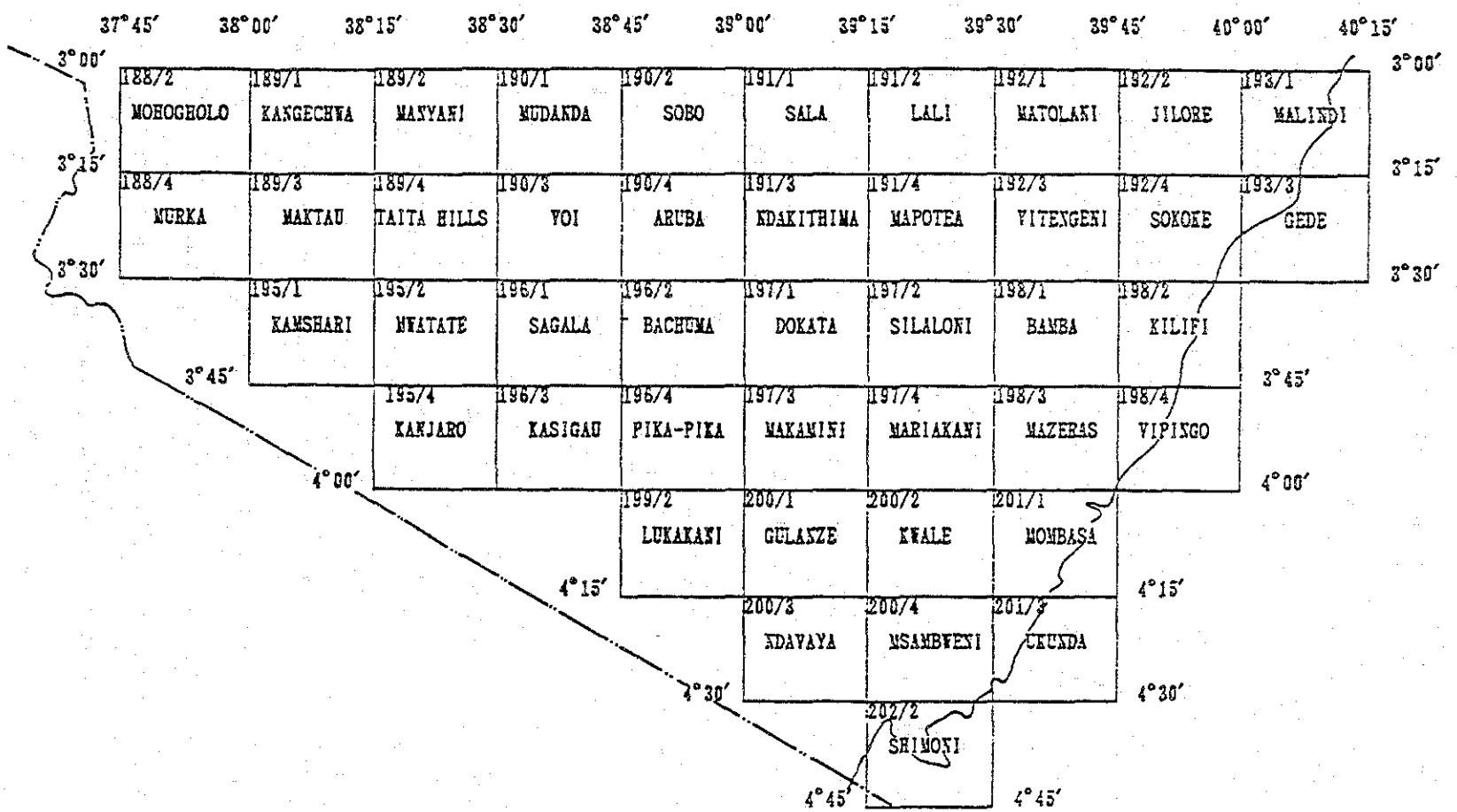


Fig. 15 Sheet Name and Number of 1/50,000 Map

(6) In compilation, extra care was taken to ensure every necessary item was represented properly. When questions arose in the course of compilation, they were noted on the overlays and referred to the field completion.

X-4 Details

(1) Administrative boundaries and names were based on SK's survey data.

(2) All roads were represented by symbol roads.

(3) Railway was shown by a double line along its center line both for single track and double track lines.

(4) Annotations for destinations will be finalized at the time of the field completion.

(5) Generalization of villages was made according to the symbols rule.

(6) Independent buildings were represented to suit their environs.

(7) For where contour lines were close together in the mountains, care was taken not to have them hurt the topography.

(8) Gas pipelimes, power lines, and other pipelines could not be interpreted on the aerial photographs and, therefore, based on the data provided by SK.

(9) Extra care was taken about the delineation of contour lines over the depressions and along the roads and rivers.

(10) For matching with existing map sheets, the reproduced maps provided by SK were referred to.

For matching of newly prepared map sheets, polyester base duplicate maps were used.

(11) Annotations were compiled on a separate sheet. Lettering sizes, spacing, style, and positioning were set by photo-composing as specified by SK. But with respect the letter types that are not available in Japan, it was decided to refer them to discussions with SK at a later date.

(12) The following four types of data maps were produced to facilitate the subsequent work process.

a. Road data map:

The roads were classified by colors, and care was taken to ensure every necessary item had been covered, matching made properly, and errors corrected.

b. Vegetation map:

c. Hydrology map:

Upon completion of the alignment of planimetric features, the polyester base duplicate maps were produced and vegetation types were represented by different colors. Care was teken to ensure everything was covered, matching properly made and errors corrected.

d. Control point data map:

Control points, bench marks and spot heights were represented.

X-5 Checking

All work done, a polyester base #150 sheet was overlaid to

compare with the field verification photos, to check if the contour lines and spot heights were properly related, and if the symbol application rules were properly observed.

At the same time, the questions were noted and referred to the field completion for confirmation.

The annotations in particular must be carefully checked by SK counterparts.

X-6 Products

The followings were the products for this phase of work. They were prepared in the present forms based on the requests from SK and suggestions of JST.

(1) Compiled manuscripts

a. Composite sheet of contour lines and planimetry

b. Annotations sheet

(2) Data maps

a. Road data map

b. Vegetation map

c. Hydrology map

d. Control point data map

XI. Comments on Second Year Work

The following comments are in order on the second year work of the topographic mapping project of South Kenya.

1) Geodetic control point survey:

The GPS instruments (US Trimble 4000SX), employed for the geodetic control point survey, functioned satisfactorily according to its published capabilities, to permit the survey work to be conducted in a most efficient manner. In view of its successful performance, the system is expected to come into wider use for geodetic control point survey in future overseas mapping projects.

2) Minor order leveling:

The leveling route was located along the eastern coastal road which was relatively flat but loaded with heavy traffic including sight-seeing buses and big transport vehicles crusing at high speeds. The survey work, therefore, was conducted with utmost care taken not to get involved in accidents.

3) Aerial photography:

The area that failed to be flown during the first year was close to the boundary of climate zones so that the weather was fast changing and clouds appeared frequently, thus making photographing difficult.

4) Aerial triangulation:

The results of aerial triangulation including the residuals of control points, their standard deviations, maximums, and

discrepancies of tie points were most satisfactory falling way within the tolerances specified in the work rules. This is attributable most possibly to the good distributions of existing control points, geodetic control points as surveyed under the present study, and the leveling routes currently set up.

5) Field verification:

The field verification was conducted efficiently thanks in large measure to the cooperation of SK counterparts as well as SK which was most cooperative in supply of data.

6) Plotting, compilation:

On the basis of the results from the aerial triangulation, though they did not cover the entire study area due to the delay in aerial photography, plotting and compilation were undertaken as planned for this year. It must be noted, however, that the plotting and compilation work of the third year must be performed with extra care taken of the matching with the sheets compiled this year.

7) Technology transfer:

Technology transfer to the Kenyan counterparts was accomplished properly covering in detail the surveys, research, project management involving accuracy and quality controls as they were conducted in Kenya and Japan.

XII. Comments on Third Year Work

During the third year, while plotting and compilation will continue to be undertaken subsequent to the second year, the field completion will be conducted. Plotting and compilation works in the third year involve the area left without photographs during the first year (about 10% of the total area) and without field verification in the second year. For the field completion of the compiled manuscripts prepared without field verified aerial photographs, geat care is to be taken in order to comply with the situation.

Since most of the above area falls in the national park, wild life paths must be duly recognized and treated carefully. Cooperation of SK counterparts is a key to the successful field completion and, therefore, it is necessary to keep their cooperation.

ATTACHMENTS

1. Chronological Records of Field Work ..... (1)

2. Minutes of Meetings with SK ..... (9)

2-1 "Minutes of Meetings on the Second Year Work for Topographic Mapping of South Kenya" ..... (9)

2-2 "Minutes of Meetings at the End of the Second Year's Field Work of Topographic Mapping of South Kenya" .....(51)

3. Contract of Aerial Photography .....(66)

4. Flight Records .....(83)

1. Chronological Records of Field Work

1) From July 25, 1988 to October 27, 1988

July	25 Mon.	Saito, leader, and 7 other members left Narita for Frankfurt via LH 711.
	26 Tue.	Left Frankfurt for Nairobi via LH 580.
	27 Wed.	Courtesy visit to JICA office and Embassy of Japan.
	28 Thu.	Courtesy visit to Director of Surveys, SK and meeting at Field Headquarters, SK.
	29 Fri.	Meeting with SK on P/O and preparatory work.
	30 Sat.	Preparatory work.
	31 Sun.	Preparatory work.
Aug.	1 Mon.	Meeting with SK on map symbols and their applications.
	2 Tue.	Continuation of above.
	3 Wed.	Meeting with SK on data made available.
	4 Thu.	Continuation of above.
	5 Fri.	Meeting with SK on Minutes (Draft) on P/O. Leader and one team member out for field reconnaissance.
	6 Sat.	Preparatory work.
	7 Sun.	Continuation of above.
	8 Mon.	Meeting with JICA, SK, on Minutes (Draft). Field reconnaissance team returned to Nairobi.
	9 Tue.	Signing of Minutes on P/O. A 6-member field work (on field verification) group arrived in Nairobi.

Aug.	10 Wed.	Visited JICA, SK, Japanese Consul, on mobilization in the field. Leader left Nairobi for Tokyo.
	11 Thu.	Field headquarters, field verification group, leveling group moved to Mombasa and Nyali.
	12 Fri.	Setting up of field headquarters. Courtesy call on the Provincial Surveyor, Coast.
	13 Sat.	Preparatory work. Leader arrived at Narita.
	14 Sun.	Rest
	15 Mon.	Field verification, leveling.
	16 Tue.	Continuation of above.
	17 Wed.	Continuation of above.
	18 Thu.	Continuation of above.
	19 Fri.	Continuation of above. A 4-member control point survey group arrived in Nairobi.
	20 Sat.	Continuation of above. The control point survey group moved to Mombasa.
	21 Sun.	Rest
	22 Mon.	Field verification, leveling, preparatory work on control point survey. JICA Supervisor arrived in Nairobi.
	23 Tue.	Continuation of above.
	24 Wed.	Field verification group moved. Leveling.
	25 Thu.	Continuation of above. Control point survey (GPS).
	26 Fri.	Continuation of above.
	27 Sat.	Continuation of above.
	28 Sun.	Rest

Aug.	29 Mon.	Field verification group moved. Leveling. Preparatory work on control point survey.
	30 Tue.	Field verification and continuation of above.
	31 Wed.	Field survey, leveling, GPS observations. JICA Supervisor left Nairobi.
Sep.	1 Thu.	Continuation of above.
	2 Fri.	Field verification, leveling, control point selection and monumentation.
	3 Sat.	Field verification, leveling, GPS observations.
	4 Sun.	Field verification group moved.
	5 Mon.	Leveling, control point computations.
	6 Tue.	Adjustments of field verified findings. Control point computations. Control point survey group moved.
	7 Wed.	Field verification, leveling, signalization.
	8 Thu.	Field verification, leveling, GPS observations.
	9 Fri.	Continuation of above.
	10 Sat.	Continuation of above.
	11 Sun.	Control point survey group moved.
	12 Mon.	Field verification, leveling.
	13 Tue.	Field verification, leveling, preparations for control point survey.
	14 Wed.	Field verification, leveling, reconnaissance for control point survey.
	15 Thu.	Field verification, leveling, control point selection.
	16 Fri.	Field verification, leveling, GPS observation.

Sep.	17 Sat.	Field verification group moved. Cross-sea leveling (Likoni). Control point survey group moved.
	18 Sun.	Cross-sea leveling (Kilifi). GPS observations.
	19 Mon.	Field verification group moved. Leveling.
	20 Tue.	Field verification, leveling, GPS observations.
	21 Wed.	Field verification, leveling, reconnaissance for control point survey.
	22 Thu.	Field verification, leveling, GPS observation.
	23 Fri.	Continuation of above.
	24 Sat.	Field verification group moved. Leveling, GPS observation.
	25 Sun.	GPS observation.
	26 Mon.	Field verification, leveling, preparation for control point survey.
	27 Tue.	Field verification, leveling, eccentric point measurement.
	28 Wed.	Continuation of above.
	29 Thu.	Field verification, leveling, preparation for control point survey.
	30 Fri.	Adjustments of field verified findings. Leveling. Control point survey computations.
Oct.	1 Sat.	Adjustments of field verified findings. Cross-sea leveling and control point survey computations.
	2 Sun.	Cross-sea leveling computations.
	3 Mon.	Adjustments of field verified findings. Cross-sea leveling computations. Preparation for control point survey.

Oct.	4 Tue.	Adjustments of field verified findings, leveling computations and adjustments, GPS results adjustment.
	5 Wed.	Continuation of above. GPS observation.
	6 Thu.	Continuation of above. Control point survey group moved.
	7 Fri.	Continuation of above. GPS observations.
	8 Sat.	Field verified findings adjustment, leveling computations and adjustment, packing of control point survey instruments.
	9 Sun.	Control point survey group moved to Nairobi.
	10 Mon.	Adjustment of field verified findings, leveling computations, preparation for control point survey group to leave.
	11 Tue.	Continuation of above.
	12 Wed.	Meeting on map symbols at SK. Preparation of Point Descriptions of leveling. 4 control point survey group members left Nairobi.
	13 Thu.	Continuation of above. Leader left Narita.
	14 Fri.	Continuation of above. 4 control point survey group members arrived at Narita.
	15 Sat.	Demobilization of field headquarters. Continuation of above. Leader arrived in Nairobi.
	16 Sun.	Rest
	17 Mon.	Field headquarters, field verification group, leveling group, moved to Nairobi. Leader and three other members visited JICA

		Embassy of Japan, Field Headquarters, SK, for reporting and courtesy call.
Oct.	18 Tue.	Briefing SK Director and officials on progress of work.
	19 Wed.	Meeting with SK on Minutes. 7 field verification group members left Nairobi.
	20 Thu.	Drafting of Minutes (Kenyan National Holiday).
	21 Fri.	Meeting on Minutes. Signing of Minutes. Seven field verification group members arrived at Narita.
	22 Sat.	Preparation for departure. (Vehicles turned in, data sorted out)
	23 Sun.	Continuation of above.
	24 Mon.	Reported to JICA, Embassy of Japan, on departure. Leader and 6 other team members left Nairobi via AF 498.
	25 Tue.	Arrived in Paris.
	26 Wed.	Left Paris, via AF 272.
	27 Thu.	Leader and 6 other team members arrived at Narita.

2) From January 29, 1989 to February 27, 1989

Jan.	29 Sun.	Aerial photography supervisor left Narita for London via BA 008.
	30 Mon.	Left London for Nairobi via BA 055.
	31 Tue.	Courtesy visit to JICA office.
Feb.	1 Wed.	Courtesy visit to Embassy of Japan. Meeting with PM company.
	2 Thu.	Standby on aerial photography.
	3 Fri.	Continuation of above.
	4 Sat.	Continuation of above.
	5 Sun.	Continuation of above.
	6 Mon.	Continuation of above.
	7 Tue.	Continuation of above.
	8 Wed.	Moved to Voi.
	9 Thu.	Moved to Malindi.
	10 Fri.	Standby on aerial photography.
	11 Sat.	Continuation of above.
	12 Sun.	Moved to Nairobi.
	13 Mon.	Standby on aerial photography.
	14 Tue.	Continuation of above.
	15 Wed.	Continuation of above.
	16 Thu.	Aerial photography of W5, T.
	17 Fri.	Inspection
	18 Sat.	Aerial photography of W1, W2, W3. Inspection: TOK, W5 NG.
	19 Sun.	Aerial photography of W5, W8. Inspection.

Feb.	20 Mon.	Inspection: W5, W8 OK.
	21 Tue.	Inspection
	22 Wed.	Inspection: W1, W2, W3 OK.
	23 Thu.	Standby on aerial photography.
	24 Fri.	Aerial photography of W9 - W15.
		Inspection: W9 - W15 OK.
	25 Sat.	Left Nairobi for London via BA 068.
	26 Sun.	Left London via BA 007.
	27 Mon.	Arrived at Narita.

2. Minutes of Meeting with SK

2-1 "Minutes of Meetings on the Second Year Work for Topographic Mapping of South Kenya"

MINUTES OF MEETINGS

ON

THE SECOND YEAR WORK

FOR

TOPOGRAPHIC MAPPING

OF

SOUTH KENYA

NAIROBI 9TH AUGUST, 1988

MR. E. M. GIKINYA
FOR: DIRECTOR OF SURVEYS

MR. SHO SAITO
LEADER
J I C A STUDY TEAM

MR. K. KUMAGISHI
RESIDENT REPRESENTATIVE
J I C A KENYA OFFICE

MINUTES OF MEETINGS ON THE START OF THE SECOND YEAR WORK
TOPOGRAPHIC MAPPING OF SOUTH KENYA

Dates: The meetings were held on Thursday 28th July, Friday 29th July, Monday 1st August and Tuesday 2nd August, 1988.

Present:

Survey of Kenya:

W. J. Absaloms	Ag. Director of Surveys
E. M. Gikinya	Ag. Assistant Director of Surveys, Mapping
O. M. Wainaina	Superintending Surveyor Mapping
F. Ito	JICA Expert Attached to Survey of Kenya
P. Ndunda	Chief Cartographer
J. Kibore	Chief Photogrammetrist
D. Chabeda	Chief Lithographer
C. Kimele	Oi/C 1:50,000 Topo Drawing Office

JICA Kenya Office

Ryuji Matsunaga	Assistant Resident Representative, JICA Kenya Office

JICA Study Team

S. Saito	Leader
K. Muraoka	Deputy Leader
M. Yoshida	Mapping Planner
Y. Kyakuno	Chief Surveyor
T. Hidaka	Chief Surveyor
M. Nakai	Surveyor
K. Miyakawa	Surveyor

1. Report to the Director of Surveys:

The JICA Study Team (hereinafter referred to as the"Team") held the first meeting with the Ag. Director of Surveys in his office on 28th July, 1988. The Team reported briefly on the progress of work and presented the Ag. Director with copies of the report on what had been accomplished during the first year. The Team also presented him with a copy of the plan of operations during the just beginning 2nd year work. See Attachment

S.S. E.M.G. K/C.

2. Review of first year work

The team made a brief review of the first years work during the rest of the meetings with the Survey of Kenya (SK) at the Survey Field Headquarters.

3. Plan of Operations for the Second Year (Phase II)

The Team presented copies of the plan of operations for the second yeaf (Phase II) to the Survey of Kenya (SK). The whole of Phase II would involve Aerial Photography, Levelling, Geodetic Control Point Survey, Field Verification, Aerial Triangulation, Stereo Plotting and Compilation. However, Plotting and Compilation will be continued to the third year. It was expected that all the work would be completed by the end of the fourth year during March, 1991.

After a detailed discussion the plan of operations for the second year was adopted. The map symbols and annotations contained in the plan of operations for the first year were reviewed in detail.

4. Counterparts

It was agreed that Survey of Kenya would provide the following:-

(a) At least 1 counterpart for geodetic control point survey party.

(b) 3 counterparts for the field verification parties.

5. Materials to be provided by Survey of Kenya (SK)

(a) Composite copies on stable material for all the maps at the edges of the mapping area. The Team will provide the material to SK for printing.

(b) Pricked diapositives, contact prints, photo index and aerial triangulation results for the old JICA maps in the North of the mapping area. This should cover 2 strips along the southern edge of the old JICA mapping area.

(c) Photographs of the old JICA levelling bench marks.

(d) Copies of the field revision data on the old maps within the mapping area where available.

6. Data to be provided by Survey of Kenya (SK)

(a) Details for the location of water pipelines, powerlines and telephone lines.

(b) Information on road classifications

A.A. E.M.G.

(c) Administrative and Cadastral boundaries. Survey of Kenya will mark the boundaries and send back to the Team. SK will also do a final checking on the boundaries before printing.

(d) SK will supply up-to-date symbols for some of the items which were not concluded like different water features, built-up areas etc., Survey of Kenya will also provide material for coral and cliffs symbols to be reproduced by the Team. A complete set of all the standard symbols and annotations were also to be provided to the Team.

(e) Survey of Kenya will also provide a list of coordinates, heights and descriptions for all the triangulation and traverse points to be shown on the maps. Survey of Kenya will also clarify the heights to be used in instances where two heights exist at a station or benchmark.

7. Administration

The Survey of Kenya will assist in obtaining permission to enter the National Parks and other restricted areas. Letters should also be sent to the Local Administration introducing the Team. The Mombasa Provincial Survey Office will also assist as during the first year. The Team provided Survey of Kenya with a list of vehicles that would be used during the field survey to enable SK obtain duty passes for the national parks.

8. Map symbols and their application

(a) Following were discussed and confirmed.

(1) Embankments, hedges, walls and similar features shall be shown, if they are longer than one centimetre on the map.

(2) Underground water pipe line shall be shown, except when it lies under the road.

(3) Oil pipe line shall not be shown.

(4) Telephone, telegraph and power lines are shown only for main lines.

(5) Road cuts and fills shall be at least 250 m long and 5 m high to be shown.

(6) For viaduct, the symbol is used only when it has intermediate pillars. Otherwise, the same symbol as the bridge shall be used.

(7) Buildings shall be shown as square, or round dot symbols according to their shapes.

(8) Annotation "Airfield (earth)" shall be included in "Grass."

S.A. E.M.G. R.K.

(9) The symbol for cemetery shall not be used, but a annotation "Cem" shall be used.

(10) Rivers shall be shown, if they measure at least one centimetre on the map for the Coastal and plains, but at least five milimetres in hilly areas.

(11) For plantation not stated in the application rules the first letter of the plant name shall be shown.

(12) For registered land the boundary and land reference number shall be shown.

(13) Photo-number at the principal point of the aerial photograph shall be noted in three figures, for example, 001 .

(14) Bench marks shall be shown only when confirmed in the field.

(b) Concerning the application of the annotation "Pan", discussions shall be made with counterparts in the field.

(c) Concerning generalization of built-up areas further discussions shall be necessary.

(d) SK requested sub-district, boundaries to be shown. The Team took note of the request.

(e) In connection with the item 6 (d), the Team proposed to modify symbols of features, like long reefs or cliffs, which cannot be shown by zipatone and not suitable to work out by scribing method. However, both parties did not reach to agreement. Further discussion shall be necessary.

9. Training

SK requested to have one person trained on photo-processing. The Team took note of the request.

A.A.

E.M.G.

K.K.

Attachment

PLAN OF OPERATIONS
FOR THE
TOPOGRAPHIC MAPPING
OF
SOUTH KENYA
IN THE
REPUBLIC OF KENYA

--- 2nd Year ---

July, 1988

JAPAN INTERNATIONAL COOPERATION AGENCY

PLAN OF OPERATIONS
FOR THE
TOPOGRAPHIC MAPPING
OF
SOUTH KENYA
IN THE
REPUBLIC OF KENYA

I. INTRODUCTION

In response to the request of the Government of the Republic of Kenya (hereinafter referred to as "Kenya"), the Government of Japan (hereinafter referred to as "Japan") decided to conduct the Topographic Mapping of South Kenya in Kenya (hereinafter referred to as the "Study").

Accordingly, the Japan International Cooperation Agency (hereinafter referred to as "JICA"), the official agency responsible for the implementation of the technical cooperation programmes of Japan, will undertake the Study, in close cooperation with the authorities concerned of Kenya. Survey of Kenya, Ministry of Lands and Settlement, (hereinafter referred to as "SK") shall act as counterpart agency to the Japanese study team (hereinafter referred to as the "Team") and also as coordinating body in relation to other governmental and non-governmental organizations concerned of Kenya for the smooth implementation of the Study.

II. OBJECTIVE OF THE STUDY

The objective of the Study is to prepare the 1/50,000 topographic map covering an area of approximately 29,800km^2 in South Kenya from east of Long. 37° 45' E to the coast and south of Lat. 3° S to the Kenyan territory of the Tanzanian border as shown in Fig. 1. Main items of the Study are as follows:

1. Aerial photography	approximately 29,800km^2
2. 1/50,000 topographic mapping	approximately 29,800km^2
	43 sheets.

III. SCOPE OF WORK

The scope of work to achieve the captioned objective is stated in a document entitled "Scope of Work for Topographic Mapping of South Kenya in the Republic of Kenya" agreed between the Ministry of Lands and Settlement and the Japan International Cooperation Agency issued on 19th March, 1987, in Nairobi, Kenya (hereinafter referred to as "S/W").

The study started in 1987. In view of the results and progress of the first year's study, coverage of the scope of work shall be modified as follows:

Aerial Photography, Leveling, Geoditic Control Point Survey, Aerial Signal and Pricking, Field Verification, Stereo Plotting, Field Completion, Drafting and Printing.

The Volume of the Study is tabulated in Table 1.

Table 1 Volume of the Study

Item	Volume	Remark
Aerial photography	approx. 29,800km^2	scale 1/60,000 (whole project area)
Leveling	approx. 920km	minor order leveling (including pricking)
Geodetic control Point Survey	9 points	satellite geodecy
Aerial signal	40 points	
Pricking	approx. 500km	existing bench marks
Field verification	approx. 26,800km^2	
Aerial triangulation	approx. 725 models	
Plotting and Compilation	approx. 29,800km^2	
Field completion	approx. 29,800km^2	
Drafting	approx. 29,800km^2	
Printing	43 sheets	in 6 colours 1,000 copies each

IV. WORK PLAN

The entire work shall be carried out under a four-year programme starting from October, 1987, and acomplishing in March, 1991. It shall consist of the following four phases in accordance with the time schedule shown in Fig. 2.

1. Phase I (First Year, 1987): Aerial Signal, Aerial Photography, Pricking and Leveling

1 - 1. Aerial Signal

To secure the proposed map accuracy, the accuracy of horizontal control point shall be not more than

0.07 mm x 1/plotting scale (= 0.07 mm x 50,000 = 3.5 m).

For horizontal control of photographs for aerial triangulation, 40 points of existing 1st and 2nd order triangulation and traverse points shall be used. The distribution plan is shown in Fig. 3. Aerial signals shall be set up on these proposed photo-control points.

1 - 2. Aerial Photography

Black and white panchromatic aerial photography shall be carried out in dry season with a super-wide angle camera (f = 8.8 cm) in two missions.

1 - 2 - 1. Mission I.

For pricking of existing bench marks and along proposed leveling routes, aerial photography shall be carried out in a form of strip courses for approximately 1,500 line km along these leveling routes at a scale of 1/40,000. This mission is done for the efficiency of the time schedule.

1 - 2 - 2. Mission II.

For mapping, the proposed mapping area of approximately 29,800km^2 shall be flown at a scale of 1/60,000 as shown in Fig. 4.

1 - 3. Pricking.

For vertical control of aerial photographs for aerial triangulation and mapping, existing bench marks shall be pricked (approximately 500 km). Pricking of proposed leveling routes (approximately 920 km) shall also be done for the same purpose at the time of leveling work. Twice enlargement of 1/40,000 aerial photograph shall be used in the field and later pricked points shall be transferred onto the 1/60,000 aerial photograph when necessary.

1 - 4. Leveling.

To secure the proposed map accuracy, the accuracy of vertical control points shall be not more than

0.07 x contour interval (= 0.07 x 20 m = 1.4 m).

For vertical control of photographs for aerial triangulation and mapping, existing 1st and 2nd order bench marks shall be used. The distribution of existing bench marks, however, is not sufficient for aerial triangulation and mapping. Consequently, minor order leveling shall be carried out to supplement existing bench marks. Minor order leveling of the accuracy of 5cm x $\sqrt{S}$ (Where S is the route length in km.) shall be carried out for approximately 920 km along main roads or national park boundaries where leveling work is found feasible, starting from and closing to existing bench marks. (Fig. 5)

Marking shall be done by utilizing conspicuous ground features or setting up marks every 2 km in average.

Pricking shall be done on aerial photographs for the vertical control for aerial triangulation and mapping on the above points and at knick points of topography along leveling routes at the time of leveling work.

Prior to the execution, reconnaissance shall be carried out for proposed leveling routes to alocate marks and for existing bench marks to find out if it is necessary to recover them in order to use them as given points for the minor order leveling.

2. Phase II (Second Year, 1988). Aerial Photography, Leveling, Geodetic Control Point Survey, Field Verification, Aerial Triangulation, Stereo Plotting and Compilation

In view of the results and progress of the Phase I's study, work plan for this Phase shall be modified from the original.

2 - 1. Aerial Photography

Of the aerial photography covering the project area of about 29,800 Km^2 at a scale of 1:60,000, about 3,000 Km^2 which were not successful in the first year's flight shall be flown (Fig. 4)

2 - 2. Leveling

It was found that among existing leveling routes, almost all bench works were destroged or lost along the route along coast. Minor order leveling shall be executed along this route for about 200 Km^2 to establish photo control points (Fig. 5).

2 - 3. Geoditic Control Point Survey.

Of the existing geoditic control points, three dimensional measurement for 5 missing points and height measurement for 4 points shall be executed by satellite geodesy.

2 - 4. Field Verification

Prior to field survey for verification of aerial photographs, reconnaissance study (photo-interpretation) shall be carried out using aerial photographs and reference data collected beforehand.

In compliance with the map style and its application rule, selection of items to express on the map and topographic information related to classification of ground features shall be verified and objects which are hard or impossible to interpret on the aerial photograph shall be clarified in the field. The key for photo-interpretation needed for mapping shall be prepared. Geographical and administrative names shall be collected by SK.

2 - 5. Aerial Triangulation.

To obtain coordinates of pass points and tie points, aerial trianbgulation shall be carried out by analytical method using 1/60,000 aerial photographs, comparators and electronic computers. Approximately 725 models shall be adjusted by block adjustment method.

The residual of the ground control points after adjustment and discrepancy at tie and pass points between adjacent models shall be not more than

1.4 per mil of the flight height

= 5,400 m x 1.4 per mil = 7.6 m

for both planimetry and altitude.

2 - 6. Stereo Plotting and Compilation

Stereo plotting shall be carried out by 1/60,000 aerial photograph and stereo plotting machine at the scale of 1/50,000 using the results of aerial triangulation and those obtained by field verification. Intermediate contour shall be plotted at 20 m intervals. 10 m of supplementary half interval contour shall be plotted for flat area, if necessary. The photogrammetric spot height shall be plotted every 5 cm in principle, taking the topography and distribution of control points into consideration.

Results shall be compiled in the format of the sheet lines of 15' x 15'. Along the northern boundary of the Study area lie the area mapped by JICA in the eastern part and that by Canada in the western part. Along the southern boundary to Tanzanian territory, the Ordnance Survey, United Kingdom, is executing mapping. The connection of maps among these maps shall be taken into consideration. Necessary data for the connection, such as pricked diapositives, results of aerial triangulation, copies of original manuscript of maps, etc., shall be obtained through SK. The discrepancy of connection to existing maps shall be adjusted in principle. If it is found dificult to tie, however, the treatment shall be discussed with SK.

This work shall be continued to Phase III.

3. Phase III (Third Year, 1989): Stereo Plotting and Compilation (continued) and Field Completion

3 - 1. Stereo Plotting and Compilation (continued)

A part of the stereo plotting and compilation works shall be continued to this phase.

3 - 2. Field Completion

Topography, ground features, vegetation, etc., which cannot be properly identified on the aerial photographs during plotting and compilation works, shall be verified in the field and inscribed on the copies of the compiled manuscript printed on the synthesized polyester sheets. Administrative and geographical names and administrative boundaries etc. shall be verified, confirmed and indicated on the paper copy of the compiled manuscript by SK.

4. Phase IV (Fourth Year, 1990). Drafting and Printing

4 - 1. Drafting

Based on the field completed compiled manuscript (original manuscript), negative scribing and preparation of masks and sheets for marginal information for printing plate making shall be carried out on stable polyester bases for 6 colour separation. Map style and symbols shall be discussed with SK. These sheets shall be composed so that one colour may be in one sheet for the sake of printing plate making (preparation of composite negative). A composite positive shall also be prepared consisting mainly of linear elements for the maintenance (revision) of maps.

4 - 2. Printing.

Making of printing plate shall be carried out using 1/50,000 composite negatives by photo-lithography.

Printing shall be carried out in 6 colours by the offset printing machine. Number of copies to be printed shall be 1,000 for each map. Specifications and size of printing paper shall be decided after discussion with SK.

5. Work Schedule.

Work schedule is shown in Fig. 2.

V. PLAN OF OPERATIONS FOR PHASE II (SECOND YEAR, 1988)

The study for Phase Ii comprises field survey and laboratory work: The field survey consists of aerial photography, leveling, geodetic control point survey and field verification. The period shall be from 25th July, 1988 to 27th October, 1988 (95 days).

The work volume is as follows:

Aerial photography	: scale 1:60,000, 14 coarses, 780Lkm.
Leveling	: about 200 bm along coast line
Geodetic control point survey	: 9 points by satellite geodesy 5 points ... new points 4 points ... height measurement
Field verification	: 26,800 Km^2
Plotting	: 1:50,000, 11,475 Km^2 (15 sheets)
Compilation	: 1:50,000, 11,475 Km^2 (15 sheets)

1. Preparations in the office

1 - 1. Planning of field survey

Chief engineer and engineers in charge of respective items of fiel survey shall prepare detailed plan for the efficiency of work.

1 - 2. Preparation of equipment and material

Followings shall shall be executed :

a. Preparation of the survey equipment and material necessary for field survey.

b. Pre-arrangement of necessary procedures for export and import of equipment and material out of Japan to Kenya.

c. Request of obtain licence of using radio.

1 - 3. Reconnaissance by aerial photograph

Proir to proceeding into the field, reconnaissance study shall be carried out in Japan to prepare materials which need field verification.

a. Thorough study of collected materials and pointing out of doubtful points,

b. Execution of photo-interpretation and picking up of keys necessary to verify,

c. Study of aerial photographs to point out points difficult to interpret and confirmation of the Study area,

d. Preparation of double enlargement of 1/60,000 aerial photographs which shall be used for field verification.

2. Field Survey

Field survey shall be carried out during 25th July, 1988, and 27th October, 1988 (95 days). During the period, team leader, deputy leader, mapping planner, 2 chief engineers, mechanic and 12 members consisting of 5 parties, - totaling to 18 member shall be dispatched for about 3 months and one member for the inspection of aerial photographs for about 1 month to the field.

2 - 1. Preparation

Before arrival of the main team to Kenya, team leader, deputy leader and other 6 staffs shall arrive in Nairobi to prepare for their reception. The main duties are as follows. Of those, the items especially indebted to the cooperation of SK are:

a. To discuss plan and execation of operations with SK, Concerning field verification, stereo-plotting and compilation, items to discuss with SK and to be confirmed are as follows:
   i. Map style and its application rule,
   ii. Administrative names and boundaries,
   iii. Data concerning names of following items: public building, church, mosque, road, railway, mountain, river, park, etc.,
   iv. Representation of military facilities,
   v. Name and/or number of each map sheet,
   vi. Marginal information and legend.

b. To secure permission for the flight for the aerial photography and use of airports (Malindi and/or Tsavo),

c. To secure licence for the use of communication facilities. The team is equipped with 7 JRC 10 W Portable HF SCB Radiotelephones JSB-20 with frequencies of 4055 and 6098 KHz.

d. To provide rangers, watchmen, laborers and drivers,

e. To arrange to study and/or copy materials related to the Study, such as existing aerial photographs, survey results and descriptions of points and place names kept by SK, for reviewing survey plan,

f. To announce to authorities concerned,

g. To ask SK to prepare tie-strips for tying adjoining existing maps,

h. To ask SK to assign counterpart personnel,

i. To ask SK to obtain credentials or identification cards to the Team members,

j. To ask SK to issue permit to enter into private properties and national parks to execute survey work when necessary.

Besides the aboves, followings shall be dealt with cheifly by the Team:

k. To prepare to establish headquarters and sub-camps in the field.

l. To receive shipped equipments, machinery and other materials,

m. To purchase equipments, machinery and other materials in Nairobi,

n. To hire vehicles,

o. To contract with local private aerial survey firm for aerial photography.

2 - 2. Aerial Photography

Aerial photography shall be carried out by contracting with a local private aerial survey firm. The air base for the work shall be in Malindi and/or Tsavo and final products shall be prepared in Nairobi. For the contract, supervision of the work

and inspection of the results, two engineers shall be dispatched. Except the inspection of the results, the works shall be in charge of members of the field headquarters.

Aerial photography shall be executed covering the proposed mapping area of approximately 29,800 Km^2 east of Long. 37 45' E and south of Lat. 3 down to the Tanzanian border.

In Phase I, the flight was executed. However, owing of the bad weather conditions, about 14% (3,000 bm^2) remained unsuccesful. In this phase, this part shall be flown. (Fig. 4)

Main specifications for the aerial photography shall be as follows:

a. Period : August, 1988 and/or Junary, 1989
b. Camera : Super-wide angle camera with califration record
c. Area to be covered: proposed area of approximately 3,000 km^2 in the South Kenya region as shown in Fig. 4 shall be covered.
d. Photographic scale: approximately 1/60,000
e. Flight course: 14 courses (including one tie course)
   eastern block (east-west) 13 courses
   tie course (along Tanzanian border) 1 course
f. Flight length: Total flight length shall be approximately 780 km including tie-course
g. Flight height: 5,840 m (datum plane 500 m)
h. Forward overlap: 60% + 5%
i. Lateral overlap: 30% + 5%
   For connection with the photogrpah taken in the Phase I, at least two models shall be overlapped.
J. κ : not more than 10 degrees

ϕ and ω : not more than 5 degrees

k. Cloud coverage: Amount of cloud shall not exceed 3 % in successive 5 photographs. However, important areas for orientation and cartography shall not be covered with clouds.

l. Number of models: approximately 128

m. Number of photographs: approximately 142

n. Film: black and white panchromatic

o. Printing paper: Kodak RC paper or equivalent

p. Results:

original negative	1 set
contact print	2 sets
index map	2 sets
flight record	1 set

Exposed original negatives being taken out to Japan, extra copy of contact prints shall be prepared and left in Kenya for security.

2 - 3. Leveling

2 - 3 - 1. Planning and point selection

In Phase I, although all existing bench marks were investigated to prick them on the aerial photographs, it was not able to find points exept along the routes shown in thick lines in Fig. 5.

Minor order leveling shall be executed along the routes along coast for about 200 Km to establish height control of photographs.

2 - 3 - 2. Observation

Observation shall be made by double observation starting from an existing bench mark and closing to another existing one. Otherswise, routes shall close to themselves. Prior to observation, check observation shall be made for at least two neighboring existing bench marks, on one of which the minor order leveling is based. When the result of check observation is coincident with the nominal value within the accuracy of the check observation, the nominal value of the bench mark shall be adopted as given value. Otherwise check observation shall be extended to reach within the tolerable closure and newly observed value shall be taken as given.

Observed marks shall be pricked on the double enlargement of 1/40,000 aerial photographs at the time of observation and later they shall be transferred on to the 1/60,000 aerial photographs as in the case of pricking of existing bench marks.

Kilindini Harbor, Mombasa, and Kirifi Creek shall be crossed over by trigonometric crossrivers leveling method.

Accuracy of observation:	50 mm x$\sqrt{S}$, where S is the route length in km.
Instrument to be used:	Autolevel
Staff:	wodden folding staff
Staff stand:	
Theodolite:	Wild T2
Distance meter :	electro-optical distance meter

2 - 4. Geodetic Control Point Survey

2 - 4 - 1. Outline

Of 40 signalized geodetic control points, geodetic control survey shall be executed for 5 missing points and 4 points whose height is unknown.

2 - 4 - 2. Method of observation

The survey is executed by satellite geodisy, applying Global Positioning System (GPS). Three Trimble 4000SX instruments shall be used. Measurement is executed geometrically. For high accuracy, simultaneous observation shall be made at two points (interference). Measured value is the coordinate difference of the two points on the reference ellipsoid. Consequently, by executing observation at three points, from the closure of a triangle, it is possible to check the accuracy of the observation. Choosing one known point, the co-ordinates of other points can be obtained. Measured height, however, being that on the basis of the reference ellipsoid, in order to make it for leveling data, it is necessary to convert it to the height on the basis of geoid. The height of a point from geoid is calculated by putting unknown point between two known points (leveled points) and adjusting the observed results by interpolation.

2 - 4 - 3. Obsevation

Observation is made by classifying the points into following two groups and shall start from a given point and close to another given point.

a. Planimetry and height

Planimetry and height shall be abtained for the following 5 points:

190S2, 193S2, 196ST4, 199ST1 and 199ST2.

b. Height

Height shall be obtained for the following 4 points:

188PT, SKP49, 195PT2 and 202S3.

2 - 4 - 4. Accuracy required

Accuracy for photo control points is required as follows:

Planimetry : 0.07 mm/map scale (=3.5m)

Height :' 0.07 x contour interval (=1.4m).

2 - 4 - 5. Monumentation

Monumentation shall be executed , when necessary. Style of the monument shall be decided after consulting SK.

2 - 4 - 6. Computation and adjustment

From the observed data, following computation shall be executed:

a. Coordinate difference or relative height between two points

b. Coordinates or Height of a point

c. Geoditic coordinates (Tranformation of the computed values obtained in WGS-84 system to the values in New Arc 1960 system)

2 - 5. Field Verification.

Using aerial photographs, the keys for photo-interpretation needed for plotting and cartography shall be prepared by verifying them in the field.

Based on the application rule of the map style, necessary items to represent on the map shall also be collected and verified in the field. Close cooperation of the SK counterparts is cordially requested.

The area for field verification of aerial photographs will be confined to that where aerial photographs were taken in Phase I, ground feature or topography in the remaining area are thought not complex. The field verification for the latter area will be executed by using compiled manuscript at the occasion of field completion in Phase III.

2 - 5 - 1. Items of field verification.

In compliance with the map style and its application rule, followings shall be investigated and confirmed in the field:

a. Result of reconnaissance study,

b. Key for photo-interpretation,

c. Items difficult to inerpret on the photograph,

d. Following items to represent on the map:

road, railway, building, control point, specified area, river, vegetation, topography, etc.,

e. Names necessary for annotation.

2 - 5 - 2. Adjustment.

Results of field verification shall be adjusted on the double enlargement of 1/60,000 aerial photographs.

2 - 5 - 3. Tying

It is necessary to investigate carefully tying among aerial photographs and between mapping area and existing maps. On account of changes in ground features, if it is imposible to tie, the treatment shall be discussed with SK.

3. Laboratory Work.

3 - 1. Aerial triangulation.

Aerial triangulation is carried out as follows:

a. Using pricked diapositives of 1/60,000 aerial photograph on which aerial signals are photographed, coordinates of pass points, control points, etc necessary for plotting are measured by stereo-comparator.

b. Adding the results of ground control point survey, adustment computation is executed.

c. Coordinates of pass points and orientation elements of aerial photographs are calculated.

3 - 1 - 1. Method.

Aerial triangulation is done analytically by the block adjustment method by means of independent models. PAT-M43 program shall be used.

3 - 1 - 2. Area covered.

The area for aerial triangulation covers the whole area of 1/50,000 topographic mapping.

3 - 1 - 3. Distribution and number of control points.

Distribution of horizontal control points is shown in Fig. 3. Their number shall be 40. Vertical control points shall be selected among pricked bench marks and spot heights. (Fig. 4)

3 - 1 - 4. Selection of pass points.

Pass points shall be selected so that their position shall be appropriate for orientation of aerial photographs and that it shall be correctly measurable on the photograph.

3 - 1 - 5. Adjustment computation.

a. The residuals of ground control points and discrepancies of pass points and tie points between adjacut models after adjustment shall be less than 1.4 per mil of the flight height for both planimetry and altitude.

b. When adjustment computation is made by dividing into blocks, the discrepancy of tie points between adjacent blocks shall be less than 1.5 per mil of the flight height for both planimetry and altitude.

3 - 2. Stereo Plotting (Restitution).

Using the results of aerial triangulation and field verification, necessary items for representing on the map shall be measured and plotted by stereo plotting machine and plotted manuscript of the topographic map shall be prepared.

Map index is shown in Fig. 1, where plotting area in Phase II is surrounded by shaded lines. The work for remaining part will be continued to Phase III.

3 - 2 - 1. Material.

For restitution, stable polyester sheet shall be used.

3 - 2 - 2. Neat lines.

Neat lines shall be 15' x 15'.

3 - 2 - 3. Plotting.

Neat lines, control points and grid lines are plotted using automatic coordinategraph. The maximum discrepancy shall not exceed 0.2 mm on the map.

3 - 2 - 4. Orientation.

a. After absolute orientation of the photographs, the discrepancy between the plotted points and their model points shall be not more than 0.3 mm on the map.

b. For orientation of height, pricked leveling points shall be used as many as possible for the sake of accuracy of height.

3 - 2 - 5. Restitution.

a. Restitution shall be executed in accordance with the map style and its application rule in the order of linear elements, like roads, rivers, railways, etc., buildings, vegetation and contour lines.

b. If necessary, planimetry and contour lines can be restituted on separate sheets.

c. Intermediate contour shall be 20 m and half interval contour lines of 10 m shall be supplemented according to topography. Care must be taken for the representation of micro topography, the project area being rich in various types of ground features and topography like hill, plain, forest, wadi, cultivated land, etc.

3 - 2 - 6. Measurement of spot height.

a. Spot height shall be measured photogrammetrically at distinct knick points of topography.

b. Spot height shall be distributed taking the topography into consideration.

3 - 2 - 7. Tying

Map tying shall be made between

a. existing 1/50,000 topographic map along the northern edge of the project area,

b. 1/50,000 topogrpahic map being worked by the Ordnance Survey along the western and southern borders to Tanzania.

Connection shall be made in principle. However, if is found difficult to tie, the treatment shall be discussed with SK.

4 - 3. Compilation.

a. On the basis of the plotted manuscript, compilation shall be carried out using the results of field verification and materials collected. The sheets in the area

surround by shaded lines in Fig. 1 shall be compiled in Phase II. The remaining sheets will be worked out in Phase III.

b. If any doubtful point arises during compilation, it shall be noted to clarify at the time of field completion.

c. Annotation items shall be compiled on a separate sheet using plotted manuscript and data obtained by field verification.

VI. REPORT

The progress report of Phase II shall be prepared.

VII ORGANIZATION OF THE TEAM

Organization of the Team is as follws:

Duty	Member	Number for a party	Number of parties	Total
Leader	Japanese engineer			1
Deputy-leader	"			1
Mapping planner	"			1
Chief-engineer	"			1
Mechanic	"			1
Geodetic control point survey	"	4	1	4
	counterpart			1
	laborer	18	1	18
Inspection of Aerial photography	Japanese engineer			1
Leveling	"	2	1	2
	laborer	6	1	6
Field verification	Chief-engineer (Japanese engineer)			1
	Japanese engineer	2	3	6
	counterpart	1	3	3
	laborer	4	3	12

VIII WORK SCHEDULE

VIII WORK SCHEDULE

The work for Phase II (2nd year) starts on 25th July, 1988, and shall continue to March, 1989. Detailed work schedule is shown in Fig. 6.

IX. FINAL PRODUCTS AND MATERIALS

Final products and materials of Phase II. (2nd year) are as follows:

1. Geodetic control survey

a. Note of eccentric calculation	1 set
b. Observed data	1 set
c. Computation notes	1 set
d. Final results	1 set
e. Others	1 set

2. Aerial Photography

a. Negative film	1 set
b. Contact print	2 sets
c. Photo index	2 sets
d. Others	1 set

3. Leveling

a. Observation note	1 set
b. Final result	1 set
c. Route map	1 set
d. Pricked Photograph	1 set
e. Point description	1 set
f. Others	1 set

4. Field verification

g. Photograph with verified data	1 set
h. Others	1 set

5. Aerial triangulation

a. Final result	1 set
b. Index map	1 set
c. Pricked dispositive	1 set
d. Pricked contact print	1 set
e. Computation sheet	1 set
f. Table for accuracy check	1 set
g. Others	1 set

6. Stereo plotting and compilation

a. Plotted original	1 set
b. Map showing control point distribution	1 set
c. Record of orientation	1 set
d. Compiled original	1 set
e. Annotation data	1 set
f. Vegetation data	1 set
g. Road data	1 set
h. Marginal information data	1 set
j. Others	1 set

Fig.1 Map Index

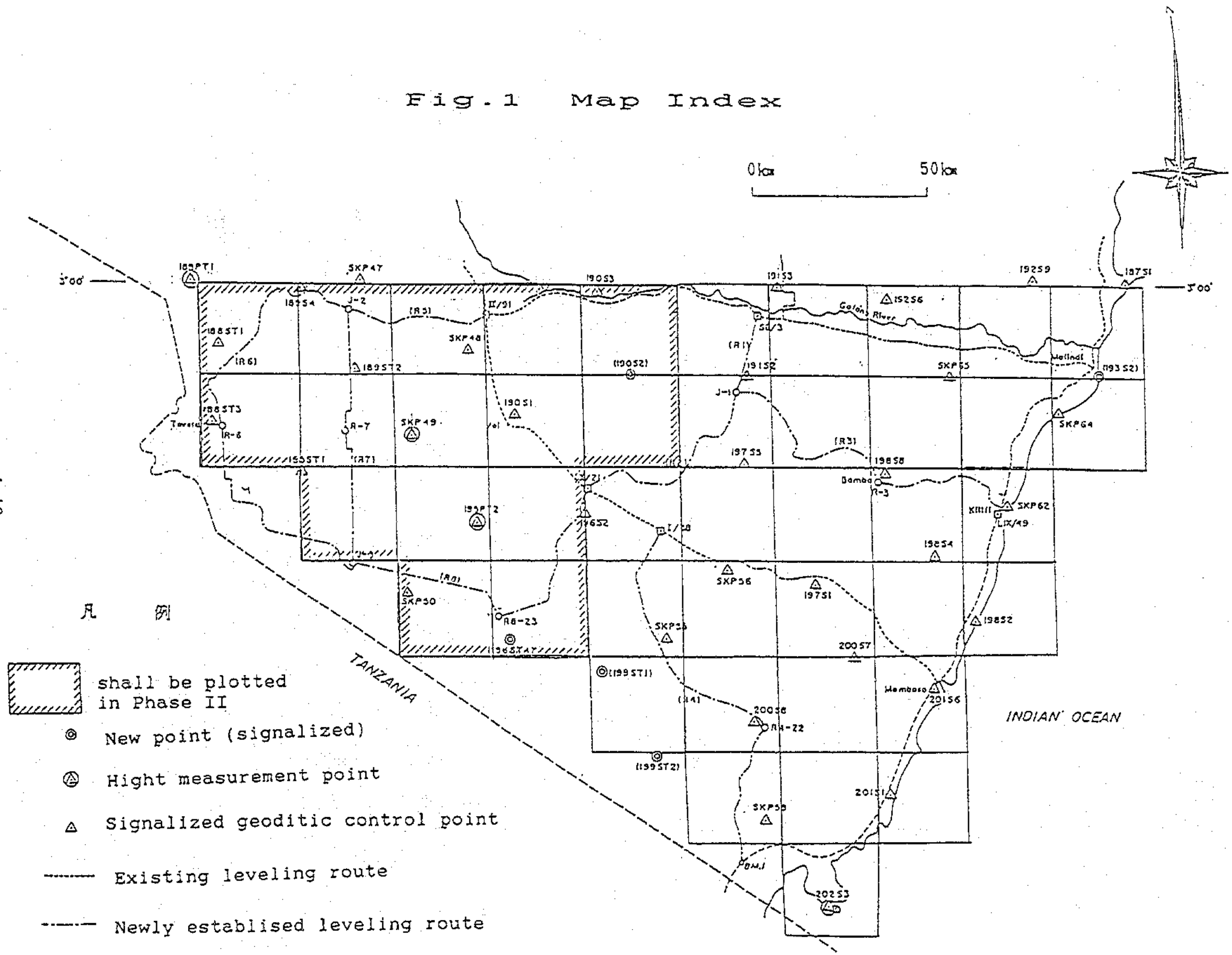


Fig. 2 WORK SCHEDULE

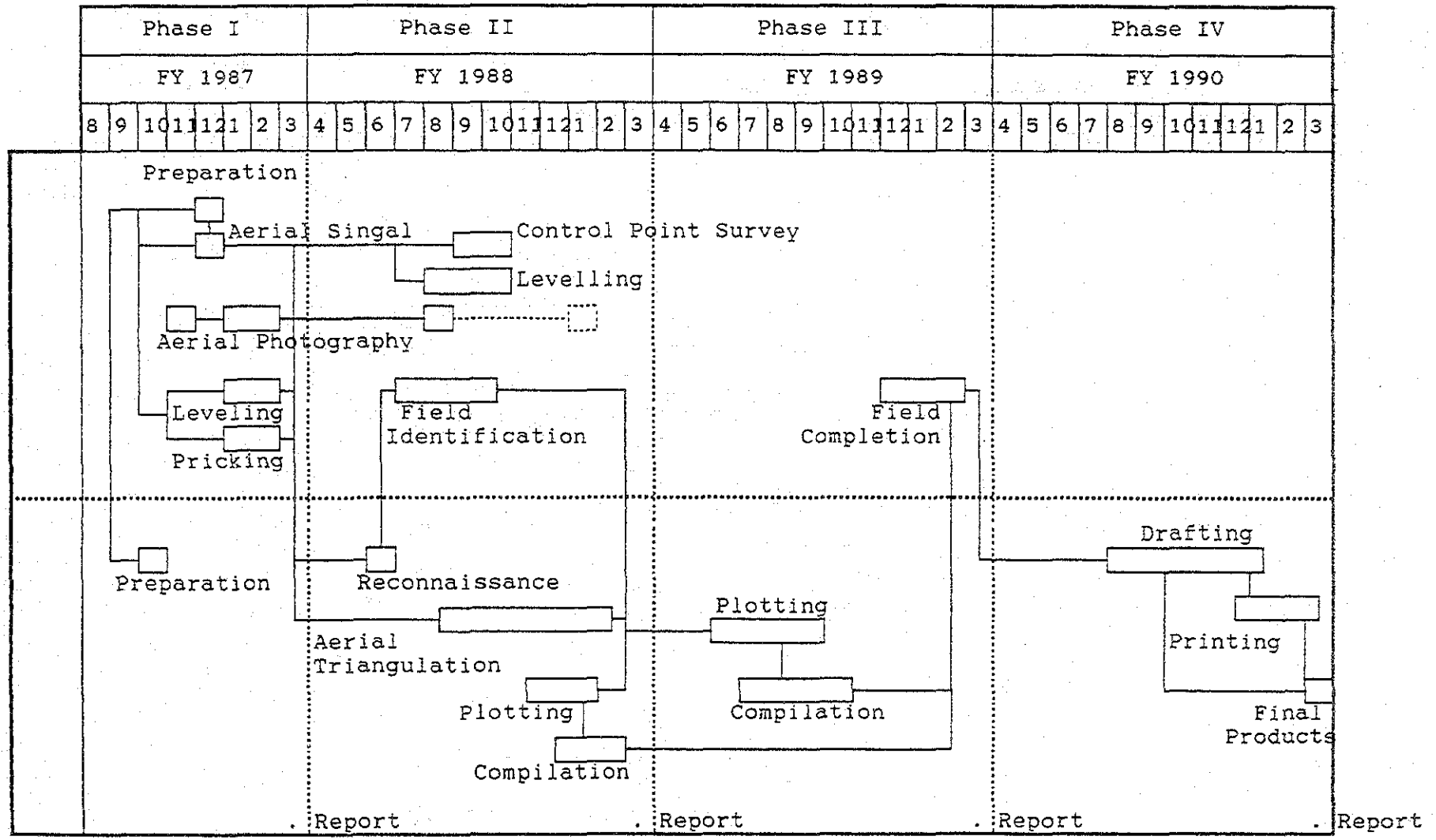


Fig.3 Plan for Geodetic Control Point Survey

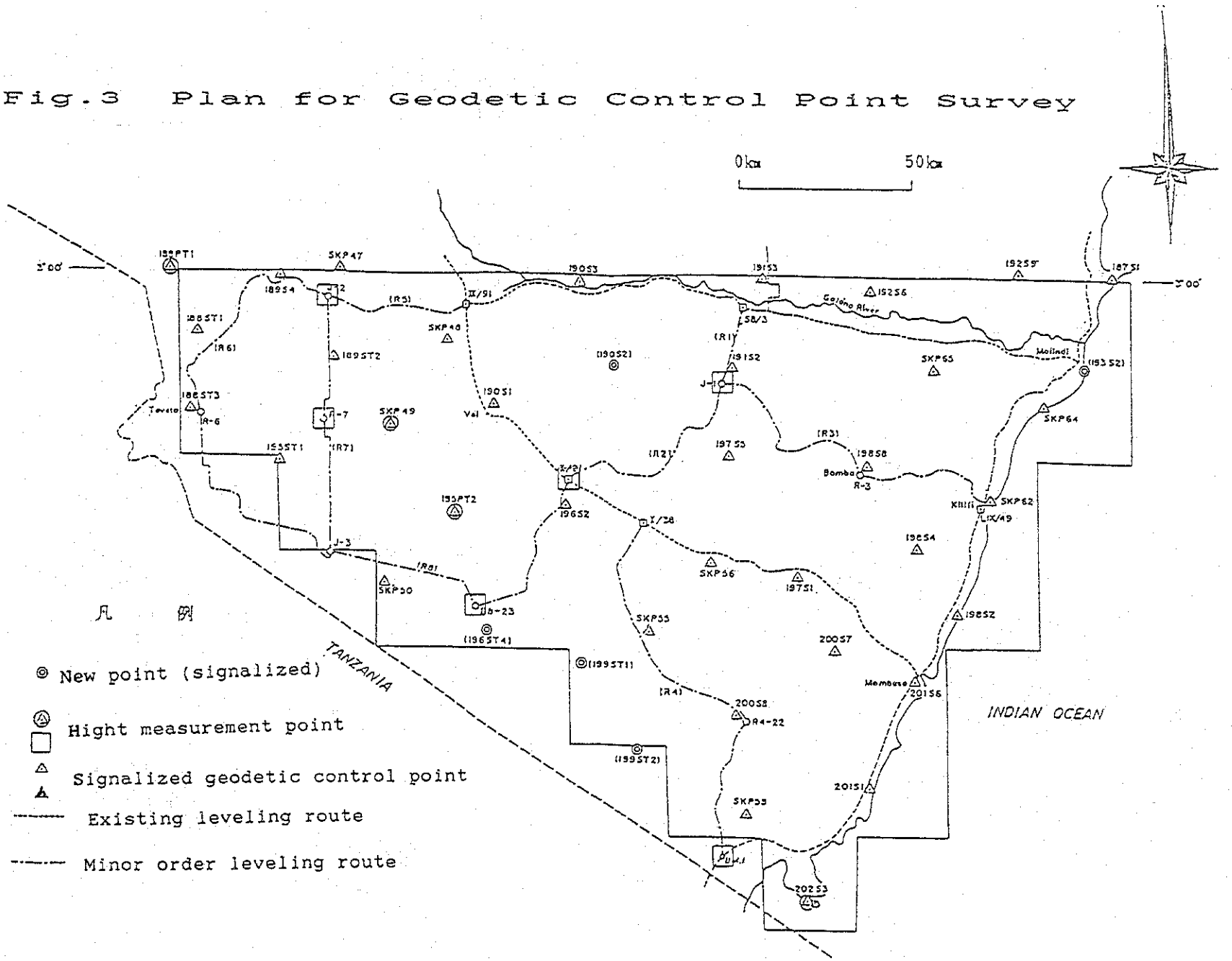


Fig.4 Plan for Aerial Photography

Photo scale : 1:60,000

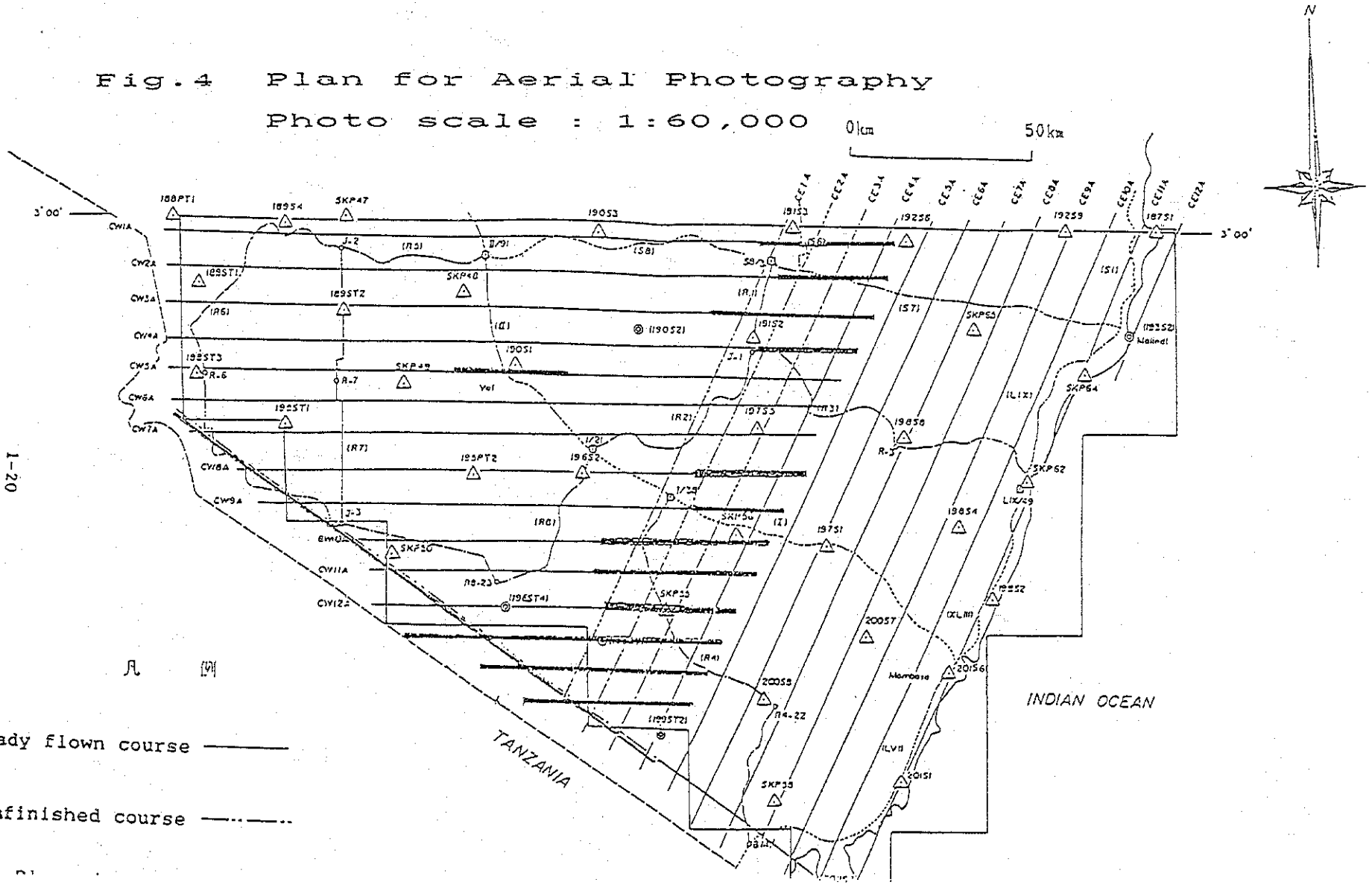


Fig.5 Plan for Leveling

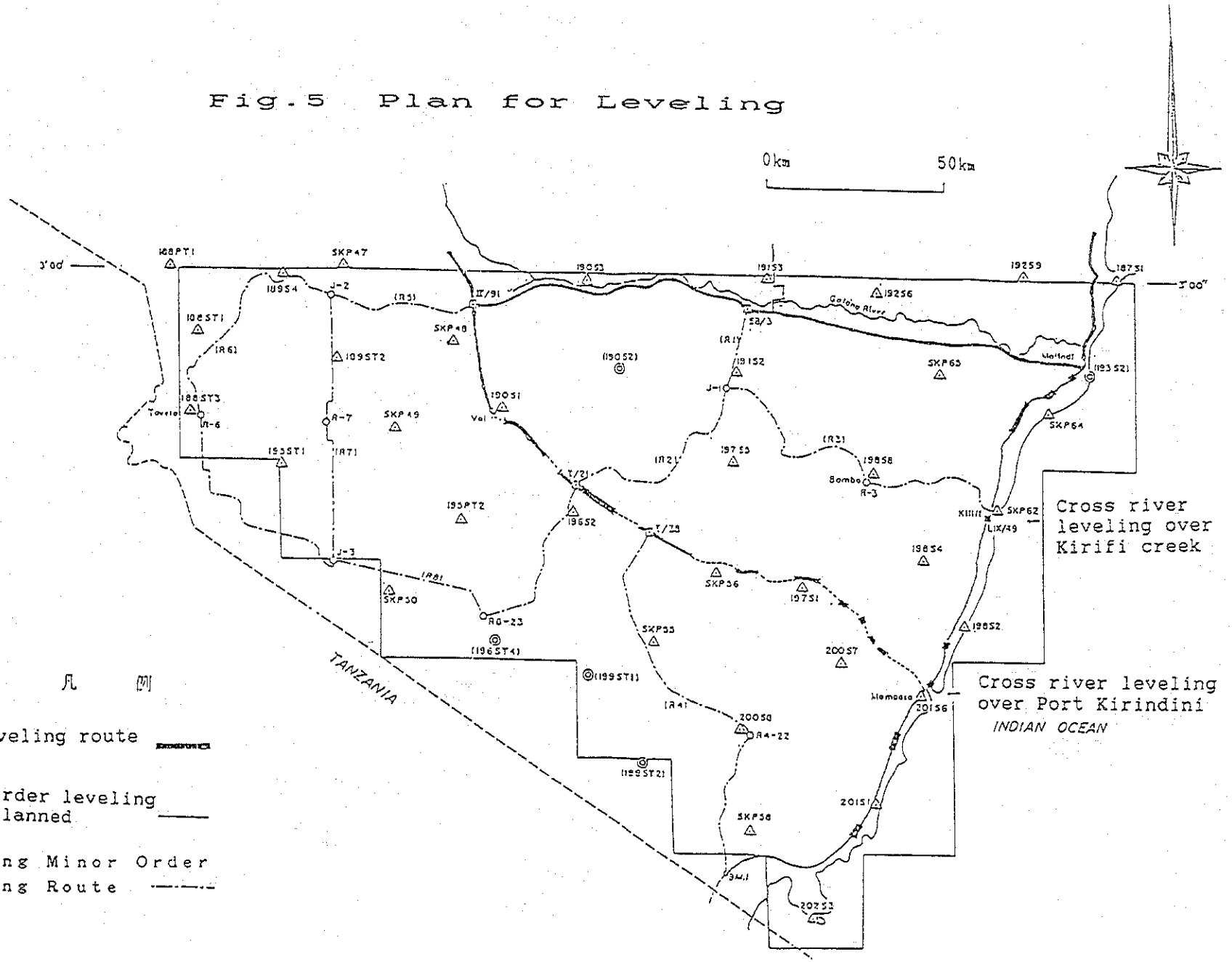
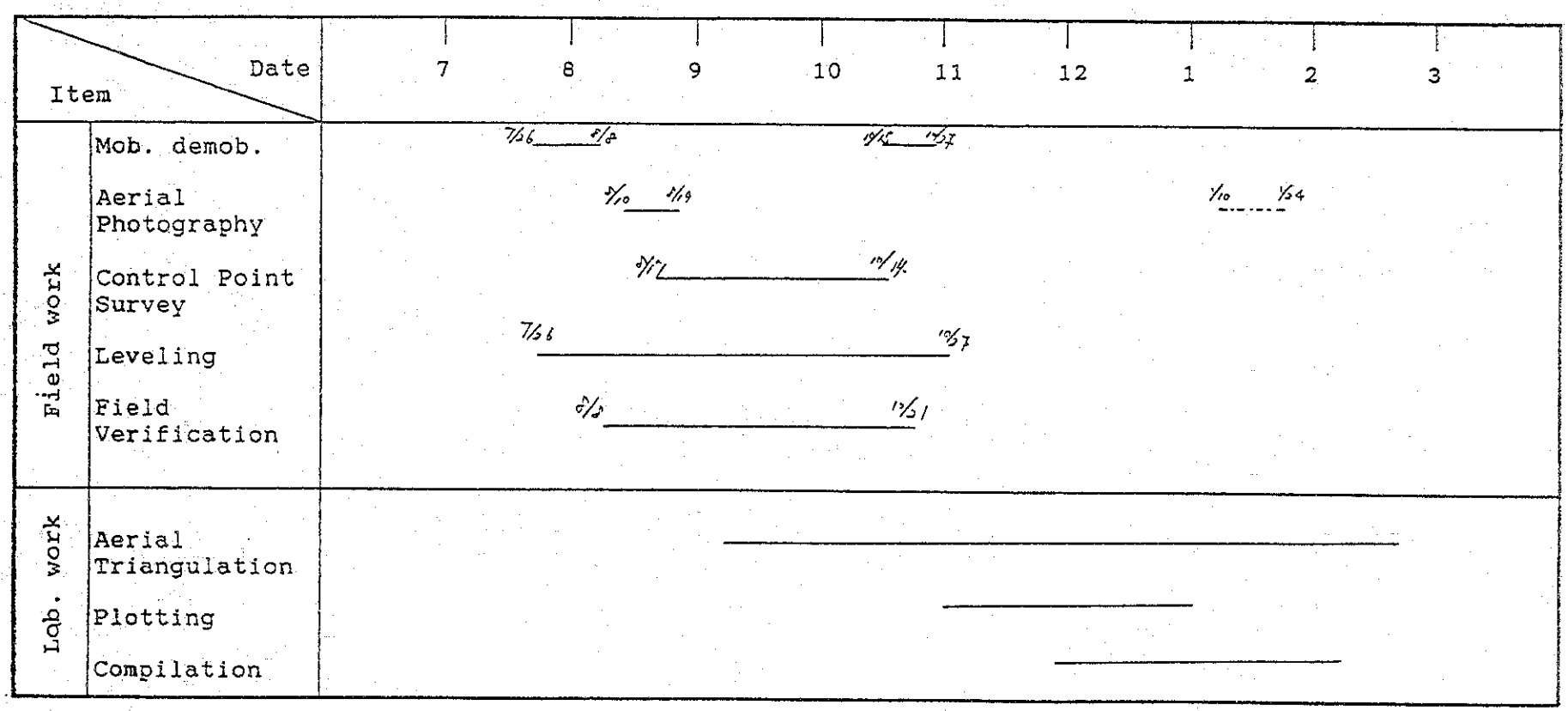


Fig. 6 Work Schedule for Phase II



2-2 "Minutes of Meetings at the End of the Second Year's Field Work of Topographic Mapping of South Kenya"

MINUTES OF MEETINGS

AT THE END OF

THE SECOND YEAR'S FIELD WORK

OF

TOPOGRAPHIC MAPPING

OF

SOUTH KENYA

NAIROBI 21ST OCTOBER, 1988

MR. E. M. GIKINYA
FOR: DIRECTOR OF SURVEYS

MR. SHO SAITO
LEADER
JICA STUDY TEAM

MR. K. KUMAGISHI
RESIDENT REPRESENTATIVE
JICA KENYA OFFICE

MINUTES OF MEETINGS AT THE END OF THE SECOND YEAR'S FIELD WORK OF TOPOGRAPHIC MAPPING OF SOUTH KENYA

Dates: The meetings were held on Wednesday 12th October, Thursday 13th October, Monday 17th October and Tuesday 18th October, 1988.

Present:

Survey of Kenya:

A. K. Njuki		Deputy Director of Surveys
E. M. Gikinya	Ag	Assistant Director of Surveys, Mapping
O. M. Wainaina		Superintending Surveyor, Mapping
P. Ndunda		Chief Cartographer
J. Kibore		Chief Photogrammetrist
D. Chabeda		Chief Lithographer
P. D. Amiani		Oi/C Technical Section
C. Kimele		Oi/C 1:50,000 Topo Drawing Office
F. Ito		JICA Expert Attached to Survey of Kenya

JICA Study Team

S. Saito	Leader
K Muraoka	Deputy Leader
M. Yoshida	Mapping Planner
YL. Kyakuno	Chief Surveyor
T. Hidaka	Chief Surveyor
M. Nakai	Surveyor

1. Review of the Minutes of Former Meetings

The Minutes of Meetings on the Start of the Second Year Work signed on 9th August were reviewed. The items to be noted are:

(a) Concerning item 5-(a), a set of tie strips were provided by Survey of Kenya (hereinafter referred to as SK).

(b) Concerning item 5-(b), pricked diapositives, contact prints and aerial triangulation results for the old JICA maps necessary for tying were lent to the JICA Study Team (hereinafter referred to as the "Team") and photo index was provided by SK. The contact prints of the Canadian project area were also lent to the Team.

(c) Concerning item 5-(c), description of bench marks was provided.

(d) Concerning item 5-(d), copies of field revision data were provided.

E.M.G.

A.A.

(e) Concerning items 6-(a) and 6-(b), data for water pipelines and powerlines were provided. However, those for telephone lines and information on road classification were not available to the Team. They requested to SK to check the result and supplement the compiled manuscript, if necessary.

(f) Concerning item 6-(c), SK will mark the boundaries on a sheet to be provided by the Team.

(g) Concerning 6-(d), SK prepared positive films of symbols and zipatones, including coral and cliffs symbols.

(h) Concerning itaem 6-(e), for the height of existing bench marks, nominal values given on the description of point were used and when they were not available, those on the final resultant table were used by the Team. SK agreed to the treatment.

(i) In connection with item 8-(a)-(8), aviation facilities shall be classified as follows:

Airfield - runway with permanent building,
Airstrip - runway
Airport - Mombasa and Malindi.

(j) Concerning item 8-(b), discussions did not reach to conclusion. Reference shall be to the old maps.

(k) Concerning item 8-(c), generalization shall be classified into two categories: permanent buildings and others.

(l) Concerning item 8-(d), SK requested to prepare maps showing sub-district boundaries as overprint using the seventh colour for the half part of the number of copies to be printed. SK will prepare necessary data. The Team took note of the request.

E.M.G.
S.A.

2. Materials provided by SK

Besides the materials described in para. 1, following were also provided by SK:

(a) Copy of a booklet showing map symbols, application rule of lines and annotation, etc.

(b) Transparency of marginal information plate for black.

(c) Sample sheet of legend.

(d) Magnetic information.

E.M.G.

S.A.

3. Reporting

The Team reported briefly the progress of the second year's field work for the Study, presenting the "Progress Report of the Second Year's Field Work for the Topographic Mapping of South Kenya in the Republic of Kenya" prepared by the Team. (Attachment) SK appreciated the report.

4. Compiled manuscript

SK requested that the form of compiled manuscript to be provided by the Team shall be

(a) Contour sheet.
(b) Composite of planimetry with annotation sheet.

They shall be printed on stable material in mirror image.

The Team proposed to add following sheets:

(c) Overprint of vegetation boundary in colour on (b).
(d) Overprint of double line roads in colour on (b).
(e) Overprint of water systems in colour on (b).

5. Future work

The Team explained the tentatively planned future works as follows:

(a) Second year (November 1988 - March 1989)

In accordance with the "Plan of operation for the Topograpohic Mapping of South Kenya in the Republic of Kenya -2nd Year-", the Team explained remaining works for this year, adding that in January - February, 1989, aerial photography is planned again for the remaining area.

(b) Third year (April 1989 - March 1990)

In accordance with the tentative plan of operations described in the "Plan of Operations for the Topographic Mapping of South Kenya in the Republic of Kenya -1st Year-", the Team explained the schedule, in which in view of the modification in the second year's work schedule, more works will be needed to field completion than originally planned. Consquently, more number of counterparts will be required forfield work. SK took note of the request.

E.M.G.
A.A.

6. Repair of aerial signals

The Team requested to repair some of the aerial signals in the area to be flown in January-February, 1989. The description of aerial signals shall be provided by the Team. SK took note of the request.

E.M.G.

A.A.

Attachment

PROGRESS REPORT

OF

THE SECOND YEAR'S FIELD WORK

FOR

THE TOPOGRAPHIC MAPPING OF SOUTH KENYA

IN

THE REPUBLIC OF KENYA

--- October, 1988 ---

STUDY TEAM
OF
THE TOPOGRAPHIC MAPPING OF SOUTH KENYA
IN
THE REPUBLIC OF KENYA

JAPAN INTERNATIONAL COOPERATION AGENCY

I. INTRODUCTION

The topographic mapping of South Kenya started in October, 1987, in four-year term study, as a technical cooperation program of JICA.

In compliance with the Scope of Work agreed upon between the Ministry of Lands and Housing and JICA on the 19th March, 1987, the JICA Study Team, composed of 18 members, was despatched on the 25th July, 1988, for 95 days to execute the second year's field work. Meanwhile Kenyan counterparts from Survey of Kenya joined the work from time to time.

In accomplishing the second year's field work, the summary of the progress of the work is reported.

II. OBJECTIVE OF THE STUDY

The objective of the Study is to prepare 1/50,000 topographic map covering an area of approximately 29,500 km² in South Kenya from east of Long. 37°45'E to the coast and from south of Lat. 3°S to the Kenyan territory of the Tanzanian border. Main items of the Study are as follows:

1.	Aerial photography	approximately 29,800 km².
2.	1/50,000 topographic mapping	approximately 29,800 km².

III. SCOPE OF WORK FOR THE CAPTIONED PERIOD

In view of the progress of the first year's study, the scope of work for the second year is modified from the original as follows:

1. Field work
   Following works shall be executed in the field.

   a. Aerial photography
      About 15% of the project area which was not covered by aerial photographs in the first year's period shall be covered by 1/60,000 aerial photographs.

   b. Geodetic control survey
      5 missing or destroyed geodetic control points shall be reestablished and height of 4 points shall be measured. The survey shall be executed by Global Positioning System (GPS).

   c. Leveling
      Minor order leveling shall be executed along coast from Lunga-Lunga to Malindi (approximately 200 km).

d. Field verification
Items needed for map representation on the aerial photographs and other materials shall be verified in the field.

2. Office work
Following works shall be carried out in Japan.

a. Aerial triangulation
Using field surveyed data, aerial triangulation shall be executed in preparation for plotting.

b. Plotting and compilation
Using the result of aerial triangulation and field verified materials, stereo-plotting and then compilation shall be executed to prepare the manuscript of the 1/50.000 topographic map. The work shall be continued to the third year.

IV. AERIAL PHOTOGRAPHY

Due to unfavorable weather conditions, no aerial photograph was taken during this period (July-Oct., 1988). Another flight is planned in Jan.-Feb., 1989.

Repairs of aerial signals were done for 9 points in the planned area and identificatilon of aerial signals for 4 points on the aerial photographs taken in the last period.

V. GEODETIC CONTROL SURVEY

Geodetic control survey was executed by satellite geodesy applying GPS. Three Trimble 4000SX instruments were used by making simultaneous observation at three points.

1. Observation
Observation was made at every three points simultaneously. Due to the limitation of the passing hours of satellites it was made from 09:00 to 11:00 local time (2 hours). 3 - 5 satellites were observed. (Nos 3, 6, 9, 12 and 13).

Observation was not successful on SKP 49. In its neighbourhood, there is a transmitting station with a power plant. Observation was made on a hill about 1 km apart from the point and the eccentricity measurement was made.

2. Unknown points
The planned points to obtain the planimetry and/or height are as follows:

188PT1, SKP49, 190S2, 193S2, 195PT2,
196ST4, 199ST1, 199ST2 and 202S3.

a. 190S2, 196ST4, 199ST1 and 199ST2 were not found. Monumentation was done at places different from their supposed position. To distinguish newly established monuments from the original ones, numbering was applied by adding suffix N to the original number:

190S2N. 196ST4N, 199ST1N and 199ST2N.

b. The monuments of 188PT1 and 193S2 were missing and monuments were buried at the same hole as the originals. The monument of 203S2 was also missing. New monument was buried at the intersection of diagonals of a quadrangle formed of four reference marks.

c. Geodetic control point R2 was newly established close to BM R2-16. in reference to which the height was measured by direct leveling.

3. Given points
Following points were adopted as given points for computation.

a. For planimetry

188PT1, 191S2, 192S6, SKP49. 195PT2.
197S1, 198S8, SKP62. 200S8, 202S3.

b. For height

J-2. J-3. R-6. 196ST4, R-2. R9-47A. SKP62, 193S2.

For the above points, measurement was done on the spot. Their planimetry can be computed at the same time.

Close to the bench marks I/21 and BM-1, temporary marks were set up exclusively for height control. Their height was measured by direct leveling. They are desingnated as I/21T and BM-1T to distinguish them from I/21 and BM-1.

4. Observation scheme

Combining unknown points with the known points, observation was made following the scheme shown in the following table and Fig. 1.

Group	Points		
1.	188PT1	J-2	R-6
2	SKP49	J-3	R-6
3	195PT2	196ST4N	J-3
4	109S2N	I/21T	J-2

5	191S2	R-2	190S2N
6	I/21T	199ST1N	196ST4N
7	200S8	199ST2N	199ST1N
8	200S8	202S3	BM-1T
9	202S3	SKP62	197S1
10	197S1	I/21T	R-2
11	192S6	198S8	R-2
12	SKP62	192S6	193S2N
13	197S1	R9-47A	BM-1T

4. Results

The coordinate closures of each triangle were computed by approximate computation in the field to check the reliability of the observation. The result is tentatively as follows, where groups 9 and 11 are excluded.

	Range	Mean
Side length	21 km - 96 km	50 km
Closure(absolute value)		
dX	1.0 cm - 25.8 cm	9.5 cm
dY	3.0 cm - 56.3 cm	31.1 cm
dH	0.0 cm - 29.9 cm	14.2 cm
Mean error of side length	0.0 cm - 7.2 cm	1.1 cm

where dX, dY and dH stand for coordinate closures in X, Y and H directions on WGS-84 ellipsoid to which GPS is referred.

VI. FIELD VERIFICATION

By using twice enlargement of 1/60,00 aerial photographhs, field verification was carried out.

Main items worked out are:

1. Classification of roads and identification of their attributes.
2. Identification of public buildings.
3. Collection of key for photo-interpretation of vegetation.
4. Verification of telephone lines, power lines, water pipe lines.
5. Verification of other ground features

LEVELING

Minor order leveling (tolerance 50 mm /S, where S is the route length) was carried out for about 240 km from Lunga-Lunga to Malindi along coastal main road (A14 and B8). dividing it into two routes:

Route number	Bench marks	Length
R 9	BM-1, R9-1,.....R9-25, LVI/30	50.9 km
	LVI/30, R9-26,....,R9-41, LVI/10	32.8 km
	LVI/8, R9-42,.....R9-48, FBM	14.0 km
R10	FBM, R10-1.....R10-10, LIX/77	21.0 km
	LIX/77, R10-11,..,R10-34, LIX/49	42.6 km
	LIX/49, R10-35,..,R10-56, S7-6	65.9 km
	Total	227.2 km

The routes are shown in Fig. 2.

Besides, check measurement among existing bench marks totaling 5.1 km (1.-a.) and measurement to give height for geodetic control points totaling 12.8 km (3.-a.) were executed.

The total length of leveling is 245.1 km.

The observation was made by double observations with automatic level Nikon AS, metal staves and staff stands.

1. Reference bench marks

There are some first order bench marks scattered along the routes (Fig. 2). Leveling was carried out passing through all these bench marks. When the closure among them was within the tolerance, the nominal values were accepted as given and they were regarded as starting and ending points.

a. Check measurement of the spans among LVI/8, LVI/9 and LVI/10 and between S7-5 and S7-6 were consistent one another. (Total length is 5.1 km) · LVI/8, LVI/10 and S7-6 were adopted as given points.

b. LIX/49, LIX/77, FBM and LVI/30 are isolated, but viewing from the result of leveling, their nominal values were taken as given. (Table in paragraph 3.)

c. Between R10-51 and R10-56 there are 10 existing bench marks. The check measurement among them, however, did not come within the tolerance. Consequently, they were regarded as unknown points and gave them new value.

2. Results

Closures between given points are,

Route number	Bench marks			Closure	Tolerance	S
R4+R9	I/38	-	LVI/30	80 mm	683 mm	186.7 km
R9	LVI/30	-	LVI/10	27 mm	286 mm	32.8 km
	LVI/8		FBM	15 mm	187 mm	14.0 km
R10	FBM	-	LIX/49	7 mm	399mm	63.6 km
	(FBM	-	LIX/77	68 mm	229 mm	21.0 km)
	(LIX/77	-	LIX/49	61 mm	326 mm	42.6 km)
	LIX/49	-	S7-6	27 mm	405 mm	65.9 km

Route R4 between I/38 and BM-1) was measured during Dec.. 1987. - Feb.. 1988.

3. Height control of geodetic control points

Some geodetic control points and bench marks were used for height control in geodetic control survey.

a. The height of 193S2, SKP62 and 196S4T4N was measured by direct leveling starting from R10-56, LIX/49 and R8-23, respectively. Closure of double measurements is as follows:

Route	Closure	Tolerance	S
R10-56 - 193S2	3 mm	115 mm	5.3 km
LIX/49 - SKP62	3 mm	52 mm	1.1 km
R8-23 - 196ST4N	11 mm	126 mm	6.4 km
		Total	12.8 km

b. I/21T, R-2 and BM-1T were used for height control in geodetic control survey. Their height was measured by direct leveling in reference to the nearest bench marks I/21, R2-16 and BM-1, respectively.

4. Cross-sea leveling

To cross over the Kilindini Harbour and Kilifi Creek, cross-sea leveling was executed at Likoni and Kilifi, respectively

Trigonometric leveling was applied by using two theodolites Wild T2 and an electro distance meter Wild DI-4. Cross-sea distances are 540 m and 470 m for Likoni and Kilifi, respectively. Observation triangle is shown schematically in Fig. 3, where

	LIKONI	KILIFI
D	540 m	470 m
A	R9-48	R10-34
B	R9-47A	R10-33A
C	R9-47B	R10-33B
Vertical closure	2 mm	4 mm

The distance between A and B is approximately 10 m for both cases. Their relative height was measured by direct leveling. The observation was checked by comparing two measurements AB and AC. The closures in the above table stand for the discrepancy between these two measurements.

5. Monumentation

Approximately every 2 km, marks were set up. The types are classified as follows:

		Number
1.	Rivet driven on the paved road	69
2.	Rivet driven on stable ground feature	14
3.	Rivet driven onto the side of the monument of the tertiary traverse point	15
4.	Permanent monument (including 6 for cross-sea leveling)	13
	Total	111

Fig. 1. Geodetic Control Survey

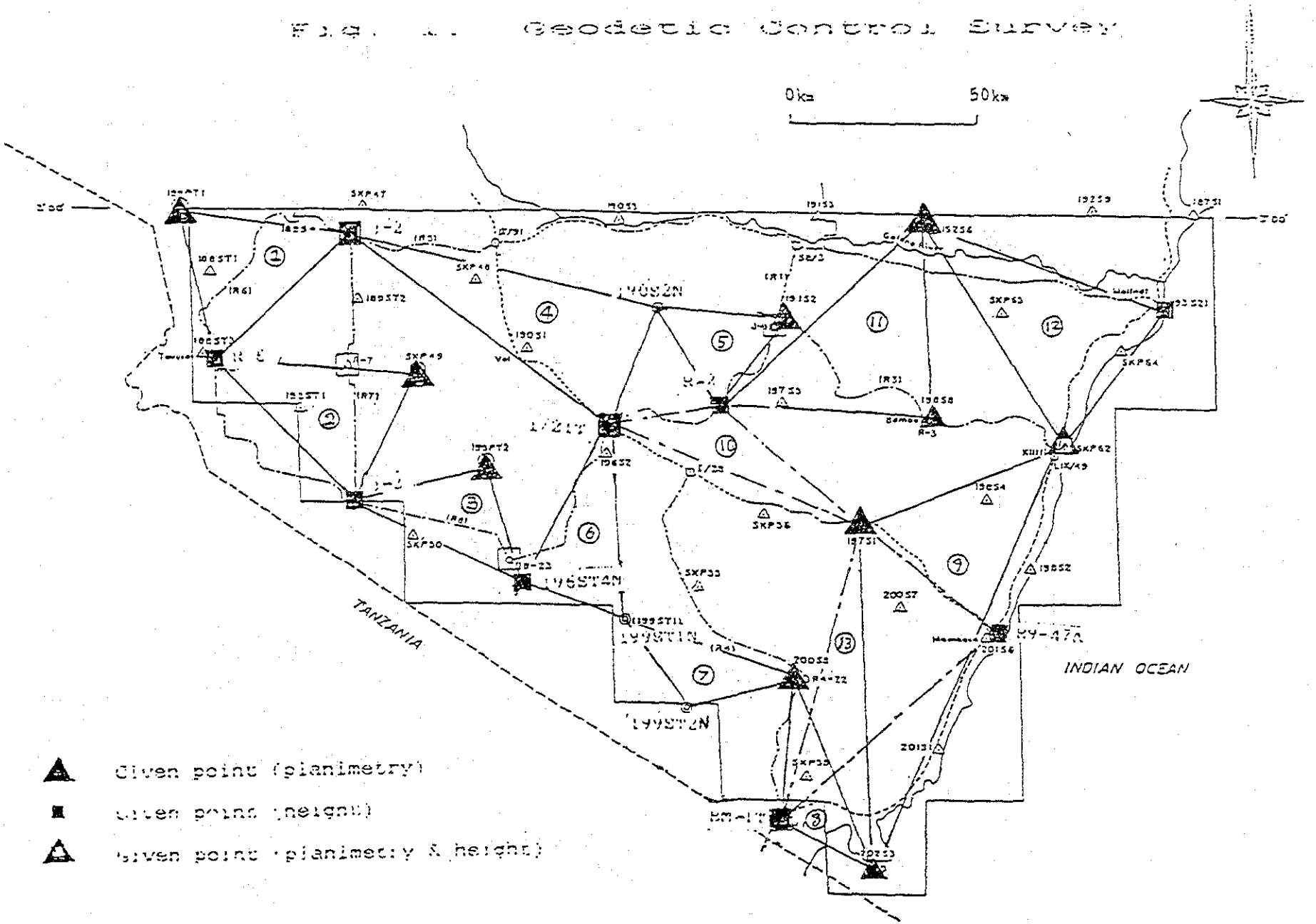


Fig. 2. Leveling

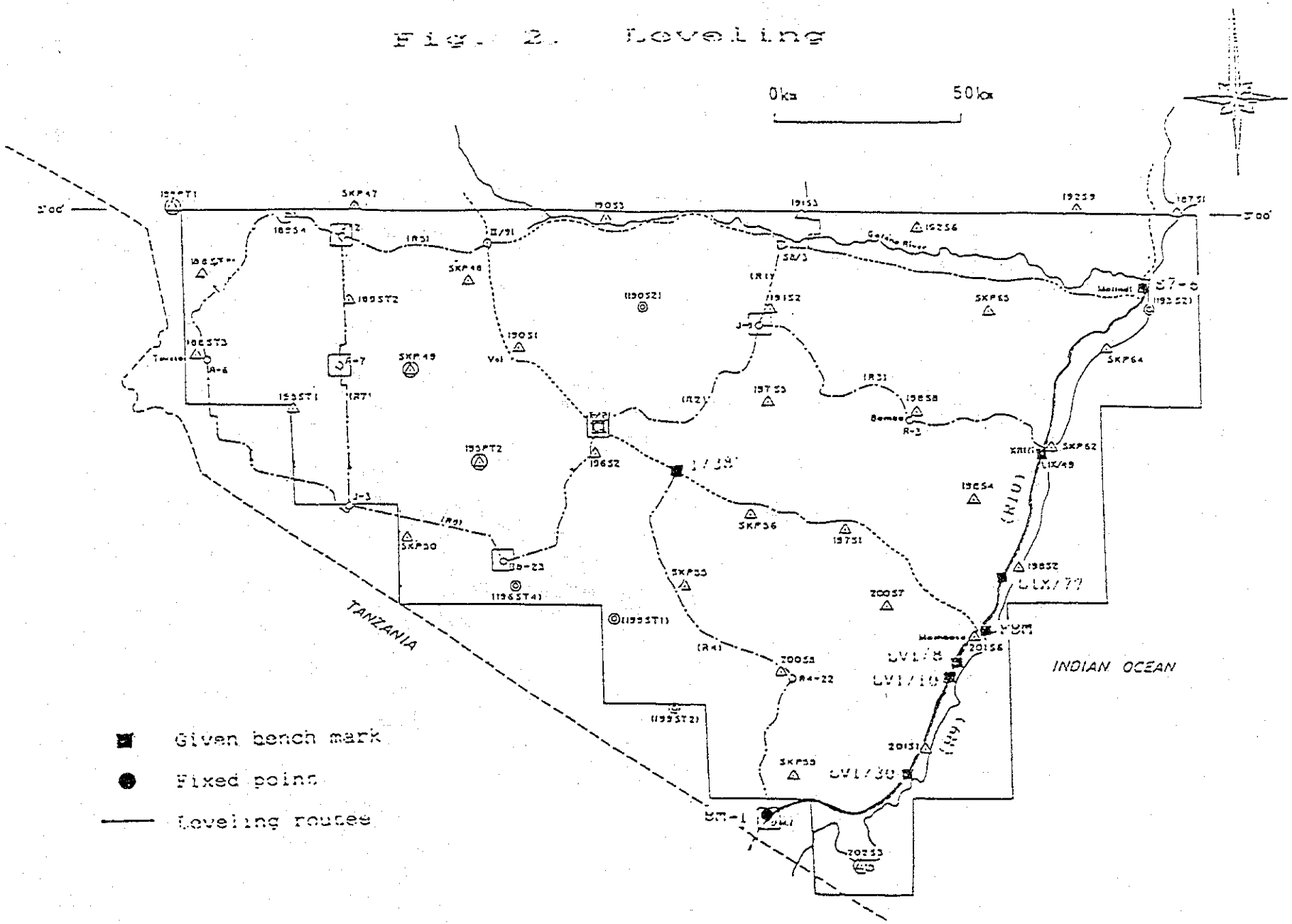


Fig. 3. Cross-Sea Leveling