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SOUTH EAST SULAWESI
TRANSMIGRATION AREA DEVELOPMENT
PROJECT . VOLUME 3

SOUTH EAST SULAWESI

TRANSMIGRATION AREA DEVELOPMENT PROJECT

3

IRRIGATION DEVELOPMENT

HUNTING TECHNICAL SERVICES LIMITED AND HUSZAR BRAMMAH AND ASSOCIATES
in association with Sir M MacDonald and Partners
FOR THE ASIAN DEVELOPMENT BANK AS EXECUTING AGENCY FOR U N D P AND
THE DIRECTORATE GENERAL OF TRANSMIGRATION GOVERNMENT OF INDONESIA

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Introduction 1

1.1 Background

The introduction of irrigation systems is relatively new to the archipelago of Indonesia. Generally, rainfall exceeds 1,500 mm and the natural vegetation combined with rainfed agriculture can support a substantial population. However, with the growth of population especially in Java and Bali, the pressure on land has increased. Rainfall is sometimes erratic, and 80 per cent of the annual total occurs over six months. Irrigation is required to grow more than one crop in a year and to increase crop yields.

The islands of Java and Bali were the first to attempt irrigated agriculture. The original form of irrigation was the diversion of water from small perennial springs. The irrigation works for this are simple and a small group of farmers can build them without any assistance from outside agencies or the Government.

The construction of larger irrigation schemes where major diversion structures and large scale canalisation are required did not start until about mid-nineteenth century, when these were built mainly for sugarcane estates. On the other islands irrigation systems came a little later. Most of the large irrigation works in Sulawesi (e.g. the Sadang Scheme) were started in the early 20 th century and work for completing them is still in progress.

There was no irrigation in South East Sulawesi until just before the Second World War. Small irrigation units built before the war and during the Japanese occupation have either been abandoned or rebuilt completely.

Most of the present irrigation units have either been constructed anew or built from an old base in the last 10 years, a major part of work being carried out in the current 5-year plan. Nearly all the schemes seem to have been poorly designed and constructed. Newly constructed weirs and canals have been either damaged by floods or abandoned for lack of adequate river draining works. In their present state most of the intakes are not capable of diverting water at low stages of flow. The existing schemes as well as those proposed for implementation in the near future need close examination and in most cases redesign and large scale remodelling would be required.

The South East Sulawesi Project has been instituted to assist the Government in preparing an overall outline plan for a period of 10 years for the development of the Study Area with particular reference to transmigration settlements. This volume contains recommendations for the improvement of irrigation facilities in the existing settlements and a development plan for a new irrigation area. Recommendations for further studies and surveys required during the second phase are also included.

1.2 The Study Area

The physiography, geology and soils of the study area are described in Chapter 2 of Volume 2. For the purposes of hydrological investigations, the loan Project Area can be divided up into two major catchment areas namely the Konaweha-Lahumbuti-Sampara river system and the Poleang river system and a number of minor catchments along the south east and the west coast. Severe soil erosion restricts the development of the Poleang river for irrigated agriculture. Within the Konaweha-Lahumbuti-Sampara river system the area surrounding Wawotobi and bordered by the Konaweha and Lahumbuti rivers has been indentified as the major area for new settlement development based on irrigated and rainfed agriculture. This is referred to as the Wawotobi Scheme.

The seventeen existing settlements are mainly situated in the central and southern part of the Study Area and range in size from villages of 43 to 1072 families. The areas presently under irrigated agriculture are small but there is potential for future development.

During this study several areas have been identified which could have potential for the development of irrigated agriculture. At present the data base for these areas is inadequate and further studies would be required to verify their potential. The gross area requiring investigation is some 150,000 ha. The main region is in the Solo river basin with smaller areas in the Lahumbuti river basin and around Ladongi. Recommendations regarding the irrigation aspects of these further studies are detailed later in Chapter 5 of this volume, while the agricultural aspects are detailed in Chapter 10 of Volume 2.

1.3 The approach

The scope of the study has been severely limited by the availability of topographic mapping and soil survey data. In effect, possibilities for new irrigation areas has been limited to the Konaweha river basin and the Wawotobi Scheme is the main component of the proposals. The irrigation of some 9,210 ha is proposed from the Konaweha river.

The Konaweha river with a catchment area of 3,600 km^2 is a substantial source of water. However, in the alluvial plains it is very unstable. There is evidence that the river has moved extensively across the plains and the entire basin is covered with large meander channels and oxbox lakes. Along the present course of the river there are numerous meander loops left by the river in the recent past.

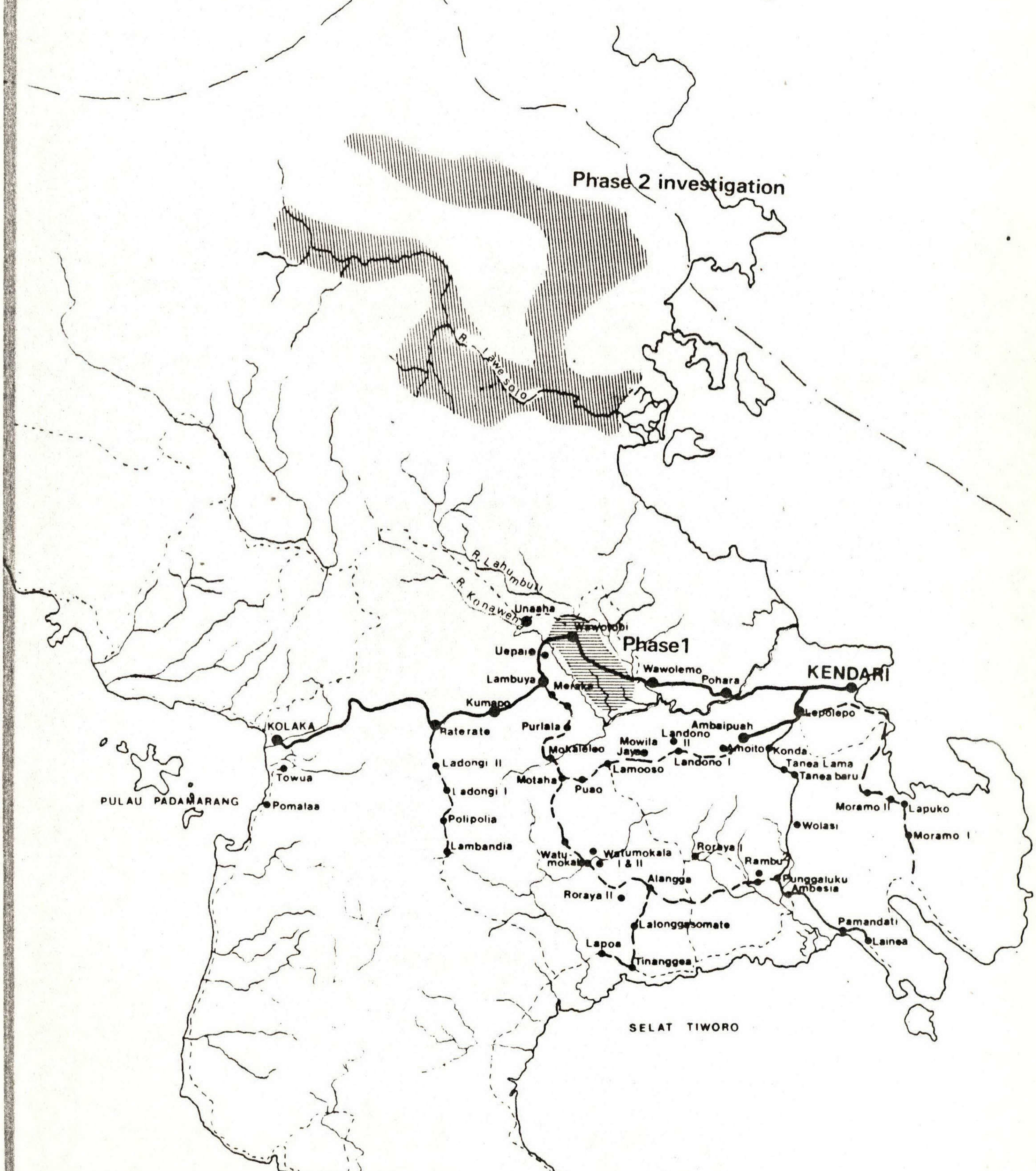
The river channel is shallow (about 50 m wide and 5 m deep) with gravel and coarse sand in the bed in upper reaches (upstream of Teteone). There is no data about river water levels or discharges. Nevertheless, it has been established that in floods the river overspills its banks and inundates a large area.

The Wawotobi alluvial plain between the Konaweha and Lahumbuti rivers offers good potential for irrigation from the Konaweha. However, the uneven and broken topography combined with the unstable nature of the river presents many engineering problems.

The planning of an irrigation system requires considerably more data than are presently available. The topographic maps on 1:5,000 scale, aerial photo mosaics and soils data are available but no hydrometric data of any kind has been collected. The available time did not permit check surveys or river gauging over a sufficient length of time. Under these conditions some theoretical and often approximate methods had to be used for evaluating the river flows, catchment yields, water requirements, etc. In the absence of site surveys and with unknown foundation conditions, the intake site has been selected from an assessment of surface geology only.

Although the ground level contours given on 1:5,000 survey maps have been accepted for planning purposes at this stage, we think that extensive check surveys will be required before they can be used with full confidence. For some parts of the area the contours are not consistent with aerial photo interpretations.

1.1 The Project Area



By using bench marks established during the levelling surveys, an attempt was made to establish the water profile of the Konaweha river. This profile has been used as a basis for determining command levels in the proposed irrigation system and flood levels for designing the flood protection embankment, flood peaks being calculated, theoretically.

In view of the weaknesses pointed out here, the first task proposed in the subsequent phase for the Wawotobi Scheme is to confirm assumptions upon which this initial design is based. The proposed approach is discussed in Chapter 3.

What can be said at this stage with confidence is that the Scheme is technically feasible, but a relatively high price will have to be paid for the resettlement of 5,654 transmigrant families, and for providing irrigated land for 3,192 farming families already settled in the area.The resulting return on investment, and its comparison with that of an alternative rainfed scheme is discussed in the feasibility study in Volume 5, where the relative advantages and disadvantages of the two main alternatives will also be considered in a wider socio-political context. The alternative agricultural development programmes for the irrigated and rainfed schemes in the Wawotobi Project Area are discussed in Chapter 7 of Volume 2.

In examining irrigation works in the existing settlements the main points of interests were:
water availability
the condition of irrigation works,
the stage of development of minor consideration,
flooding and drainage problems,
scope for further extension.

Irrigation data were not available for existing schemes either. Our observations had to be based on theoretical estimates of water availability combined with some spot measurements. The comments on the condition of canalisation are based on field inspections.

The present settlements are of two types, as far as the irrigation works are concerned. There are smaller ones with an independent irrigation system which could be studied relatively easily, identifying the major problems. However, the study of settlements which lie within the command of the larger irrigation schemes was more complicated. Such irrigation schemes are generally surveyed and designed by the Directorate General of Irrigation and the construction is supervised by the Provincial office of the Directorate General of Irrigation.
A considerable amount of time was spent on trying to collect design drawings and calculations for such schemes. The information that could be obtained (i.e. generalised layout maps and contour sheets) was not adequate to comment constructively on the designs.

In the subsequent phase it is therefore important that check surveys are undertaken to confirm the accuracy of contours and an examination made of as-built canalisation. It is to be expected that a considerable amount of remodelling and major modifications will be required. Redesigning of at least those works which will affect the resettlement areas will form an important part of the project. The proposed programme is given in Chapter 4.

Hydrology 2

2.1 Introduction

The Study Area is almost totally devoid of hydrometric data. Reliable rainfall records are available only for four stations, and these are not sufficient to prepare on isohyetal map. Some field measurements and estimates of river flow were obtained during the surveys, but information on flow regimes must depend heavily on synthetic calculations.

2.2 Rainfall

The rainfall records for Rate Rate and Tobea Besar were found inconsistent when they were checked for accuracy. This has left only four rainfall records available for analysis. Of these, Kendari and Wawotobi lie within or near the Konaweha basin; Mowewe is a short distance outside the south west part of the watershed, and Kolaka is some 20 km from the watershed, on the western side of the penisula.

The records are of variable length, and at Mowewe and Wawotobi have poor continuity. Kendari has the longest record, observations having commenced in 1908. Kolaka and Mowewe records commence in 1927, and those for Wawotobi in 1936. All records are complete up to the end of 1941. Observations were re-commenced in 1947, but in the cases of Mowewe and Wawotobi the records from 1947–1960 are very intermittent. No observations after 1961 were available at the time of writing this report. The following are the lengths of complete year records used in establishing mean annual rainfall, probabilities of annual rainfall, and average distribution of rainfall days.

Kendari	50 years
Kolaka	28 years
Mowewe	20 years
Wawotobi	11 years

Table 2.1 Probability of annual rainfall, mm

	DRY Return period yrs				WET Return period yrs		
Station	1 in 20	1 in 10	1 in 5	Mean	1 in 5	1 in 10	1 in 20
Kendari	1055	1175	1345	1768	2190	2490	2750
Kolaka	1220	1320	1455	1795	2125	2350	2550
Mowewe	1330	1425	1550	1815	2105	2290	2440
Wawotobi	–	–	–	1702	–	–	–

Source : SESP

Wawotobi, because of its limited records, was not used for a probability analysis. Summary statistics are given in Table 2.1. The probability data was obtained by plotting logarithmically. The mean in the above table is the arithmetic mean, not the 50 per cent value, although the two values are in all cases very close. There is very little variation in mean rainfall at the stations, but the coastal stations illustrate a greater range of variability.

2.2.2 Monthly distribution

Tables 2.2 and 2.3 summarise mean monthly rainfalls and average number of rain days per month. Note that in Table 2.2 the sum of the monthly means does not necessarily equal the mean value given in Table 2.1, as for the former, all available months of record were used, whether they were contained in a complete year or not.

Table 2.2 Mean monthly rainfall, mm

Station	J	F	M	A	M	J	J	A	S	O	N	D
Kendari	207	194	223	192	214	209	152	87	71	43	86	172
Kolaka	196	157	191	202	235	168	128	85	91	84	128	141
Mowewe	150	159	175	208	284	225	174	111	131	93	120	82
Wawotobi	148	138	169	153	261	217	212	135	124	67	74	122

Source : SESP

Table 2.3 Average number of rain days per month

Station	J	F	M	A	M	J	J	A	S	O	N	D
Kendari	14	13	14	13	14	14	10	7	6	4	7	13
Kolaka	12	11	13	12	14	22	10	7	7	6	8	11
Mowewe	13	11	14	14	17	15	12	9	6	6	9	9
Wawotobi	13	12	14	12	17	41	14	10	8	6	7	11

Source : SESP

Figure 2.1 give the mean monthly rainfall at the four stations.

2.2.3 Seasonal variations

Rainfall occurs all the year round, although a clearly marked drier period exists from August to November inclusive, however, in the interior it would appear that the season is shorter. The wetter period of the year is fairly uniform from January to June, although a wetter period is more marked in May and June at Wawotobi and Mowewe. Nil rainfalls occur on a few occasions in August, September and October at all stations, and in dry years drought conditions can prevail in these months.

In wetter years these months can however receive high totals (200 mm or more); so, conditions are very variable. Variability over the wetter months of the year is considerably less – Table 2.4 summarises the monthly rainfall probabilities at Kolaka and Mowewe, the two stations closest to the Project Area. Briefer inspection of the Kendari record indicates a similar range of conditions. The table illustrates from the minimum recorded rainfalls that in exceptional years the dry season could start as early as June or extend into December.

However, during the period of records there is no drought that extends over all these months. Defining a drought month as one whose rainfall is less than the 1 in 5 years dryness level, in the 24 years of records available from Mowewe, there are only 3 years in which drought conditions extend over more than two months. The longest dry spell was from July to October inclusive in 1941. Total rainfall over the 4 month period was 65 mm.

2.1 Mean monthly rainfalls

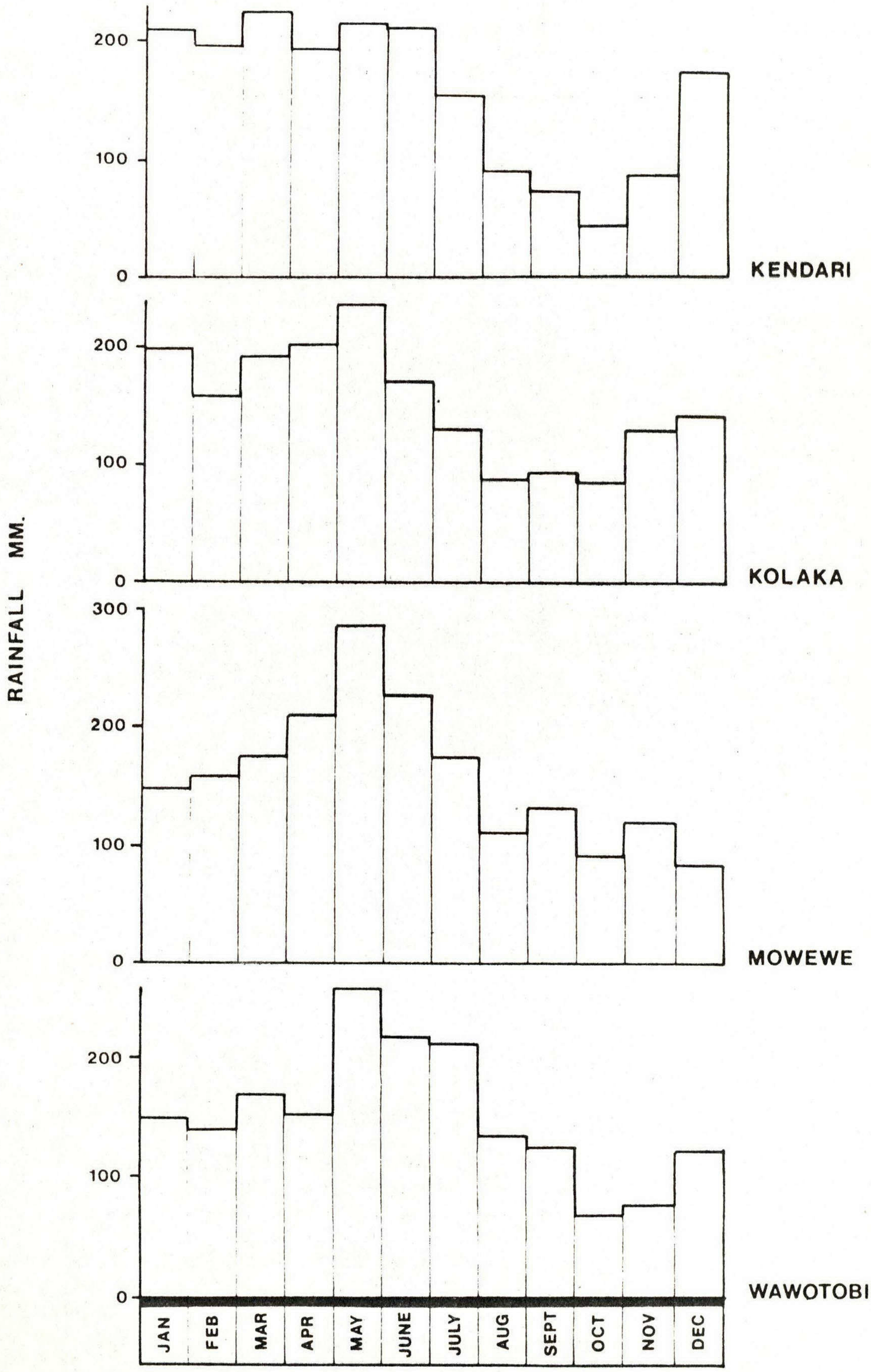


Table 2.4 Monthly rainfall summary statistics

KOLAKA

Month	Minimum	1 in 5 yr dry	Median	1 in 5 yr wet	Maximum
January	17	142	188	249	502
February	37	95	170	234	240
March	97	108	174	280	399
April	28	124	192	296	371
May	124	154	222	322	406
June	44	95	154	248	306
July	5	77	124	200	286
August	2	35	71	143	222
September	11	39	79	156	252
October	0	33	70	147	257
November	6	51	103	207	350
December	14	76	124	200	332

MOWEWE

Month	Minimum	1 in 5 yr dry	Median	1 in 5 yr wet	Maximum
January	69	110	151	205	257
February	52	99	148	220	361
March	20	94	159	267	414
April	88	136	208	320	452
May	82	181	269	400	495
June	70	118	191	310	552
July	7	101	160	252	335
August	3	41	85	177	313
September	0	37	82	180	330
October	0	43	82	157	223
November	13	67	109	178	351
December	36	51	79	122	145

Source : SESP

2.3 River flows

2.3.1 Konaweha catchment fields

In the absence of any flow gauging or water level records, estimates of river flow have been derived from known conditions in similar environments in Indonesia. A twenty year record of mean monthly flows at selected stations on the Brantas River[1] was used to establish monthly patterns of discharge. These figures, expressed as discharge per unit area, were transposed to the study catchment in Sulawesi. The maximum proportional run-off for the wettest month was evaluated for Konaweha catchment, and this was expressed as a percentage run-off by dividing by the mean monthly rainfall. The low point of the

[1] Report on the Brantas Development Plan. Rep. of Indonesia, Directorate General of Water Resources Development, May 1973.

range is known locally from estimates of the dry weather flow of the Konaweha being 30 m^3/s. The curve of the Brantas conditions was then fitted to this range, allowing for the different time of occurence of the wet and dry seasons. Mean monthly flow estimates for the Konaweha River at Wawotobi Bridge are given in Table 2.5 and Figure 2.2 based on run-off percentages and mean monthly rainfall taken from the four stations in Table 2.2.

Table 2.5 Estimates of mean monthly flow, (m^3/s) Konaweha River, Wawotobi

	J	F	M	A	M	J	J	A	S	O	N	D
Run–off factor	·39	·48	·55	·58	·60	·53	·47	·41	·37	·32	·30	·32
Mean flow m^3/s	92	105	140	147	200	146	105	58	52	31	41	56

Source : SESP

2.3.2 Catchment fields for smaller streams

Run-off factors for streams with a catchment area less than 25 m^2 would be as given below

	J	F	M	A	M	J	J	A	S	O	N	D
Run-off factor	0.4	0.5	0.6	0.7	0.5	0.4	0.3	0.3	0.2	0.1	0.2	0.3

2.4 Floods

In the absence of any river flow or water level records[1] the estimates of floods must be derived indirectly from rainfall probabilities and a synthetic flood model.

The annual maximum daily rainfalls from Kolaka, Kendari and Mowewe were ranked and plotted on Gumbel Extreme distribution paper. Summary results for various return periods are given in Table 2.6.

Table 2.6 Probabilities of annual maximum rainfalls (mm)

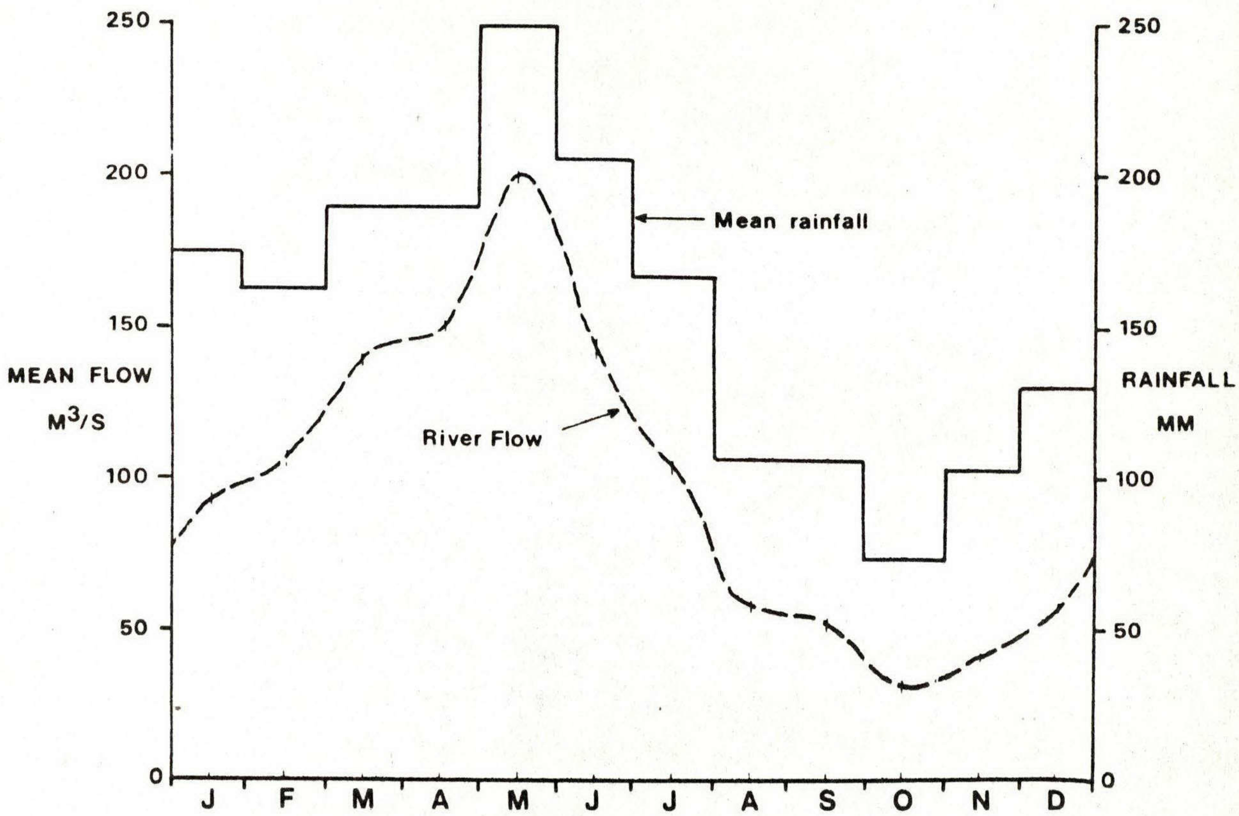
		Return period years		
Station	Mean	Mean	1 in 20	1 in 50
Kendari		103	182	212
Kolaka		96	162	187
Mowewe		83	126	143

Source : SESP

The relationship between the stations would appear to be the converse of that observed for mean annual and mean monthly falls, where the east coast falls (Kendari) are less than the west coast ones (Kolaka) the latter figure is again smaller than that for the interior (Mowewe). The occurence of the annual maximum daily rainfall is predominantly confined to the wet season, giving the optimum conditions for flood generation, as intense storms will be falling on near-saturated catchments.

[1] South East Sulawesi Transmigration Area Development Project, Interim Report, September 1976.

2.2 Mean monthly rainfall and riverflow of the Konaweha river at Wawotobi bridge



The selection of an appropriate flood model is notoriously difficult. Both the empirical and conceptual approaches are based on experience and conditions in temperate areas. Models for un-gauged watersheds are also largely based on small catchments either for agricultural purposes or drainage design. The model selected for this study is based on extensive studies in East Africa[1]. The model can be applied to upland and forested or jungle catchments, subjected to intensive tropical rainstorms, and is therefore very suitable for the Konawaha catchment. It is however primarily intended for much smaller catchments, but careful choice of parameters should result in a reasonable guideline to flood volume to be expected.

The model requires the input of catchment characteristics, i.e. length, area, mean river slope, and of indices representing catchment morphology and vegetation, and a design rainfall. The rainfall inputs were those of the three return periods given in Table 2.6; the return period of 1:2.33 years is the statistical equivalent of the mean annual flood. Actual values for Kolaka were used rather than means for the three stations, as the former are approximately in the middle of the range of values obtained, and also producing the most accurate extreme probability plot.

In such a large catchment (3,600 km^2), two major problems arise over the estimation of catchment mean rainfall and the attenuation of a flood peak during a long passage down the river. The nature of heavy tropical rainfall, being of short duration, and limited areal extent, the situation where a single storm affects the whole catchment simultaneously probably never arises. It is impossible to make meaningful assumptions on depth – area – frequency relationships, so a suitably severe areal reduction

[1] The TRRL East Africa Flood Model, D. Fiddes. Transport and Road Research Laboratory, Report 706, 1976.

2.3 Theoretical stage discharge relationship for the Konaweha river at Wawotobi bridge

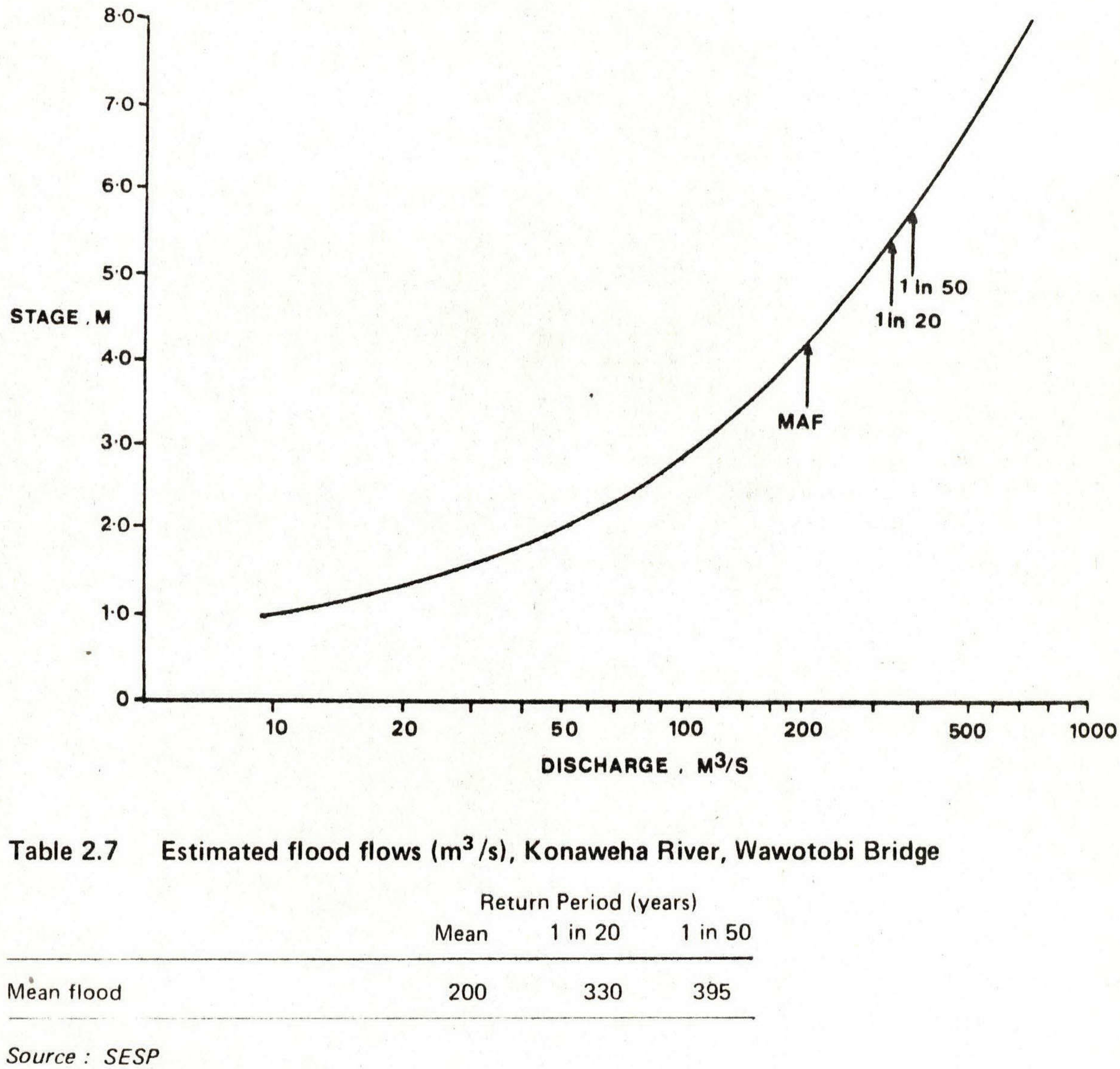


Table 2.7 Estimated flood flows (m^3/s), Konaweha River, Wawotobi Bridge

	Return Period (years)		
	Mean	1 in 20	1 in 50
Mean flood	200	330	395

Source : SESP

factor must be chosen. Based on a formula used for tropical rainfall conditions in East Africa[1], a factor for the size of areas under study of 58 per cent was calculated. The method of flood estimation produces an estimate of mean flood discharge, from which a peak flow is estimated by a generally applicable factor, dependent upon catchment area. Because the area under consideration is much greater than those used in the derivation of the method which gives $Q\ max/Q = 2.3$ for catchments with a lag greater than 1 hour, the peak flow factor was taken from results of studies in a similar catchment in Papua, New Guinea[2]. Here the wet season hydrograph was observed to have very little range between mean and peak flows, flood peaks being very attenuated. A relationship between Q max and Q of 1.5 appears usual, and is taken as applicable to the Konaweha catchment. Results of calculation of flood peaks at Wawotobi Bridge are given in Table 2.7, and Figure 2.3 gives the stage-discharge relationship.

1 The prediction of Storm Rainfall in East Africa. D. Fiddes, J.A.Forsgate and A.O. Grigg. Transport and Road Research Laboratory Report 623, 1974.

2 Flood characteristics of the Ramu river, New Guinea. E.M. Laurenson, Proc. Second Int. Symp. in Hydrology, Fort Collins, Colorado 1972.

APPENDIX I

Specimen calculation of flood flow

Location	:	Konaweha River, Wawotobi Bridge
Catchment area (A)	:	3600 km^2
Length of river (L)	:	150 km (from "Hydrological Map", Scale 1 : 250,000)
Approximate river slope (S)	:	0.5%
Return period of flood	:	1 in 2.33 years (mean annual flood)
Rainfall (Kolaka)	:	96 mm
Areal reduction factor	:	ARF = 1 – 0.044 X $A^{\cdot 275}$ = 58%
Contributing area (CA)	:	CA = $C_s \cdot C_w \cdot C_l$

Where C_s = standard contributing factor based on topography and drainage type = 0.4
C_w = wetness co-efficient, for wet season field capacity conditions = 1.0
C_l = land use factor, forest & swamp, 0,33
∴ CA = 0.4 X 1.0 X 0.33 = 0.132

T_P = Typical storm profile peak time = 2 hours
K = Typical catchment lag time for forest & dense valley bottoms = 8 hours
First approximation for hydrograph base time:

$$T_B = T_P + 2.3 \times K + T_A \qquad (1)$$

T_A is attenuation time, and is assumed 0 at the first case

∴ T_B = 2 + 2.3 X 8 = 20.4 hours

Effective rainfall (P) = 96 X 0.58 = 56 mm

This is for a 24 hour rainfall total, which is adjusted to T_B by:

$$R_B = \frac{T_B}{24} \times \frac{24.33}{T_B + 0.33} \times P \qquad (2)$$

In this case R_B = 54.5 mm

Using two formulae, a first approximation of mean flood flow is obtained

$$\text{Run-off (Ro)} = CA \times R_B \times 3600 \times 10^3 \qquad (3)$$

$$\text{Mean flow (Q)} = \frac{0.93 \times Ro}{3600 \times T_B} \qquad (4)$$

This evaluates to 328 m^3/s

But attenuation time (T_A) is not allowed for:

$$T_A = \frac{0.028 \times L}{Q^{1/4} \times S^{1/3}} = \frac{0.028 \times 150}{328^{1/4} \times 0.005^{1/3}} = 14 \text{ hours}$$

Substitute value of T_A into equation (1) to obtain second approximation of T_B

T_B = 2 + 2.3 X 8 + 14 = 34 hours

A new value of R_B must now be calculated using new value of T_B in equation (2)

R_B becomes 59.2 mm

From equation (3) and (4) a new Q value of 214 m^2/s is obtained

A further estimate of T_A is made using the new value of Q. This gives T_A = 15.5 hours, and a T_B value of 36 hours. This is sufficiently close to the previous approximation to be regarded as correct.

Using T_B of 36 hours R_B is calculated as 59.7 mm

This is evaluated to a Q value of **204 m^3/s**

As referred to in text, a peak flow factor of Q_{max} = 1.5 Q was chosen

Hence peak flood flow = **306 m^3/s**

Wawotobi Irrigation Project

3

3.1 The Project Area

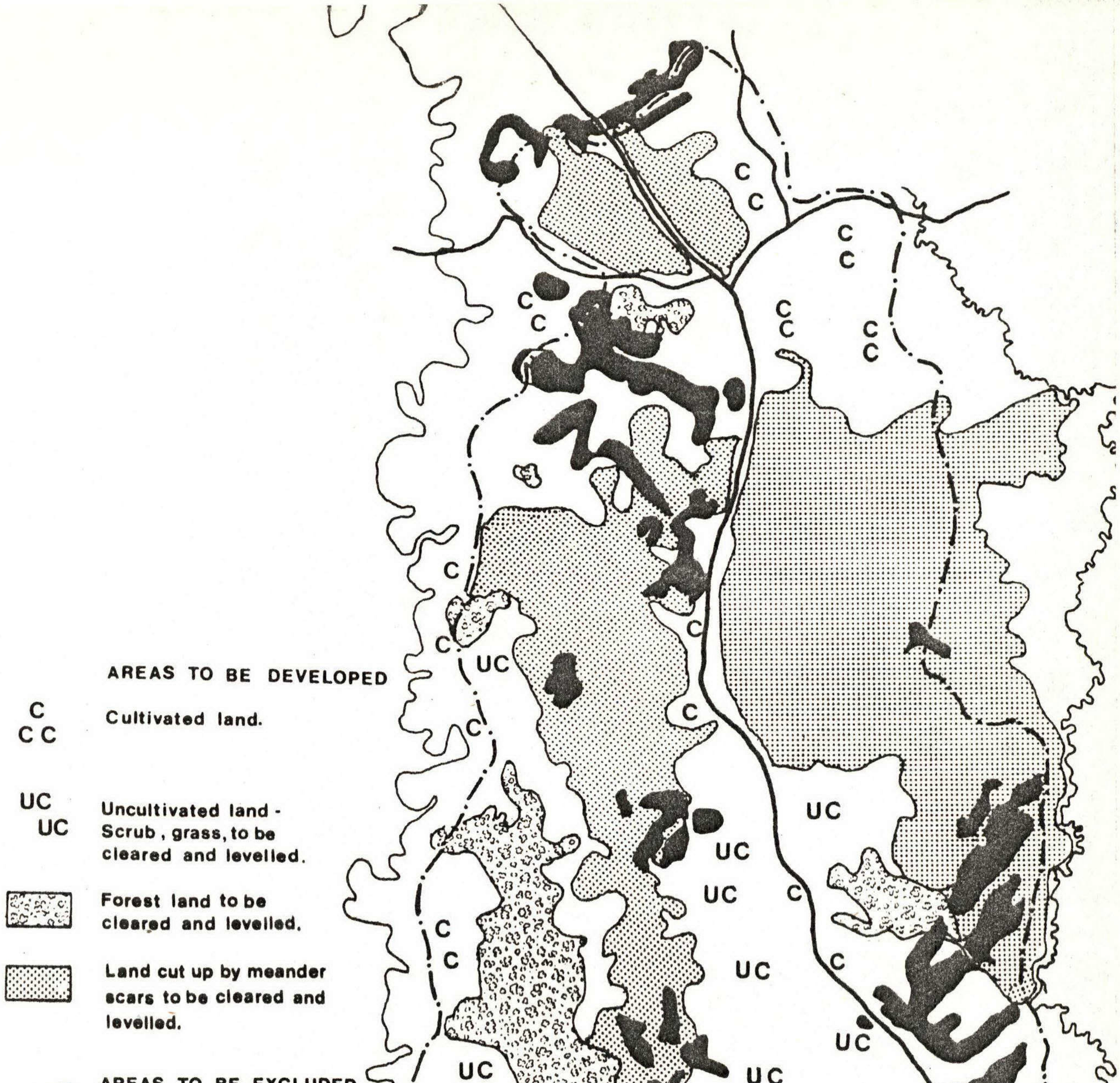
The Project Area is located on the main Kendari-Kolaka road from Wawotobi to the south east. To the north east it is bounded by the Lahambuti river and to the south west and south east by the Konaweha river.

3.1.1 Physiography

The Project Area is essentially a meander flood-plain sloping gently from north west to south east. The Angkadola river drains the area to the south of the main road and its upper reaches constitute an intricate mass of meander scars and oxbow lakes. To the north of the road the arca is severely cut up by old channels of the unstable Lahumbuti river. The southern boundary comprises swamps and peaty soils. The essential features are shown on Figure 3.1 and full details are given in Chapter 2, Volume 2.

3.1.2 Land development

The constraints to development of land are described in detail in Chapter 7, Volume 2. Areas to be excluded from development are swamps, peaty soils, deep meander scars and out-of-command land. The latter areas will however be used for villages or rainfed cropping. Areas for development include forests, scrubland and land which is cut up by old meanders and oxbow lakes. These areas, particularly the forests will require substantial clearing and then levelling into terraces. In the old meander areas, deeply incised land will not be possible to drain, and the intensity of meander scars will affect the density of canals and terraces. The areas of land to be developed are shown in Table 3.1. The location of these areas within each canal command is shown in Table 3.3 and further detailed in Chapter 4, Volume 4.



3.1 Constraints on irrigation development

Table 3.1 Land development

Gross area		14,010 ha
Excluded from irrigation		
Out of command	1,220 ha	
Presently occupied	1,370 ha	
Meanders etc	273 ha	
Proposed road & canals	704 ha	
For dry cropping and villages	1,233 ha	
Total	4,800 ha	
Net irrigation area		9,210 ha

Source: SESP

3.2 General description

3.2.1 Layout

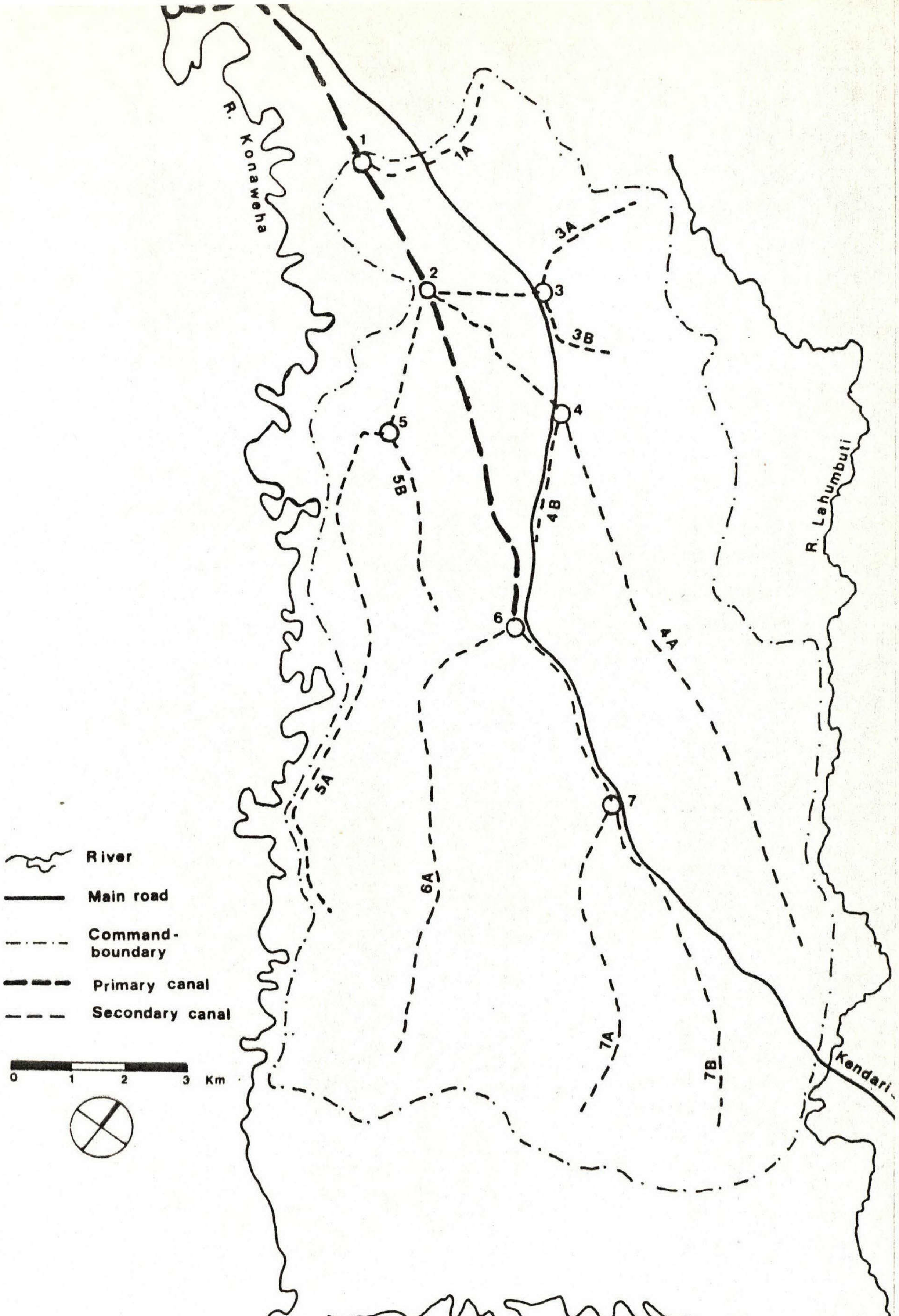
The preliminary layout of irrigation, drainage and flood control works is shown in Figures 3.2 and 3.3. The alignment of canals and location of drainage lines is based on the 1:5,000 contour sheets produced by PT Indah Karya for the Directorate of Irrigation, Ministry of Public Works. The accuracy of these contours and spot levels cannot be guaranteed and when detailed ground surveys have been carried out changes in the alignment and arrangement of channels may be necessary.

The irrigation intake is located on the Konaweha river, some 9 km west of Wawotobi town. The primary canal runs through the central part of the area, approximately following the general direction of the main road, with the secondary canals irrigating to the north east and to the south. The existing waterways can be improved to provide adequate drainage, and flood embankments will be required on the north and western boundaries.

Table 3.2 Estimated irrigation areas

	ha	percent of gross
Gross area	14,010	100
Out of command areas: land that is too high for gravity irrigation	1,220	9
Occupied or under meander scars and oxbow lakes: land unsuitable for development	1,643	12
Homesteads, roads & channels: land that will not be available for field crops	704	5
Land which could be irrigated but is required for dry crops and villages (includes some meanders, etc.)	1,233	9
Total excluded from irrigation	4,800	35
Net irrigable area	9,210	65

Source: SESP



3.2 Proposed irrigation network

The area deducted for homesteads does not include future settlements. In general, new villages will be located on the out of command lands or adjacent lands outside the irrigation boundary, but where these are unsuitable or insufficient some further reduction at the irrigable area may be necessary.

It should be stressed that as these areas are based on the 1:5,000 sheets the figures must be considered only approximate. It has therefore been necessary to ensure that the results are conservative rather than optimistic.

Table 3.3 and Figure 3.4 show the irrigable areas by canal units. The gross area has been obtained by planimetering from the 1:5,000 contour sheets.

3.2.2 Canal capacities

The future cropping patterns and crop water requirements are discussed in Chapter 3 of Volume 2. The canal capacities are based on the requirement for a rice intensive pattern. For the purpose of outline designs the following have been adopted:

	l/s/ha
requirement at tertiary head	1.50
requirement at secondary head	1.75
requirement at primary head	2.00

Figure 3.4 shows the resulting design discharges at the controlling points of the system. Canal sections and slopes are based on these figures; however, sufficient freeboard would be provided for passing overloads of up to 25 per cent. Again, it must be pointed out that these are provisional discharges, which are liable to adjustment at the detailed design stage. For the drainage systems a design discharge of 4.0 litres per second per hectare has been used.

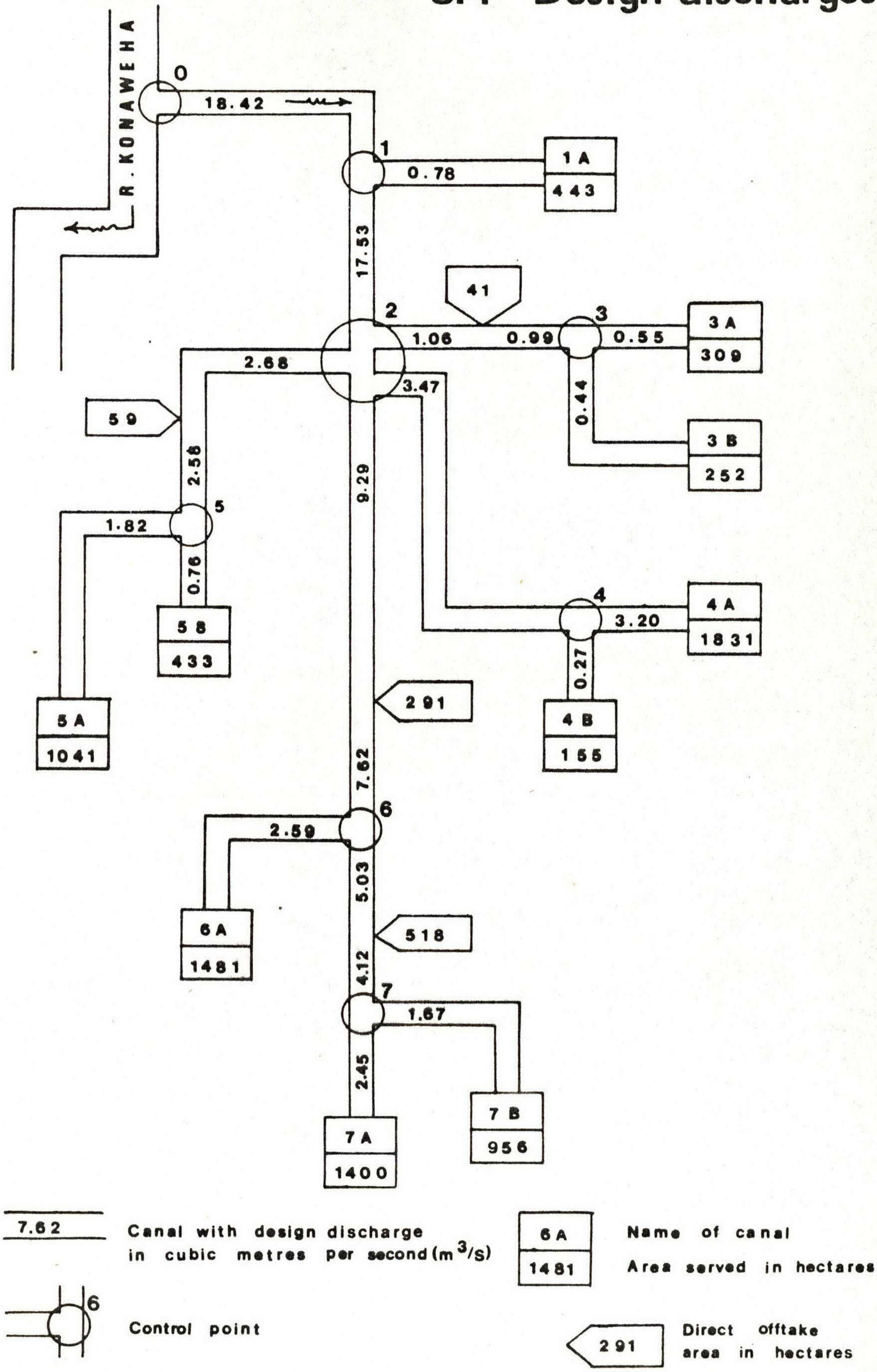
3.3 The intake

In the flood plains, the Konaweha river has meandered extensively. The whole length of the river between the bridge near Latoma and the gorge downstream of the Lahumbuti confluence is unstable. Any permanent structure placed in this reach could at any time be abandoned or eroded by the river.

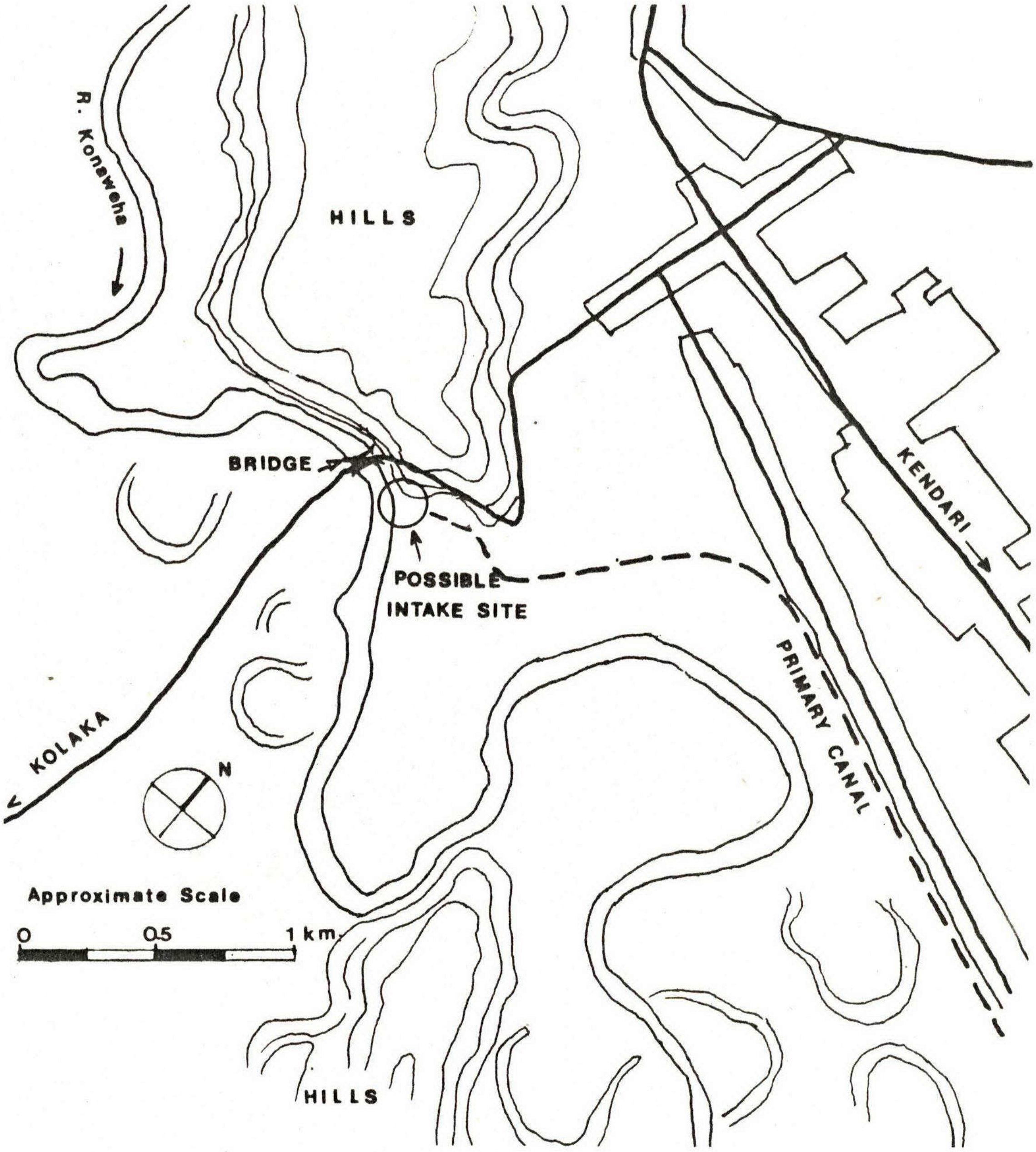
A possible site for the intake is immediately downstream of the bridge and near the toe of the hills on the left bank (see Figure 3.5). With another outcrop about 500 m downstream on the right bank this section of the river is relatively stable. There is no lithological information but the outcrops in the vicinity suggest that rock can be encountered fairly close to the surface. This will mean a substantial saving in the cost of the intake structure.

Even though it means that some areas near the intake will not be commanded no attempt has been made to raise the river water level by constructing a barrage or a diversion weir across the river. Such a structure will be extremely expensive and may cause the river to move in a big loop round the rock outcrop on the right bank. The lowest river level for command purposes has been assumed to be 46.50 m, some 0.50 m below the minimum level below the minimum level observed in the 1976 dry season. The elevation is referred to the benchmark value on the road bridge, which according to local authorities is part of the benchmark network used for the topographical survey of the Konaweha left bank. Examination of the contour sheet spot levels indicates that the levels at the intake site are reasonably consistent with those on the contour sheets. However, confirmatory surveys from the intake site and re-surveys of the command area must be carried out to firmly establish the intake location and arrangements.

3.4 Design discharges



3.5 The intake site



The nature of sediment transported by the river is not known. At the time of survey the river was flowing at a low stage and the sediment load was very small. However, it has to be accepted that at high flow stages there would be sediment in suspension.

It is proposed that the intake structure should be set back slightly from the river bank to enable a smooth streamlined approach. This arrangement may not be very suitable for silt exclusion, but interference with the main river stream must be avoided.

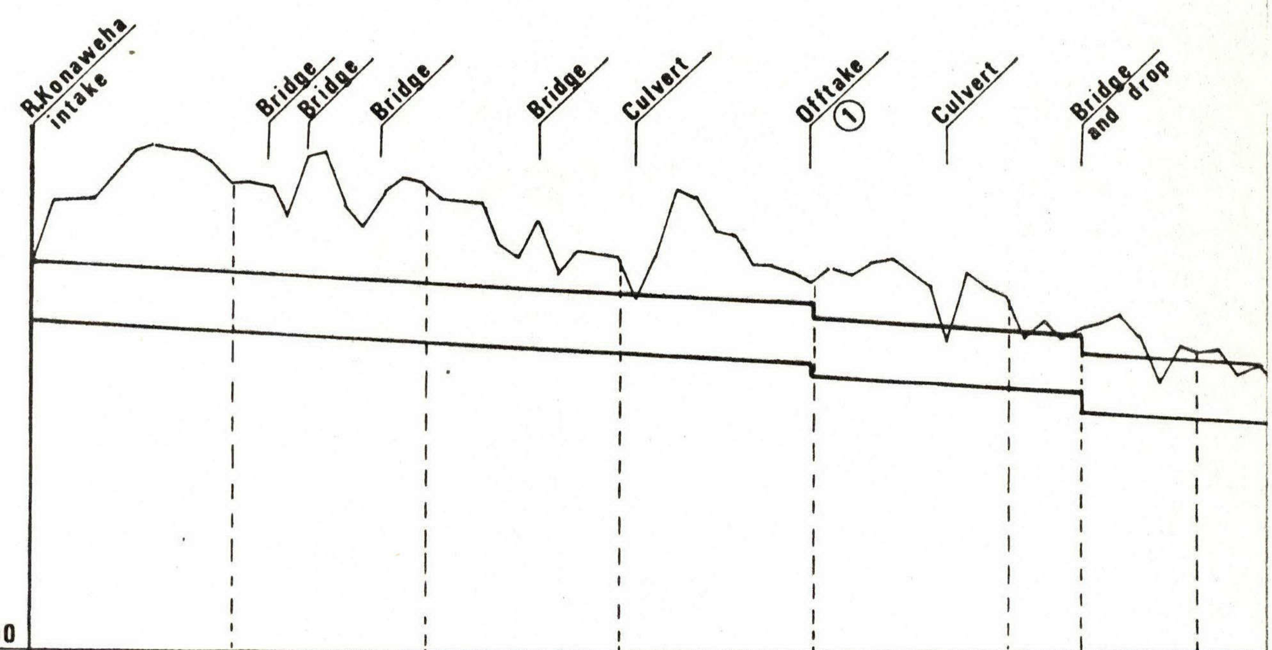
The variations in the stages of peak flow and base flow at the intake site are of the order of 5 metres. Moveable weir gates with no fluming at the structure should be suitable. These will ensure minimum loss of head at low stages and partial silt exclusion at high stages of flow.

Before river protection and intake structure designs are undertaken, the following field work would be required:

- a Confirmatory levelling to commanded area.
- b Stream gauging. An automatic level recorder should be installed at the bridge as soon as possible and current meter measurements carried out at weekly intervals.
- c Sediment sampling at monthly intervals.
- d River survey covering about 1 km upstream and 1 km downstream of the bridge with cross sections at 200 m apart.
- e Site survey of the intake site covering both rock outcrops and meanders in a radius of about 500 m from the site.
- f Lithological survey consisting of about 8 bore holes up to the bedrock, if rock is not encountered up to a depth of about 50 m.

Items *a, b* and *c* should be started now and the remaining should be carried out under the supervision of the designers.

3.6 Primary canal long section



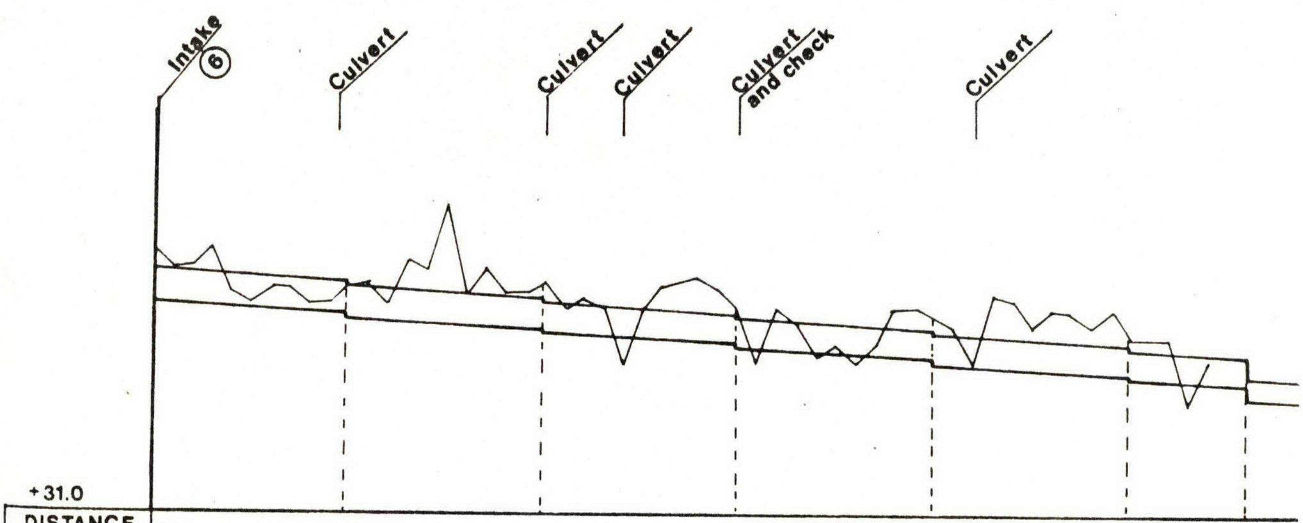
DISTANCE Km	0.0	1.0	2.0	3.0	4.0		5.0	5.4		6.0
GROUND LEVEL	47.0	48.5	48.1	45.8	45.9		44.6	44.5		44.0
WATER LEVEL	46.3	46.1	45.8	45.5	45.3	44.9	44.6	44.5	43.9	43.7
BED LEVEL	44.7	44.5	44.2	43.9	43.6	43.3	43.0	42.9	42.3	42.1
DESIGN DATA	Q = 18.42 M^3/SEC			S = 0.00025		Q = 17.53 M^3/SEC				S = 0.00025

Table 3.3 Areas irrigated from each canal command

Canal command	Gross area	Out of command	Presently occupied	Excluded from irrigation: Meanders etc.	Proposed canals & roads	For dry cropping or villages	Total excluded	Net irrigation area
1 A	990	60	320	19	50	98	547	443
2–3	260	30	140	8	13	28	219	41
3 A	500	–	110	–	25	56	191	309
3 B	330	10	20	3	17	28	78	252
4 A	2610	260	20	97	131	271	779	1831
4 B	350	20	120	9	18	28	195	155
2–5	350	150	80	15	18	28	291	59
5 A	1340	10	70	12	67	140	299	1041
5 B	620	60	10	30	31	56	187	433
2–6	630	130	100	21	32	56	339	291
6 A	1840	90	20	41	92	116	359	1481
6–7	800	20	130	8	40	84	282	518
7 A	1750	130	50	10	88	72	350	1400
7 B	1640	250	180	–	82	172	684	956
TOTALS	14010	1220	1370	273	704	1233	4800	9210

Source: SESP.

3.7 Typical secondary canal long section



DISTANCE Km	0.0	1.0	2.0	3.0	4.0	5.0
GROUND LEVEL	38.0	37.1	37.2	36.5	36.3	35.8
WATER LEVEL	37.4	37.1 | 37.0	36.7 | 36.6	36.3 | 36.2	35.9 | 35.8	35.5 | 35.4
BED LEVEL	36.6	36.3 | 36.2	35.9 | 35.8	35.5 | 35.4	35.1 | 35.0	34.8 | 34.7
DESIGN DATA	Q = 2·59 M^3/SEC S = 0.0003		Q = 1.89 M^3/SEC S = 0.0003		Q = 1.42 M^3/SEC	

3.4 Primary and secondary canals

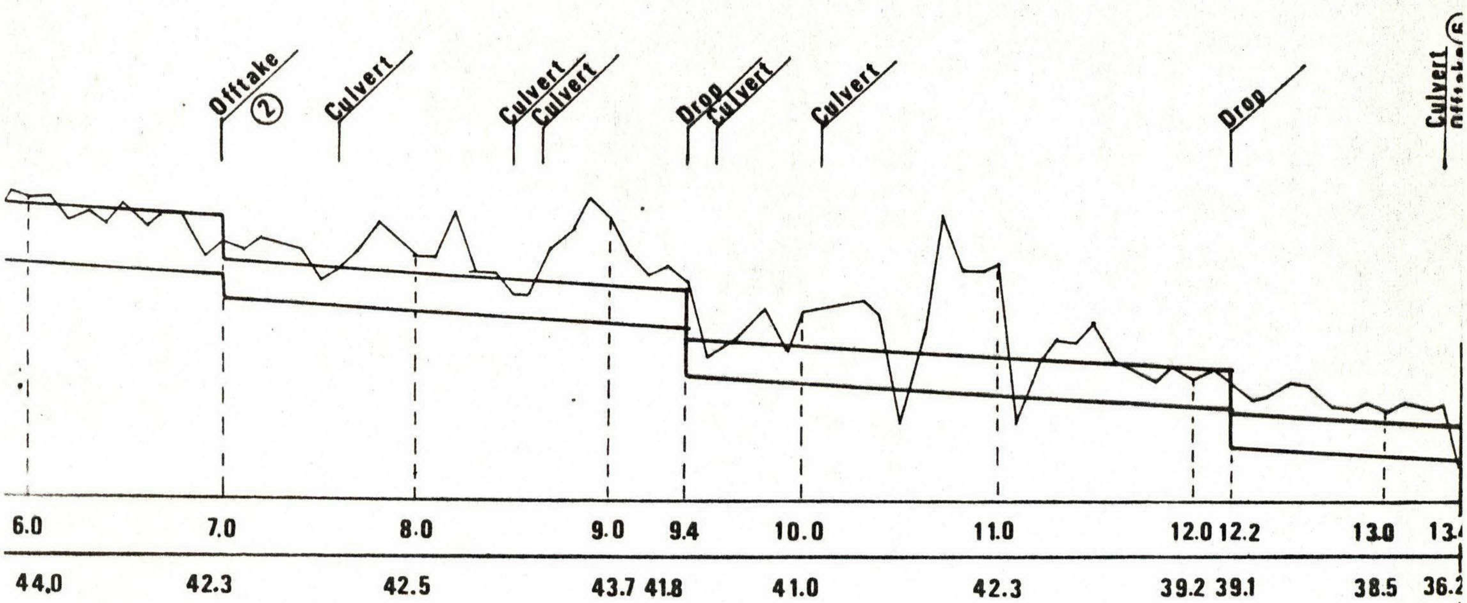
3.4.1 Design of canals

The alignment of canals has been selected using the topographical information from the 1:5,000 sheets. The lines were plotted on the sheets and longitudinal sections prepared. The longitudinal section for the primary canal and for a typical secondary canal are shown in Figures 3.6 and 3.7.

Command water levels were obtained from the contour-sheet spot levels and referred to secondary canals and the required water profiles evolved. Adjustments were made to bring in as much land as practicable. The estimated out of command areas by canal units are shown in Table 3.3.

Canal design is based on the Lacey regime theory. This method is applicable to the silty clay loam soils through which the canals will pass. The bedwidth and depth of flow were obtained and cross sections established. Typical sections for canals in cut and in fill are shown in Figures 3.8. The sections will accommodate peak flows of up to 25 per cent excess on the design discharge. In general, primary canals would have inspection roads on both banks and secondary canals on one bank.

Table 3.4 indicates the estimated canal lengths and earthwork volumes. The latter comprise both cut and fill; at this stage no attempt is made to balance cut and fill.

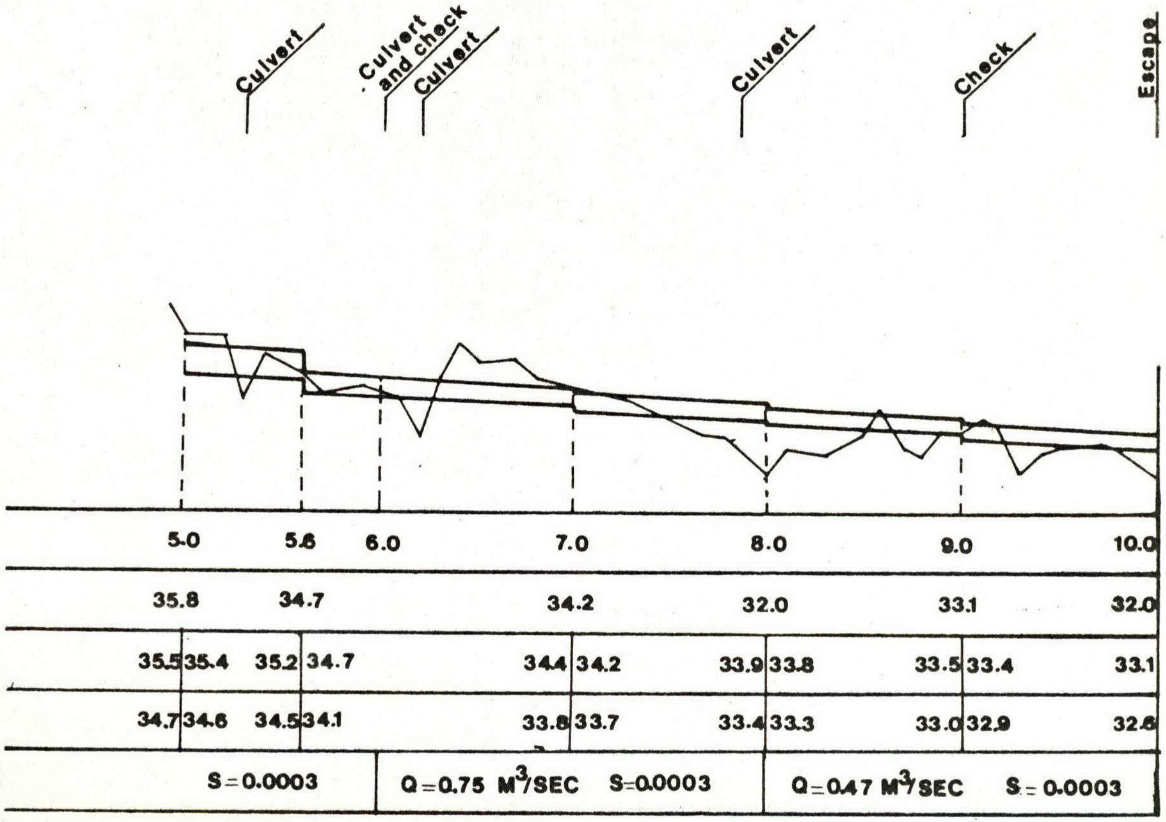


6.0		7.0	8.0	9.0		9.4	10.0	11.0	12.0		12.2	13.0	13.
44.0		42.3	42.5	43.7		41.8	41.0	42.3	39.2		39.1	38.5	36.2
43.7	43.5	42.5	42.2	41.8	41.5	40.2	40.3	40.0		39.8	38.6		38.2
42.1	41.9	41.3	41.0	40.7	40.5	39.3	39.2	38.9		38.6	37.5		37.1
		$Q = 9.29\ M^3/SEC$						$S = 0.00025$					

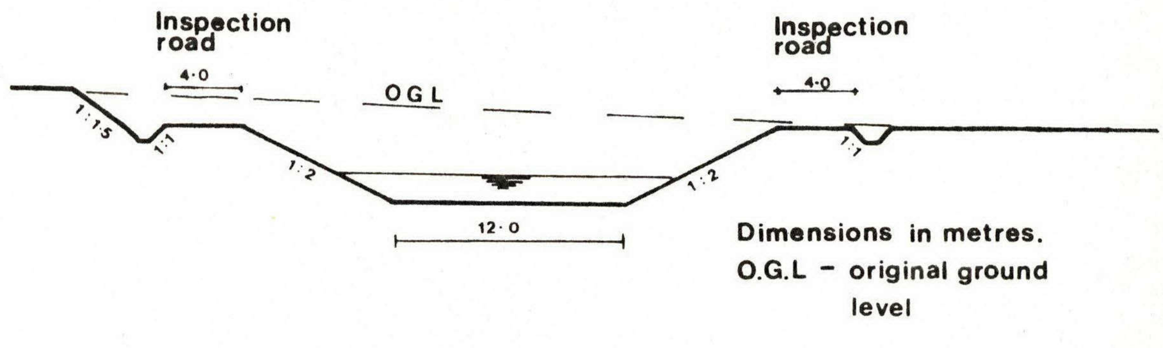
Table 3.4 Primary and secondary canals

Canal	Length km	Average discharge m^3/s	Earthwork volume m^3
Primary			
(0–1–2–6)	13.5	18.42	455,700
Secondary			
1 A	3.6	0.78	46,700
2–3	1.9	1.06	26,300
3 A	2.0	0.55	15,100
3 B	1.5	0.44	11,300
2–4	3.3	3.47	62,500
4 A	10.0	3.20	280,000
4 B	2.8	0.27	57,800
2–5	2.6	2.68	32,300
5 A	10.0	1.82	112,600
5 B	3.4	0.76	39,600
6–7	3.4	5.03	72,300
6 A	10.0	2.59	142,800
7 A	10.0	2.45	155,500
7 B	6.0	1.67	51,000
Total	84.0		1,561,500

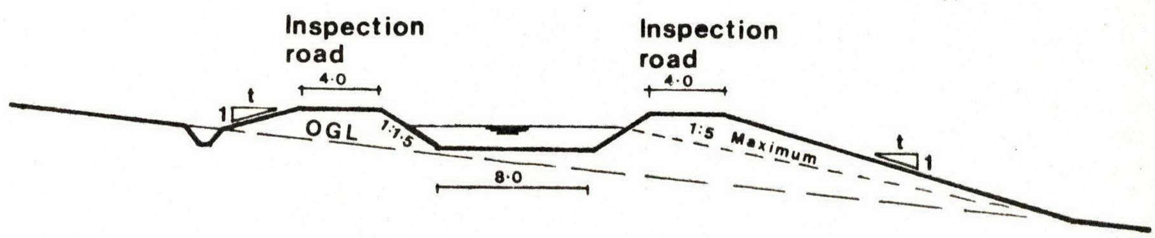
Source: SESP.



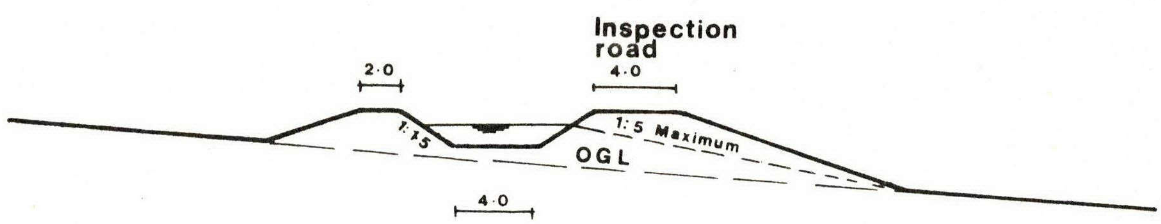
3.8 Typical canal cross section



Typical cross section of primary canal in cut



Typical cross section of primary canal in fill



Typical cross section of secondary canal in fill

3.5 Structure

There are three basic types of canal structures, control works, cross drainage structures and road crossings. Control works comprise canal offtakes, cross regulators and falls. Canals cross drainage channels in syphons, culverts or aqueducts depending on the relative sizes or stability. Road crossings are provided at all major control works and additional bridges or culverts are provided giving an approximate density of at least one footbridge at every 500 metres and one road briadge at every 2 kilometres of main canal.

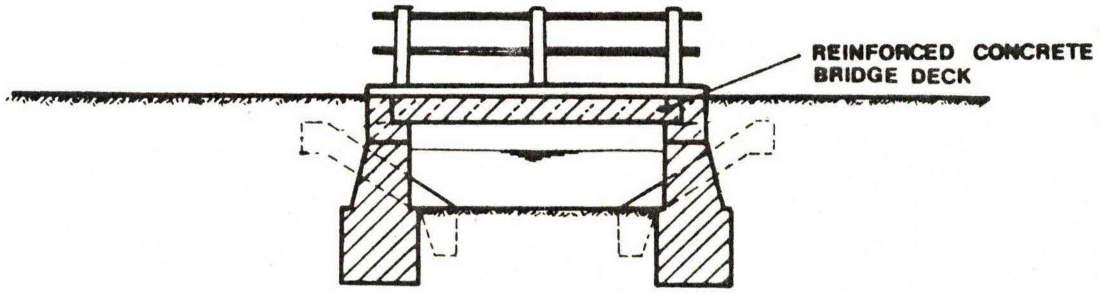
The location of structures for the primary canal and the typical secondary canal are shown in Figures 3.6 and 3.7. Minor structures such as tertiary offtakes and footbridges are not shown. Typical structures are shown in Figures 3.9 and 3.10. In general, traditional construction materials such as stone masonary and lime mortar would be used, suitably protected with cement pointing. Reinforced concrete would be used for bridge deckings. The provisional number of structures together with the extent of stone pitching is given in Table 3.5.

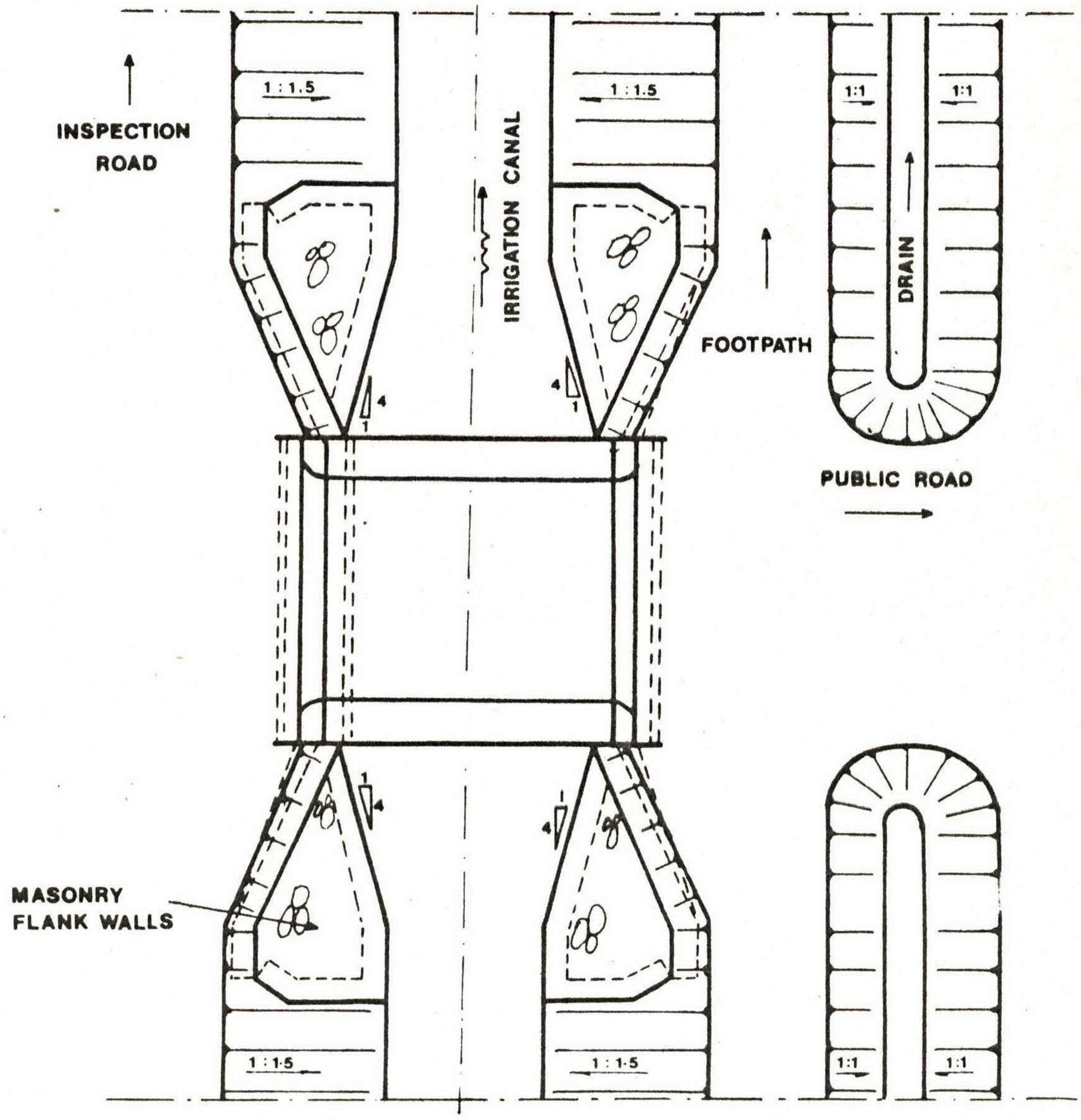
Table 3.5 Primary and secondary canal structures

	Control works					
	River intake	Regulators or falls	Tertiary offtakes	Cross drainage works	Bridges	Stone pitching M
Primary canal 0–1–2–6	1	10	6	7	7	2,700
Secondary canals						
1 A	–	3	4	2	–	360
2–3	–	4	5	2	1	390
2–4	–	4	4	2	–	330
3 A	–	3	5	4	–	200
3 B	–	2	4	1	–	100
4 A	–	11	13	7	–	1,100
4 B	–	3	4	2	–	280
2–5	–	4	4	3	–	260
5 A	–	9	9	1	1	1,000
5 B	–	3	4	4	–	340
6–7	–	3	2	1	–	340
6 A	–	11	11	6	–	1,000
7 A	–	10	11	8	–	1,000
7 B	–	6	7	2	3	600
Total secondary	–	76	87	45	5	7,200
Total (inc. primary)	1	86	93	52	12	9,900

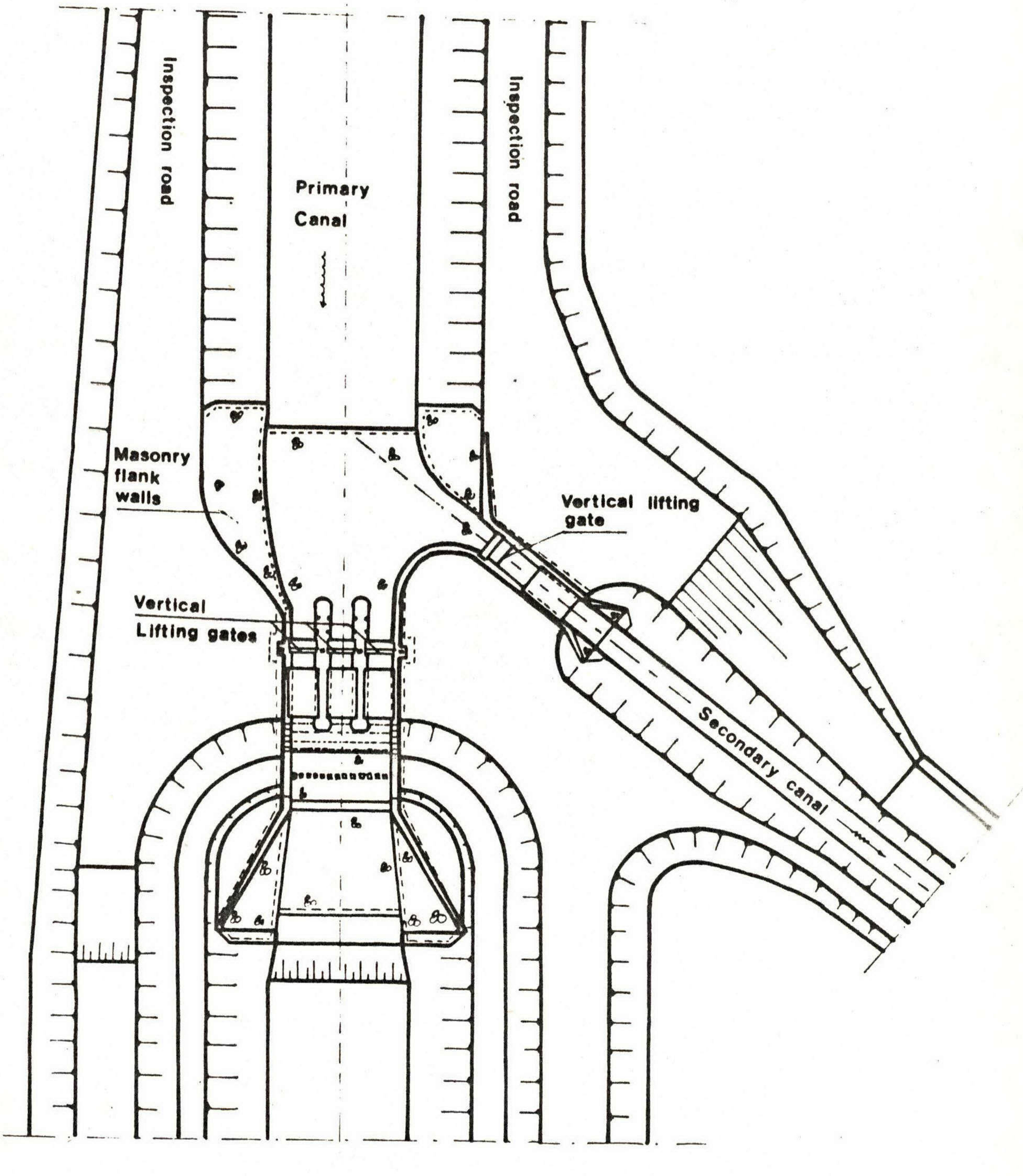
Source: SESP

3.9 Typical bridge on secondary canal





3.10 Typical regulator on the primary canal



3.6 Tertiary and lower units

Figure 3.11 shows the layout of minor canalisation in a sample tertiary unit. The main tertiary canal with a discharge of about 150 l/s runs along a ridge to irrigate 110 hectares. Quaternary canals offtake at fan control points to supply water to farm channels. This particular tertiary sample has two small out of command areas. Drainage will be provided along the tertiary command boundaries.

The tertiary and all its structures (distribution boxes, falls, culverts etc.) will be constructed by the project authorities, whereas the quaternary and lower systems will be constructed by the farmers. However, the project authorities would give the farmers guidance on channel alignment, dimensions and structures, and in addition materials may be provided for difficult structures, i.e. pipes for exceptional drainage crossings or stones for unusually large channel falls.

The arrangement shown in Figure 3.11 has been used as the basis for estimating costs; however, in some areas, particularly the commands of secondaries 4A and 5B with their numerous meander scars, the layouts will be more complex and structures more numerous. Appropriate increases in costs have therefore been made for these areas with difficult topography. The following table indicates the density of structures.

Table 3.6 Minor structures

Structures	Density of structures number/1000 ha	
	Average topography	Complex topography
Tertiary distribution boxes	20	25
Quaternary distribution boxes	40	50
Other structures	30	37

Source: SESP.

Channel earthworks are of the order of 100 m^3/ha under average conditions and in difficult land this would increase to about 133 m^3/ha.

General specifications (Prosida projects) for tertiary units are:

a The size of tertiary units should normally between 80 and 100 hectares, but sizes up to 150 hectares are permissible.

b The size of quaternary units should generally be between 10 and 20 hectares, and be as nearly equal to each other as possible.

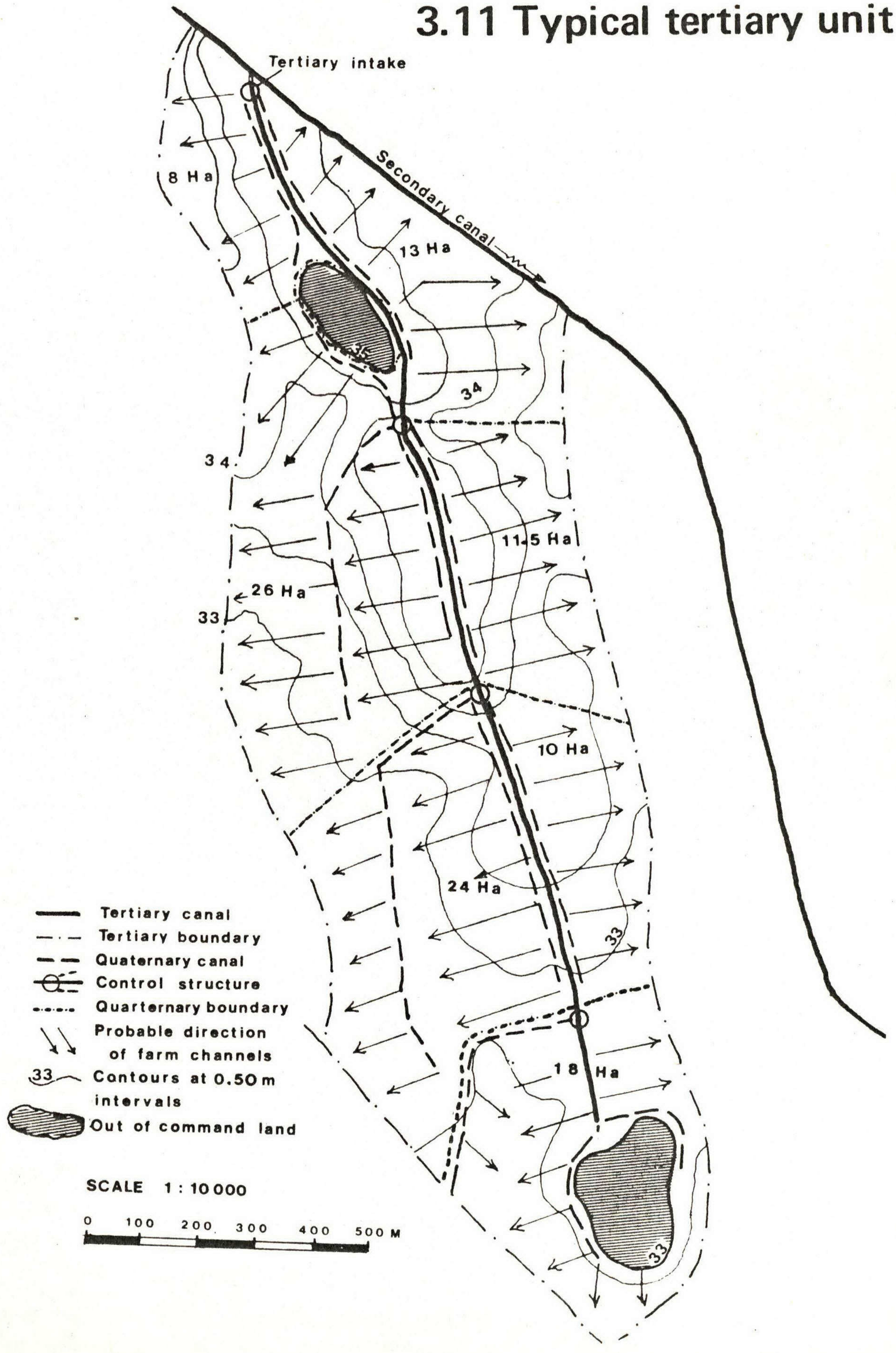
c Tertiary and quaternary channels should not be longer than 2,500 metres and 500 metres respectively.

d The irrigation of individual rice fields should be from the quaternary only. Field to field irrigation should be limited 6 or 7 fields in sequence and no field should be more than 300 metres from a channel.

3.7 Land levelling

Over a large part of the area much work will have to be done to prepare the land for irrigation. In the southern part extensive areas of forest will have to be cleared and in most other areas vegetation has to be removed and the land levelled. From examination of contour sheets, aerial photographs and field inspections it is estimated that on an average 25 cm of land over the whole project area (except for existing sawah land) will have to be moved to create level terraces. The resulting estimated cost is of course very approximate. Detailed surveys should be carried out in representative sample areas to establish the amount of work required and the best methods of forming terraces.

3.11 Typical tertiary unit



3.8 Drainage and flood control

3.8.1 Drainage

The natural drainage system is shown in Figure 3.12. This system will be improved and extended to enable adequate surface drainage of the irrigated area. The capacity of the drains has been based on an estimated discharge of 4 l/s/ha. The earthwork has been calculated by preparing long sections. Drain inlet or junction structures and some bridges are provided. Table 3.7 indicates channel lengths the earthwork required. Except for the main drains in M and L, all drains are located in existing channels.

Table 3.7 Drainage works

Drain system	Length, km	Earthworks, m^3
A	8.5	35,600
B	8.8	54,800
C	6.5	14,400
D	11.5	87,000
E	12.0	81,100
F	10.0	152,700
G	9.5	112,700
H	3.0	10,100
J	3.0	9,500
K	8.3	36,800
L	5.5	130,500
M	13.6	322,700
Total	100.2	1,047,900 m

Source: SESP.

3.8.2 Flood control

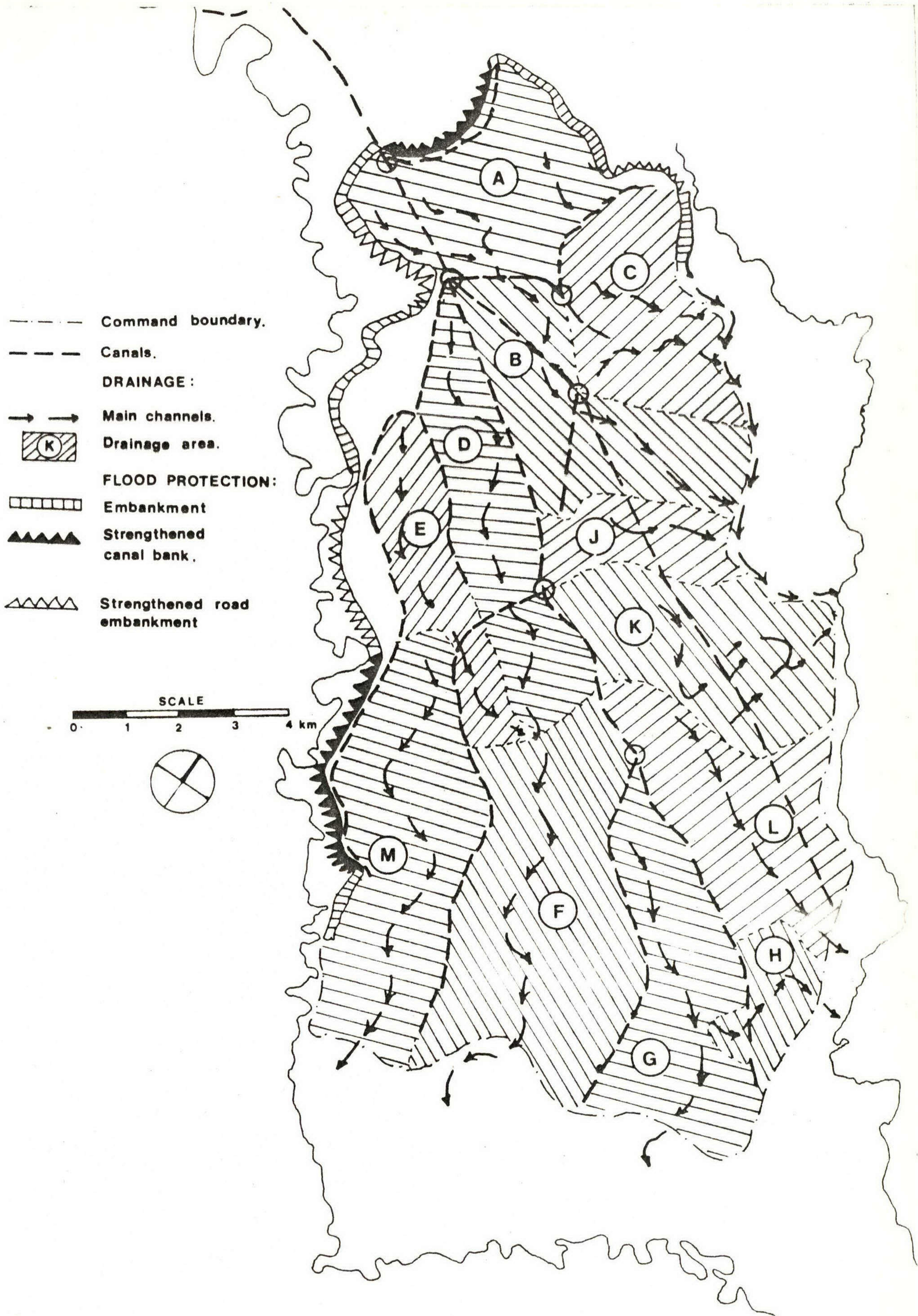
The irrigated area is vulnerable to floods from the Konaweha, particularly south of Teteona for 7 km, where flood depths between 0.5 and 0.7 m are experienced, and to some extent from the Lahumbuti. In addition, the north west boundary is liable to inundation by sheet flow on the other side of the main road. In general, flood protection can be provided by flood embankments and strengthening or raising canal and road embankments. Figure 3.12 shows the nature and extent of works. Table 3.8 indicates the length of embankments and the approximate volume of earthworks.

Table 3.8 Flood protection works

Work	Length – km	Earthworks–m^3
Flood protection bank	15.3	168,300
Strengthened canal bank	8.3	45,700
Strengthened road bank	8.5	76,500
	32.1	290,500

3.9 Cost estimates

The rates used for estimating the cost of works are shown in Table 3.9. The table also indicates the local and foreign currency components and the distribution of the foreign exchange element. The estimated capital costs are summarised in Table 3.10 and details are given in Table 3.11.



3.12 Drainage and flood protection system

Table 3.9 Unit rates

Item	Rate	Currency Local %	Currency Foreign %	F.E. Distribution % Cement	Steel	Reinf. steel	Machinery
Excavation							
In cut	Rp 400/m³	25	75	–	–	–	100
In fill	Rp 600/m³	25	75	–	–	–	100
Stone pitching	Rp 6,000 m²	70	30	75	–	–	25
Structures							
Regulators	) from	65	35	50	15	25	10
Bridges	) cost	70	30	55	–	30	15
Cross drainage	) curves	70	70	55	–	30	15
Intake structure	Rp 500 million	50	50	50	25	15	10
Tertiaries	Rp 65,000/ha	75	25	50	–	10	40
Quaternaries	Rp 25,000/ha	100	–	–	–	–	–
Land levelling	Rp 52,000/ha	25	75	–	–	–	100
Engineering							
Design	8% of total	50	50	–	–	–	–
Supervision	7% of total	50	50	–	–	–	–
Admin	Rp 500 million	100	–	–	–	–	–
Offices & buildings	Rp 200 million	80	20	50	25	15	10
Maintenance equipment	Rp 124,5 million	0	100	–	–	–	100

Table 3.10 Summary of capital costs

Item	Amount million Rp	Foreign exchange element – million US$
Primary canal	624.40	0.682
Secondary canals	1,843.40	2.154
Tertiary canals	598.33	0.360
Quaternary canals	230.13	–
Land levelling	478.66	0.865
Drainage	479.20	0.798
Flood protection	174.30	0.315
Intake Structure	500.00	0.602
	4,928.42	5.776
Contingencies 20%	985.68	1.155
	5,914.10	6.931
Engineering		
design	473.13	0.570
supervision	413.99	0.499
Overheads & Administration	500.00	–
Offices & buildings	200.00	0.096
Maintenance plant	124.50	0.300
Total estimated cost of project	7,625.72 Rp x 10^6	8.396 US$ x 10^6
Average cost per hectare	Rp. 828,430 US$ 1,996	

Source: SESP.

Table 3.11 Cost estimate details

Item	Quantity	Rate Rp x 10^6	Amount Rp x 10^6	Foreign exchange element US$ x 10^6
Primary canal				
Excavation: cut	406,147 m^3	0.0004	162.5	0.294
: fill	49,531 m^3	0.0006	29.7	0.054
Stone pitching	900 m	0.102	91.8	0.066
Bridges	7 no	( )	79.0	0.057
Cross drainage wks	7 no	( )	79.0	0.057
Regulators	10 no	( )	176.4	0.149
Tertiary offtakes	6 no	1.000	6.0	0.005
			624.4	0.682
Secondary canals				
Excavation: cut	122,668 m^3	0.0004	49.1	0.089
: fill	1,105,800 m^3	0.0006	663.5	1.199
Stone pitching	7,200 m	0.03	216.0	0.156
Bridges	5 no	(1.2)	6.0	0.004
Cross drainage wks.	40 no	(12.6)	505.8	0.341
Regulators	69 no	(4.4)	304.8	0.008
Tertiary off takes	59 no	1.000	89.0	0.008
			1,834.4	2.154
Tertiary canals	99,205 ha	0.065	598.3	0.360
Quaternary canals	9,205 ha	0.025	230.13	–
Land levelling	9,205 ha	0.052	478.66	0.865
Drainage				
Excavation: cut	1,047,900 m^3	0.0004	419.2	0.865
Stone pitching	1,000 m	0.03	30.0	0.018
Structures	20 no	(1.5)	30.0	0.022
			479.2	0.908
Flood embankments	290,500 m^3	0.0006	174.3	0.315
Intake structure	1 no	500.0	500.0	0.602

Source: SESP

3.10 Operation and maintenance

The operation and maintenance of the Wawotobi scheme is envisaged through the Provincial Irrigation Service. The present organisation will have to be expanded by creating a separate section which will be responsible for the operation and maintenance of this scheme. The technical staff required is listed below:

- Section engineer (operation)
- Assistant engineer (maintenance)
- Technical assistants, draughtsmen (8)
- Surveyors (2)
- Field assistants (6)
- Artisans
- Mechanics and operators for maintenance machines
- Maintenance labourers and gate operators

In addition to the main Wawotobi scheme the staff will be able to look after other irrigation units in the vicinity, e.g. Ameroro and Unaaha. A technical assistant will be in charge for each scheme.

The actual numbers of mechanics and operators will depend on the numbers of maintenance machines, and those of maintenance labourers on lengths and sizes of canals.

A provisional list of maintenance plant is given below:

4-wheel drive vehicles	2	US $ 15,000	
Hydraulic excavators	2	80,000	
Bulldozer	1	30,000	
Motor grader	2	50,000	
Trailer truck	1	20,000	
Pumps (capacity 50,100 lbs)	2	25,000	
Concrete mixers	2	8,000	
Vibrating rollers	2	4,000	
Vibrating plates	4	4,000	
Water tanker	1	20,000	246,000
20% spares			50,000
			296,000

For maintenance of this small quantity of mechanical plant a separate workshop is not considered feasible. Arrangements can be made with other government or private workshop for plant maintenance. Based on the experience of similar work in East Java, a summary of O&M costs is given below. The costs are expressed in rupiah/ha/year:

Annual O & M costs summary

	Rp/ha/year
Staff costs	1,600
Transport costs	350
Office running	250
Maintenance works*	2,200
Overheads	150
Total	4,550

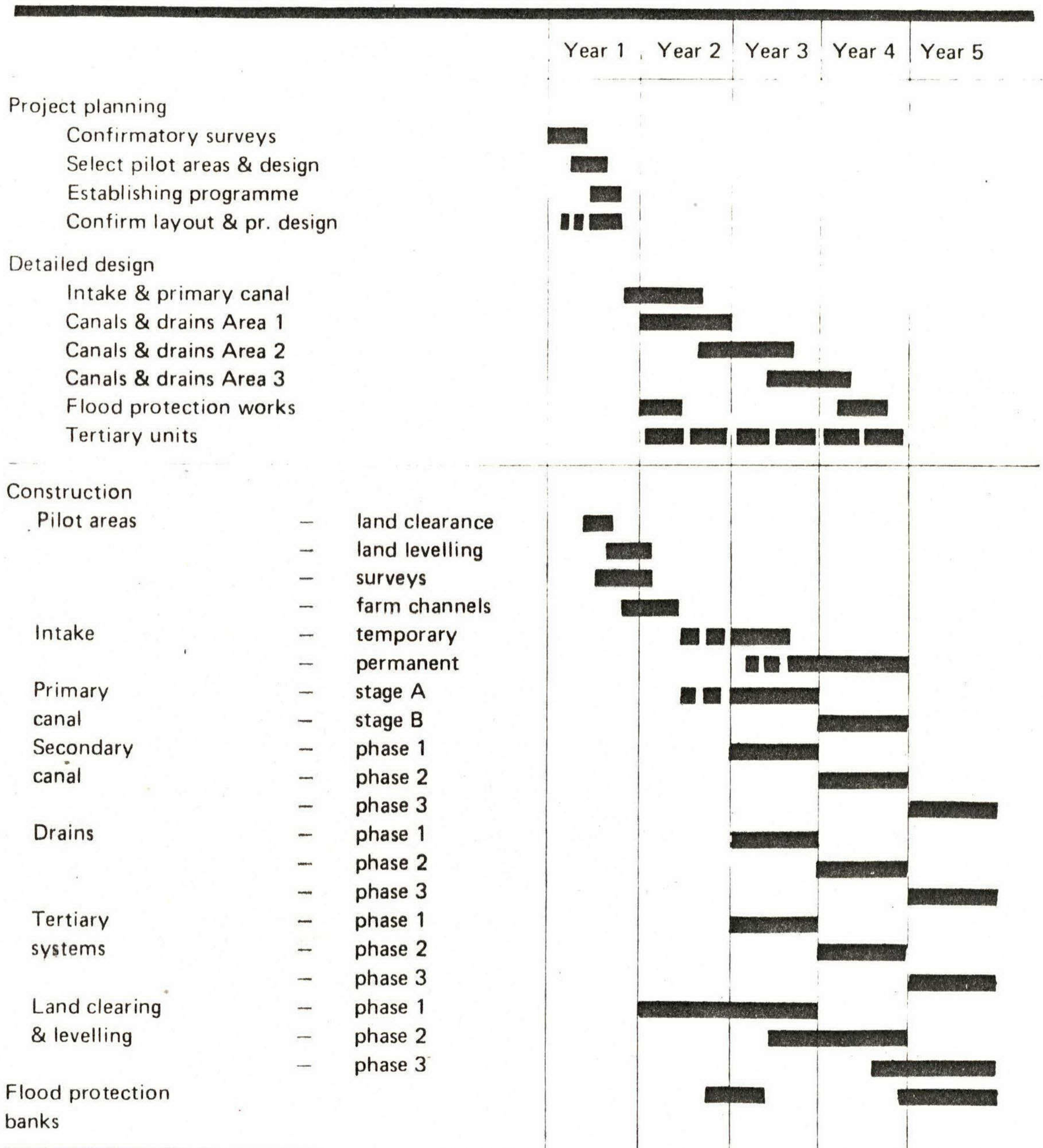
* Maintenance plant running and replacement cost are included.

3.11 Implementation

The following criteria are considered in planning the implementation of the new Wawotobi irrigation scheme:

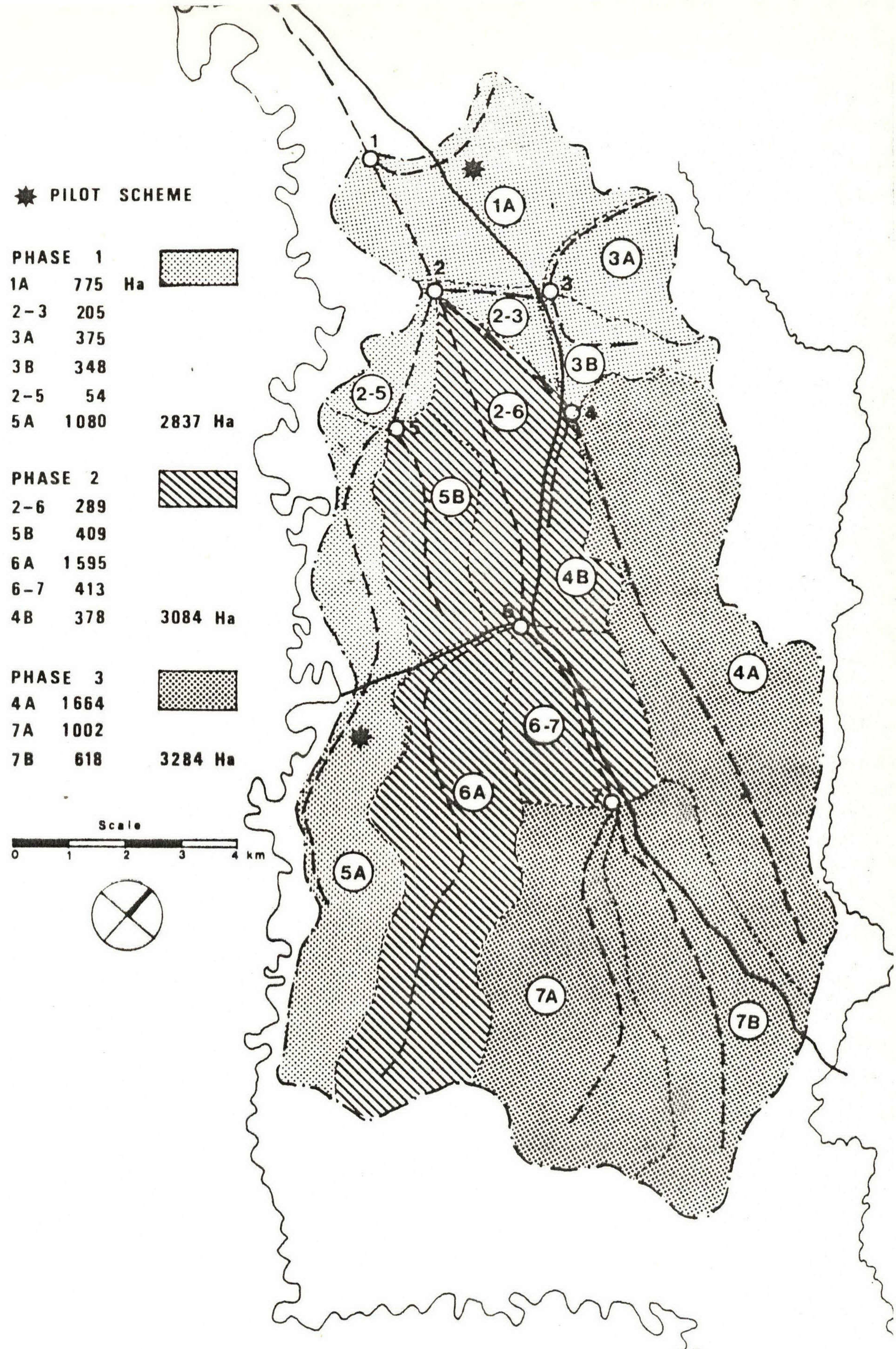
a As much new land as possible should be brought under cultivation and as soon as possible.
b The easier lands should be tackled first.
c Irrigation development normally proceeds from upstream to downstream.
d Early construction and operation of small pilot schemes enable the solution of development problems and serve as training/demonstration centres.

A provisional programme for development is shown in Figure 3.13. This programme envisages a five year programme; during the first two years project planning is completed and pilot projects are set up and during the last three yars the irrigated area is brought up from 2,800 ha to 9,000 ha.



Area development		Year 1	Year 2	Year 3	Year 4	Year 5
Annual	ha		20	2817	3084	3284
Cumulative	ha		20	2837	5921	9025

3.13 Programme of development



3.14 Phasing of irrigation development

Table 3.12 **Distribution of costs (Rp x 10^6)**

Year	1	2	3	4	5	Total
Figures in brackets are foreign exchange element in (US $ x 10^6)						
Preconstruction						
Project planning & detailed design	130 (0.12)	140 (0.18)	100 (0.15)	100 (0.12)		470 (0.57)
Construction						
Pilot schemes	10 (–)	10 (–)				20
Intake		30 (–)	220 (0.30)	250 (0.30)	–	500 (0.60)
Primary canals		20 (–)	500 (0.60)	100 (0.08)	–	620 (0.68)
Secondary canals			1240 (1.85)	300 (0.20)	300 (0.10)	1840 (2.15)
Drains			280 (0.70)	100 (0.08)	100 (0.02)	480 (0.80)
Tertiaries			200 (0.12)	200 (0.12)	200 (0.12)	600 (0.36)
Quaternaries			70 (–)	80 (–)	80 (–)	230 (–)
Land levelling			270 (0.75)	110 (0.06)	100 (0.06)	480 (0.87)
Flood protection			100 (0.20)	20 (0.10)	50 (0.02)	170 (0.32)
Contingencies		10 (–)	570 (0.90)	230 (0.20)	170 (0.05)	980 (1.15)
Miscellaneous						
Supervision of construction			140 (0.20)	140 (0.20)	130 (0.10)	410 (0.50)
Overheads & admin	100 (–)	100 (–)	100 (–)	100 (–)	100 (–)	500 (–)
Offices & buildings		200 (0.10)				200 (0.1)
Maintenance plant				100 (0.25)	20 (0.05)	120 (0.30)
Total	240 (0.12)	510 (0.28)	3790 (5.77)	1830 (1.71)	1250 (0.52)	7620 (8.40)

Source: SESP

Project planning is an essential initial step. Confirmatory surveys are required to establish ground levels in the Project Area (it is noted that the present 1:5,000 scale contour sheets do not correspond with topography indicated in aerial photographs), to determine river levels at the intake site, and to tie them to the corrected ground levels in the irrigation area. Topographic and hydrological surveys together with site investigations at the proposed intake site should also be carried out at an early date. The layout of canals and drains would be updated and a review of the project would be carried out in the light of any changes. Priorities would be established and a detailed programme of development would be prepared.

Construction and operation/maintenance plant and equipment would be specified. During the project planning stage the pilot areas would be selected and designed. Provided that an early start was made on the confirmatory topographic surveys, the project planning phase should be completed within 9 months of year 1, thus enabling a start on detailed design by the end of year 1.

In Figure 3.14 we show a detailed design of works phased in with construction. The project has been divided into three areas each being developed in a phased programme. Figure 3.14 indicates a provisional division. In general, the upstream and easier areas are completed first, and the downstream and harder areas last. The two pilot areas should be completed by the middle of year 2. By the end of year 3, the first stage of the Primary Canal with temporary intake arrangement and Phase 1 irrigation and drainage works would be complete to serve some 2,800 ha. At the end of year 4 phase 2 works would enable the cultivation of 3,000 additional hectares and at the end of year 5, phase 3 works would bring the total area with irrigation and drainage facility to about 9,000 ha. Flood protection works would be carried out concurrently. On-farm development (farm and field channels, formation of irrigated fields etc.) can be expected to lag behind the main works programme. The estimated distribution of costs (including foreign exchange element) is shown in Table 3.12

Existing settlements 4

4.1 General

The transmigration of farmers from Java and Bali to the Province of South East Sulawesi started in 1968. There are now some 20 separate settlements within the Study Area.

In principle, the Directorate General of Transmigration have allocated a total of 2 hectares of land per family each was meant to include one hectare of irrigated field. However, in practice, the sizes of cultivated holdings vary considerably. Of the allocated area often a major part is either undeveloped or unsuitable for development. It is clear that detailed topographic land use and soil surveys have not been carried out before allotting land to settlers. The result is that actual land available to farmers for agriculture falls far short of the theoretical standards.

Attempts are made to set out land holdings both for housing areas and for fields in a rectangular pattern without any regard to topography or any other local constraints. The adverse effects of this have been discussed in Volume 2 and 3 of this report.

However, in most areas arrangements are made for diverting irrigation water from a nearby river or spring. The level of irrigation works built for each settlement depends upon the size of the scheme; larger ones, with more permanent structures, are avoided and the smaller ones have to rely on temporary diversion. For most larger schemes topographic survey maps are available and the Directorate General of Irrigation have assisted with designs and construction. The canals and diversion arrangements for smaller schemes have been constructed by the Directorate General of Transmigration apparently wihout sufficient engineering assistance.

Whatever the size or level of the schemes, most of them are not functioning properly. The problems are of varied nature. In some cases the rivers or torrents have by-passed the diversion weirs and the intakes have been left dry. In some other cases torrents have started to flow through the irrigation canal, causing widespread flooding and damage to crops. Where temporary structures have been used the common complaint is that they are washed away by floods, which necessitates rebuilding every year. Minor canals have not been built, as the construction of those has been left to the settlers. From experience elsewhere in Indonesia it is clear that this is a major task far beyond the capacity of local farmers. Minor canals cannot be constructed satisfactorily without some help from the Government especially with structures and designs.

The settlement areas established so far are clearly those for which irrigation arrangement were considered to be simpler. Most of the present ones are settled on smaller rivers. The bigger rivers like Konaweha and Lahumbuti have not been developed, presumably because of the engineering problems involved in diverting water from these big rivers.

The time available for this study was not sufficient to survey the irrigation works in each settlement in sufficient detail to assess fully the remodelling requirements. Long section surveys of canals and controlling levels on each structure will have to be made before redesigning becomes possible. In some cases details of the foundations of structures would also have to be known. This has been further complicated by a general lack of mapping and canalisation information. However, on the basis of a reconnaissance level survey of each system, major problems have been identified and some solutions have been proposed. In preparing estimates of costs, approximate quantities have been used and a lump sum figure of cost has been quoted.

Except for rainfall data for four stations there is absolutely no hydrological information which can be used to evaluate water availability and irrigation requirements. A very approximate relationship of rainfall and runoff derived from experience in other regions of Indonesia has therefore been employed to estimate water availability. Similarly, the irrigation requirements have been calculated on the basis of assumed rates of infiltration and evaporation. The assumptions used for extricating both the availability and the requirements have been discussed in Chapter 3 of Volume 2.

Figure 4.1 gives the location of the settlements and salient features are given in Table 4.1.

4.1 Improved irrigation facilities

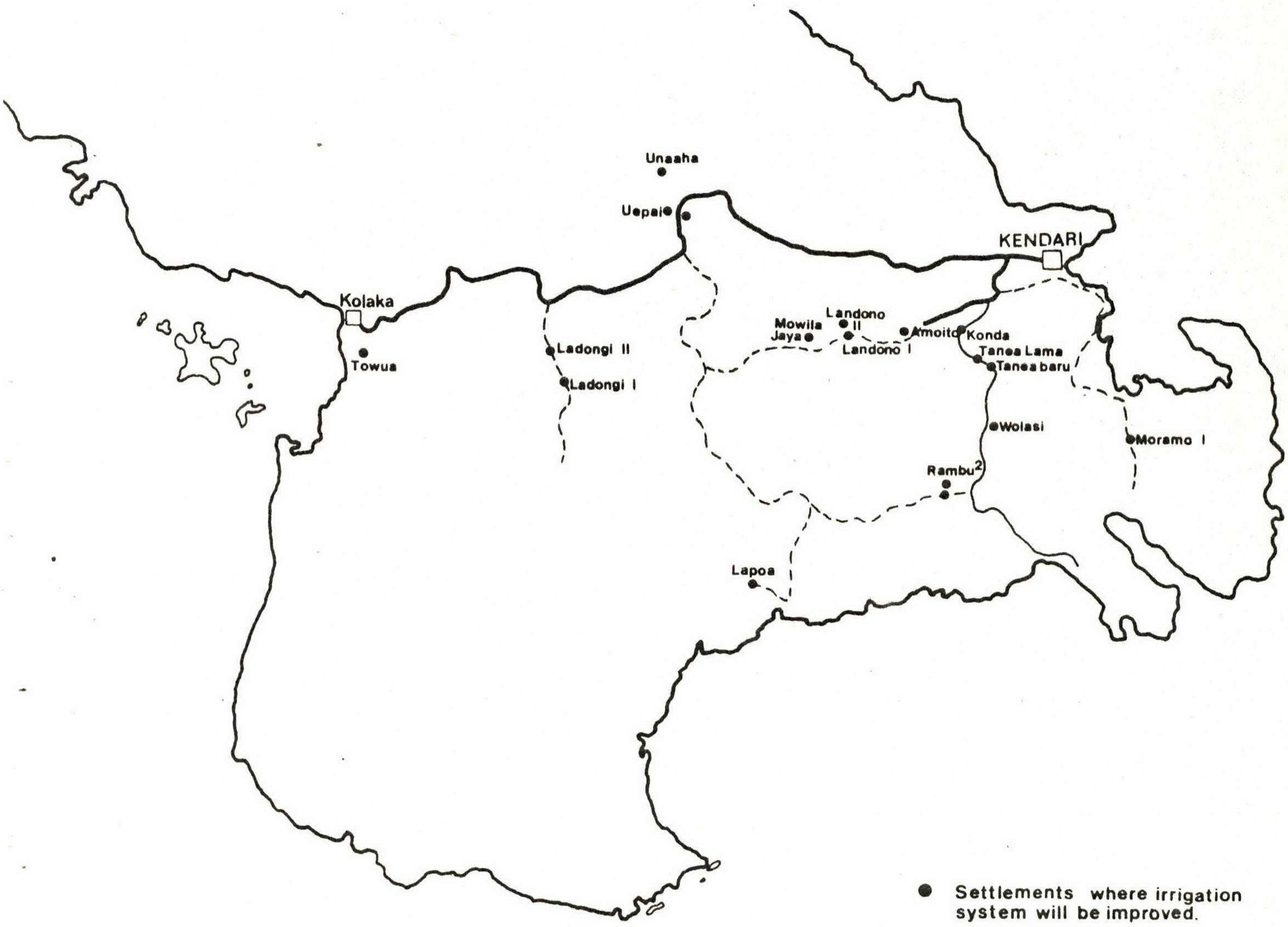


Table 4.1 Salient features of settlement areas

	Number of families	Total planned land area ha	Land already allocated ha			Land already cultivated ha			Proposed area for irrigation ha	Potential size of irrigation ha	Remarks
			Village	Dry land	Irrigated	Village	Dry land	Irrigated			
Amoito	269	535	250	250	250	75	75	150	250	150	Water limiting
Landono	444	–	158	326	400	214	149	188	444	250	Water and some available
Mowila Jaya	312	–	100	300	275	100	733	150	312	± 450	land available
Konda	209		100	100	100	100	–	10	100	100	
Tanea Lama	163	150	125	125	–	125	–	–	150	–	Situation unknown
Tanea Baru	500	1000	128	385	385	128	128	–	500	±1000	
Wolasi	43	100	50	50	–	43	–	–	50	50	Land limiting
Rambu Rambu (T)	85	250	100	–	–	100	–	–	85	± 120	Land and water limiting
Rambu Rambu (S)	169	400	169	–	169	169	–	–	169	–	Water from Laeya project ± 1500 ha
Pamandati	110	220	55	55	110	55	55	–	110	110	Water limiting
Lapoa	500	1000	125	375	–	125	–	–	500	± 350	Water and land limiting
Unaaha	280	560	171	436	–	171	100	–	280	–	Part of the Lahumbuti project of ± 4000 ha
Uepai	549	1000	135	415	–	104	205	–	500	–	Part of the Ameroro project
Ladongi I	1072	2000	266	275	545	266	226	100			of ± 2,200 ha
									±1000	–	Water from Ladongi dam
Ladongi II	531	1000	125	260	500	125	200	–			
Towua	300	600	75	225	100	75	99	6	300	–	Part of the Wundulako project ± 4000 ha
Moramo I	1000	2000	248	744	–	248	129	–	1000	± 50	

Source: SESP

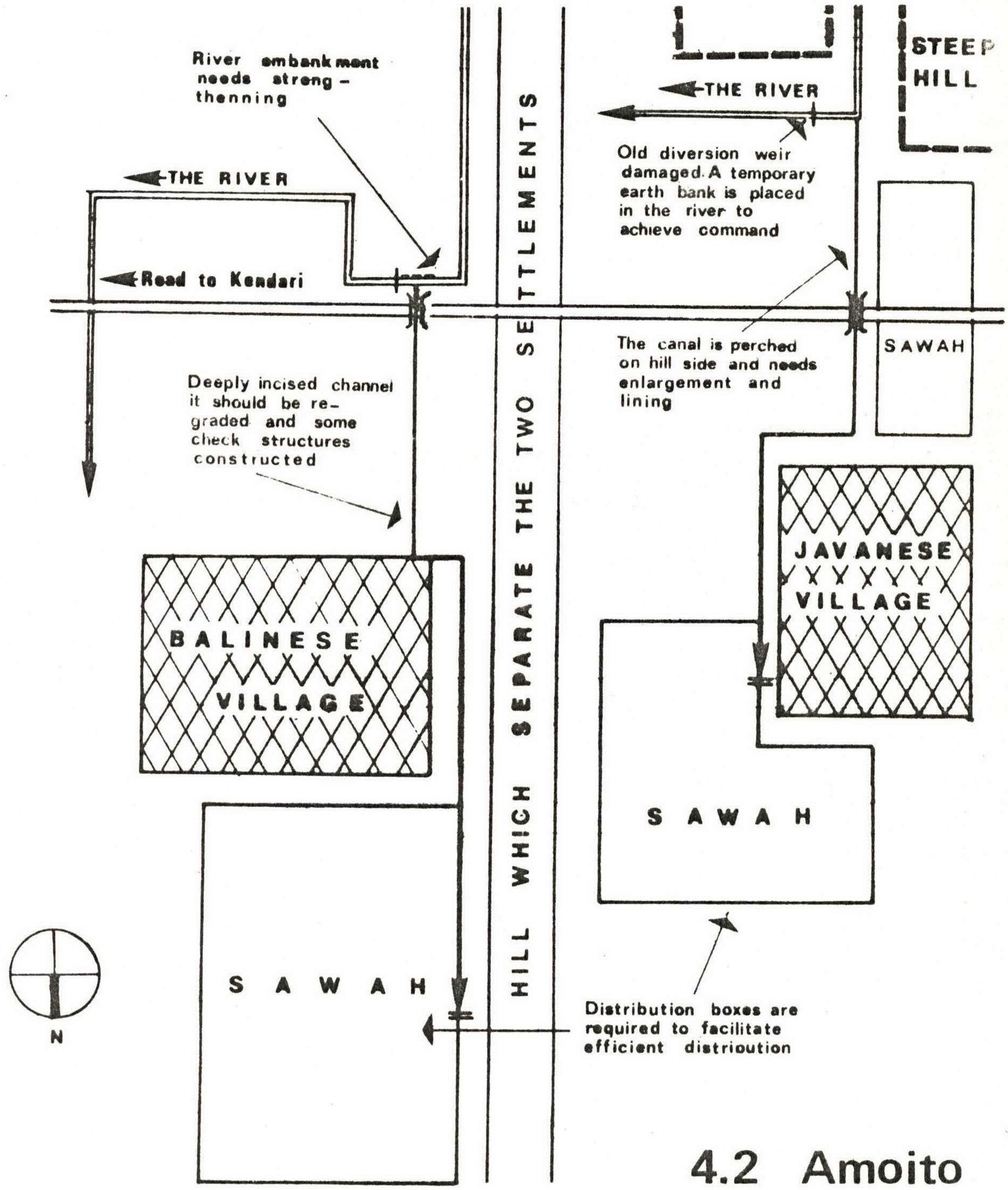
T Directorate General of Transmigration
S Department of Social Services

4.2 Amoito

The settlement of Amoito is situated in the plains north of Boro-Boro hills about 30 km west of Kendari along the airport road, 5 km beyond Ambaipuah. It is a non-technical irrigation unit. Irrigation or topographic maps could not be found and the area is not covered by aerial photography. The sketch in Figure 4.2 gives an approximate schematic plan.

4.2.1 Irrigation area

This is one of the older settlements, established in 1968. There are 269 families and the settlement is divided in two nearly equal parts. The Balinese are on the eastern side and Javanese on the western. The total cultivable area is about 500 ha, of which a part is irrigated.



4.2 Amoito

For the area irrigated, conflicting figures have been received from different sources ranging from 20 to 195 ha. From a general assessment, the lower figure is considered more reliable. The irrigation area is also approximately equally divided between the two villages; each has approximately 60 hectares.

4.2.2 Water availability

The two villages have separate sources of water. The water for the Javanese section is drawn from a small stream south of the road. The catchment is about 20 km^2. The current meter measurements suggested a discharge of 17 l/sec in October 1976; this can be regarded as the dry season base flow.

The source of water for the Balinese section is another stream to the east of the hills which separate the two villages. The catchment area is only about 5 km^2. However, the discharge measurements which were taken at about the same time as for the other stream suggested a little higher rate of base flow, 20 l/sec.

Most of the dry season flow is used for domestic purposes and very little water reaches the fields. For both the streams the representative rainfall station will be Kendari. On the basis of assumption given in Chapter 2, monthly catchment yield estimates are given below:

Table 4.2 Estimated monthly catchment yields (mean monthly flow l/s)

	J	F	M	A	M	J	J	A	S	O	N	D
Javanese village	618	802	998	1038	798	645	340	195	110	32	133	385
Balinese village	155	200	250	259	200	161	85	49	27	8	33	96

Source: SESP.

4.2.3 Irrigation works

For the Javanese section a permanent diversion weir was constructed in 1970, which is now badly damaged. The foundations are undermined and the embankments breached. The canal intake which was a permanent gated structure has been by-passed. At present, the water is diverted directly into the canal. Command is achieved by putting an earth bank across the river channel, about 100 m downstream of the old weir. It is presumed that the earthbank would require annual strengthening and regular maintenance.

Up to the point where it crosses the road, the irrigation channel is benched into the side of a steep hill. The present capacity is estimated at about 60 l/s. Enlargement would entail cutting deeper into the hill-side and lining of the channel section. The canal is generally in a good condition. However, two new drop structures should also be constructed if it is decided to increase the capacity.

The diversion weir for the Balinese village is adjacent to the road crossing. The structure is quite satisfactory but the guide bank on the right side will require raising and strengthening.

The irrigation offtake is also in good condition but the canal slopes are too steep. As a result of this, the channel section downstream of the road bridge is eroded and incised. The canal requires regrading and some check structures will be required to achieve satisfactory command of sawah.

The irrigated fields are generally neatly set out and terraced. Quaternary and field channels also exist, but there are no control structures.

4.2.4 Improvements and their cost

There is no scope for any substantial extension. The improvements discussed in the earlier section are listed below:

a Javanese village
   i There is no need to construct a new diversion weir. The present arrangements should be allowed to continue.
   ii Enlarge the canal to about 200 l/sec capacity and line the section up to the road crossing.
   iii Construct 2 drop structures.
   iv Construct 6 distribution boxes.

b Balinese village
   i Strengthen the right guide-bank upstream of the diversion weir.
   ii Regrade the canal and construct 3 check structures.
   iii Construct 6 distribution boxes.

The cost of the above works is estimated approximately at US $ 20,000.

4.3 Landono I and II

The settlement villages Landono I and Landono II with a total irrigation area of 188 ha are situated along the Kendari–Mowila road, 45 km from Kendari. The two settlements are separated by the Anotowo river.

No maps were available from which topography, land use, canalisation or diversion arrangements could be ascertained. A diagrammatic plan of the village prepared by the Provincial office of the Directorate General of Transmigration was the only mapping information. The 1975 aerial photographs of 1:22,000 scale cover part of the area.

However, the Provincial Office of the Directorate General of Irrigation have recently carried out a survey of this and a few other settlements but the plans will not be available until after February 1977. Figure 4.3 shows existing and potential irrigation areas.

4.3.1 Irrigation area

The irrigated areas in Landono I and II are 163 ha and 25 ha respectively and the rainfed cropland and village housing areas total another 335 ha. With 523 settler families, the average allocation of irrigated field is 0.36 ha/family. The development of the area is done by the villagers according to the so called "Balinese system".

Landono I is close to the foot-hills of the Boro Boro mountain range. The area about the village is fairly even, to gently undulating interspersed with small hillocks and water sources.

Landono II is situated to the north of Landono I and the village is spread over a section of high ground away from water sources. The irrigation areas are generally even ground and do not require much levelling.

4.3.2 Water availability

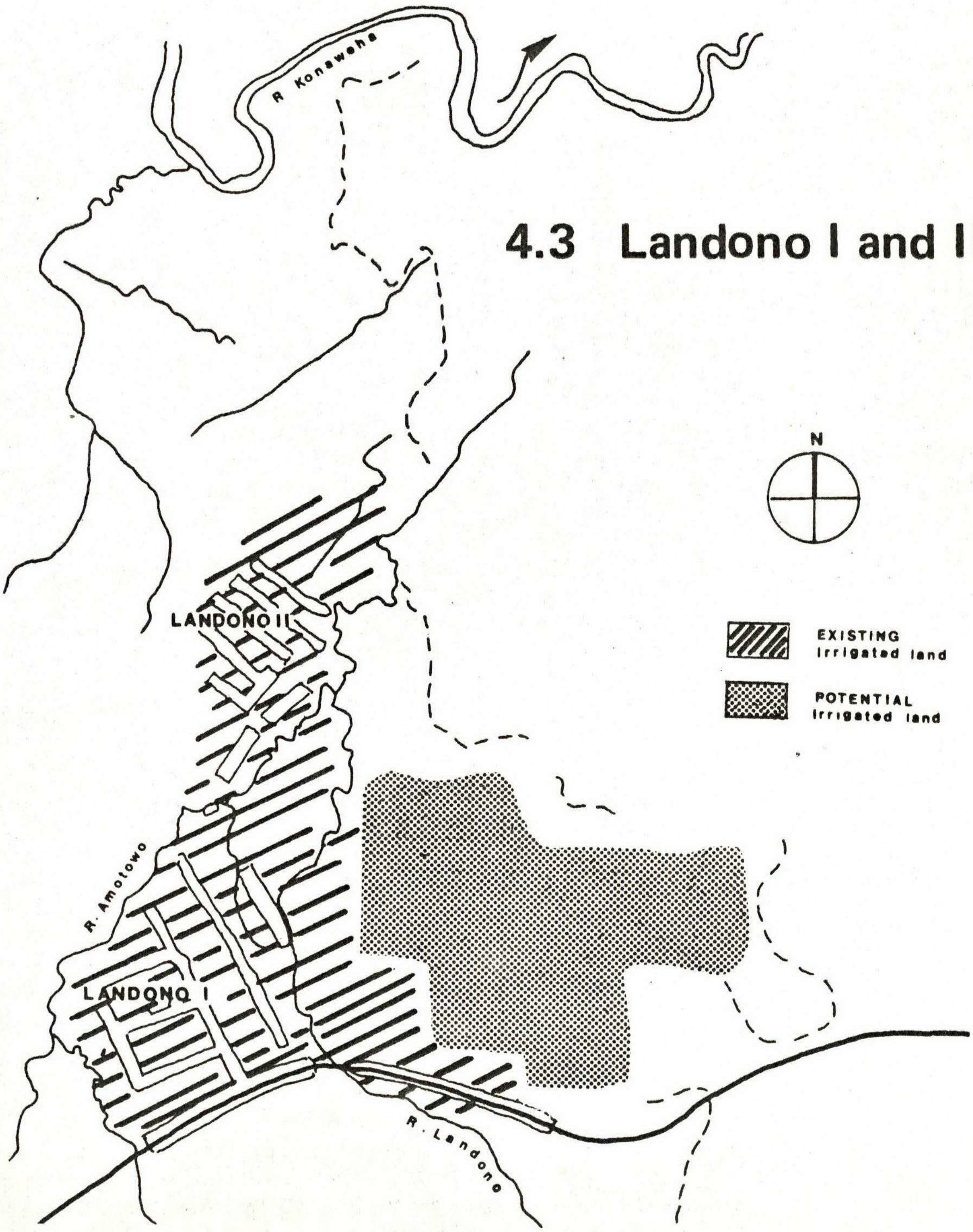
The Landono settlement receives irrigation water from three separate sources:
   the Amotowo river,
   the Landono river,
   a small unnamed stream between the two with a spring source.

The catchment areas for these rivers have been measured from a 1:250,000 topographic map and are not likely to be very accurate. Some current meter measurements of flows in the rivers were taken in November 1976 at a time when it had not rained for more than a month. Measured discharges can thus be interpreted as the annual minimum base flow. Catchment areas and base flows are given in the table below.

Table 4.3 River catchments and base flows

River	Catchment area (km²)	Measured flow (l/sec)	Area irrigated
Amotowo	16.0	27.3	163
Landono	10.0	± 5.0	15
Small unknown stream	7.0	9.0	10

Source: SESP.



4.3 Landono I and II

The rainfall station at Kendari is most representative. The average annual rainfall is 1768 mm and the monthly distribution is given in Table 4.4. By using catchment yield factors given in Chapter 2, approximate availability and monthly average rates of flow for each source have been calculated.

Table 4.4 Monthly rainfall and catchment yield

	J	F	M	A	M	J	J	A	S	O	N	D
Rainfall (mm)	207	194	223	192	214	209	152	87	71	43	86	172
Catchment yield (l/s)												
Amotowo river	512	605	826	829	661	515	282	162	88	27	106	318
Landono river	320	278	516	518	413	322	176	101	55	17	66	199
Unnamed river	224	265	361	363	289	225	123	71	38	12	46	134

Source: SESP.

4.3.3 Irrigation works

Ten hectares are irrigated from the unnamed small stream. There is no permanent structure and diversion is achieved by a temporary obstruction across the river made of brushwood and mud. This gets washed away in the wet season and has to be rebuilt every year. The irrigation intake is uncontrolled, and in times of floods very high discharges go down the canal damaging the section and causing flooding in the area. As a result, the section of the channel has become deeply incised by erosion.

The new diversion weir on the Amotowo river completed in early 1976 is made of stone masonary and is functioning fairly satisfactorily. The irrigation intake is gated and the canal serves 163 ha in the Landono I area. The old intake built about 2½ years ago was abandoned by the river within 2 years of construction.

A low gabion type weir across the Landono rivers, which was originally constructed to raise the water level has now been by-passed. The irrigation of 15 ha which used to get water from this source is now erratic. Farmers put an earth bank across the river in the dry season to achieve command. In the wet season the bank gets washed away but the water level is high and some irrigation is possible.

The irrigation canals are in a poor condition. There are no control structures, and in most cases channel sections are deeply incised so that they are not able to command the area except when large flows are diverted from the river.

4.3.4 Proposals for improvement and extension

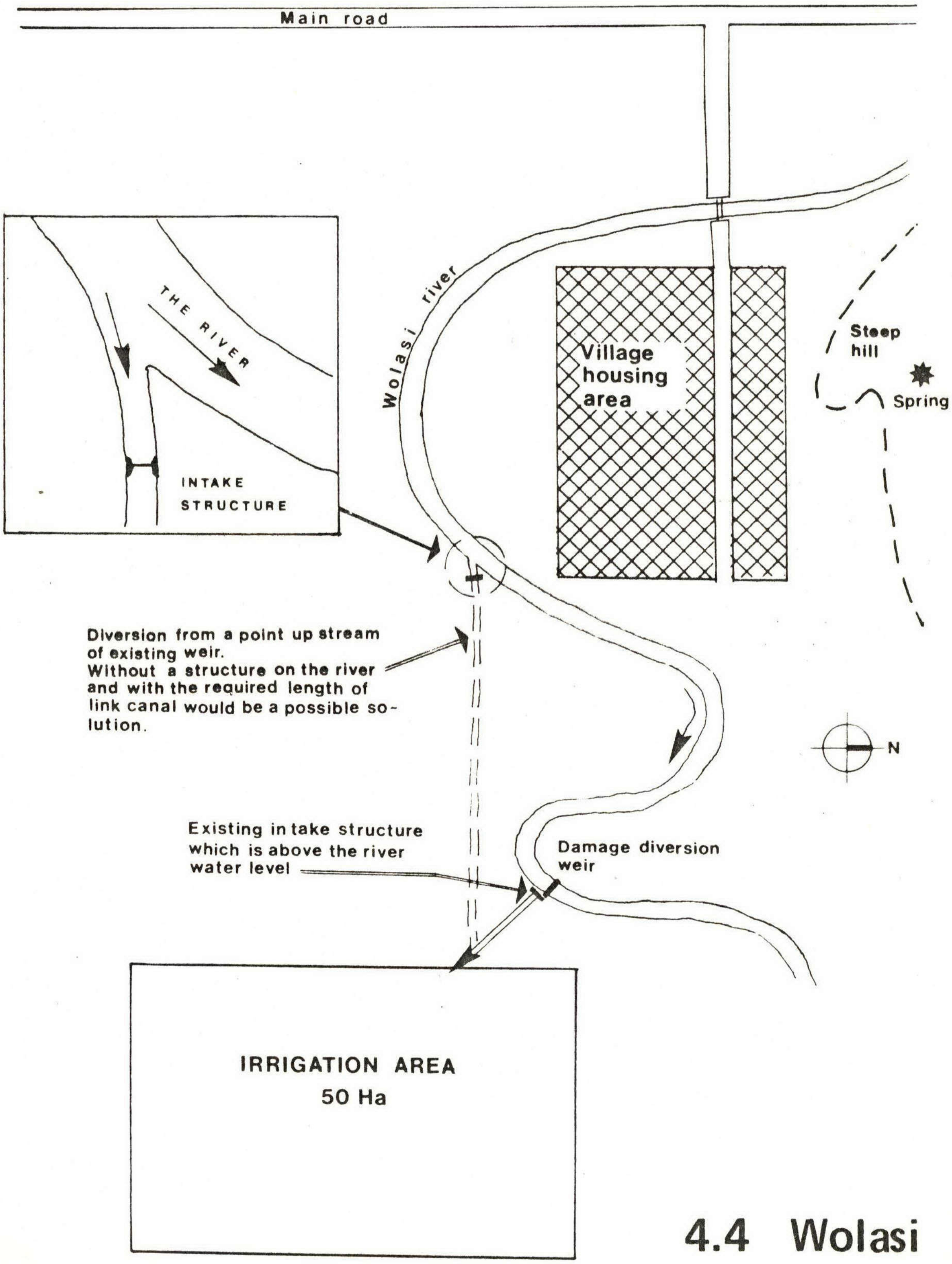
There is a possibility of extending the irrigation area on the right bank by diverting water from the Landono river. The gross extension potential is about 400 ha. There is no scheme at the present time in which this extension has been considered. A possible offtake point is shown in the sketch.

The feasibility of an irrigation system for the new area can only be established when the results of surveys carried out by the Directorate General of Irrigation become available. However, it must be pointed out that the dry season base flow for the Landono river is low and a large part of the area will have to do with one wet season crop. Further assessment of this potential has been proposed in the next phase.

As far as the existing system is concerned, it is recommended that rehabilitation of canalisation in the Landono I area should be given a high priority. The cost of constructing new control structures, checks and regrading of channels is estimated at approximately US $ 35,000. The cost includes the construction of distribution boxes to assist farmers with minor canalisation.

4.4 Wolasi

The Wolasi village is situated about 40 km from Kendari on the road to Tinanggea and the Roraya plains in the south. In the village, which is populated mainly by local people, there are 50 transmigrants from West Java.



4.4 Wolasi

In 1971–72 a non-technical irrigation system was constructed to irrigate 50 ha. Irrigation maps or drawings could not be located and the area is not covered by the aerial photography. Figure 4.4 shows the irrigation arrangements.

4.4.1 Water availability

A small river (catchment 8 km^2) rising in a well forested catchment to the west of the village is the source of irrigation water. The stream is very flashy and storm discharges are reported to be high. However, the floods do not inundate the irrigated area. The minimum dry season base flow is estimated at 15 l/sec, based on current meter measurements in October/November 1976. Mean monthly yields based on the rainfall of the Kendari station are given below.

Table 4.5 Yields of Wolasi catchment (litres/second)

J	F	M	A	M	J	J	A	S	O	N	D
247	321	399	415	319	258	136	78	44	13	53	154

Source: SESP.

4.4.2 Irrigation works

A gabion type weir and canalisation were constructed in 1971 to irrigate 50 hectares. It is reported that within one month of the completion of the weir, the river eroded the bed under the gabions and left the structure ineffective.

At the time of measurements, in November 1976, the floor of the intake structure was 50 cm above the water level. It is clear that except at times of high flows diversion would not be possible with the present arrangements.

The canal itself is 3 km long, is in good condition, but in the absence of water at crucial times farmers have not shown interest in developing minor canalisation.

4.4.3 Proposed improvement

On a flashy river such as this one, any diversion weir across the river will require substantial foundations and major river draining works. These would be costly and can hardly be justified for the irrigation of only 50 hectares. A possible solution would be to arrange the offtake without a weir on the river. From the present diversion point this would not be possible because the river water level is too low in the dry season to allow command of irrigation area.

It is therefore proposed that, after necessary surveys, diversion should be arranged some distance upstream of the present site—here the water level will be higher. Without constructing any obstructions in the river channel a new intake structure should be built and connected to the existing canal by excavating an extra length of canal (see Figure 4.4).

A reasonable point about ½ km upstream of the present site was located during field visits. About ¾ km long canal will be required to link the existing canal. Site surveys for the intake and canal line surveys will be required to design the proposed arrangements.

In order to assist farmers with minor canalisation, the construction of 5 distribution boxes is also recommended.

The cost of the proposed improvements is estimated at US $ 12,000.

4.5 Rambu Rambu

Rambu Rambu village is situated in the Asole river basin about 65 km from Kendari on the Kendari–Tinanggea road. The settlement was established in 1970 and there are 85 families in it now.

An area of about 120 ha has been allocated to the settlers for irrigation south of the village and to the east of the Lambu Lambu river. However, in the absence of water, irrigated fields have not been established satisfactorily and most of the irrigation area is covered on alang alang grass.

Maps are not available and the area is not covered by aerial photography. Therefore the rough sketch given in Figure 4.5 has been used to show the irrigation arrangements.

4.5.1 Water availability

The Rambu Rambu river is a tributary of the Asole river. It has a catchment of about 10 km^2. There is evidence that water has been diverted in the past to the area in which the proposed irrigation area has been established.

Current meter measurements in November 1976, suggest the base flow to be 30 l/sec. An estimate of monthly catchment yields for the Rambu Rambu river based on assumptions given in Chapter 2 is given below:

Table 4.6 Estimate of catchment yields (l/s)

J	F	M	A	M	J	J	A	S	O	N	D
309	401	499	519	399	323	170	97	55	16	66	192

4.5.2 Irrigation works

There are remains of an old structure and other indications that irrigation has been practiced for a long time. However, no information could be found about the extent of irrigation or the effectiveness of the old system.

The present offtake and a gabion type weir were constructed in 1970. Both the weir and the intake structure are in good condition. However, a section of the canal about 250 m from the intake has been washed away by a torrent. Attempts by villagers in the past to repair it themselves have failed and the area remains unirrigated.

Apart from the breach the canal is in good condition and can carry up to about 500 l/sec. However, in the upper reaches some silt and gravel clearance will be required.
It was not possible to ascertain existing minor canalisation because of the thick cover of tall grass over the area. Consequently, for planning purposes, it has been assumed that a new network of minor canals and distribution structures will be built.

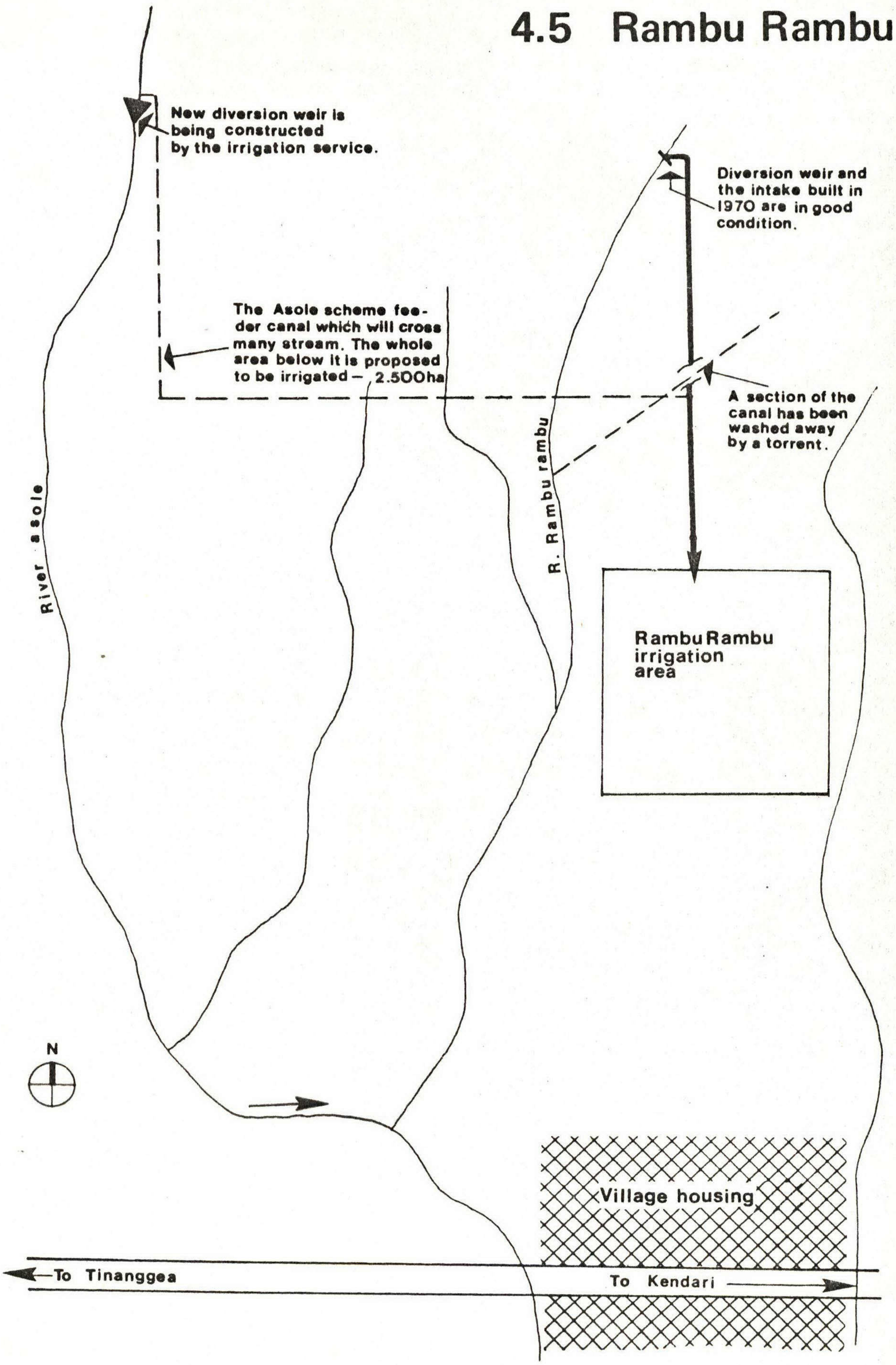
4.5.3 , Asole scheme

The Provincial Office of the Directorate General of Irrigation have prepared a scheme to irrigate some 2,500 ha in the Asole river basin with a diversion weir on the river as shown in Figure 4.5. Designs are in progress and it has not been possible to study the proposals in detail.

However, discussions with the Directorate General of Irrigation staff have revealed that the 120 ha in the Rambu Rambu resettlement area are included in the command. A canal has been proposed to cut across the Rambu Rambu and several other streams.

In the absence of information regarding water balance and without studying the canal design it is difficult to comment on the feasibility of the proposal. However, the fact remains that base flow of most of the rivers in the area is small. Therefore it is recommended that the existing irrigation works should

4.5 Rambu Rambu



be repaired and irrigation restored for the Rambu Rambu resettlement rice fields when the Asole scheme is implemented, and if there is surplus water in the dry season it should be used to supplement supplies. The Asole has a catchment of 74 km^2 and its catchment yeild estimates are given below.

Table 4.7 Estimates of mean yield, Asole catchment (times/sec)

J	F	M	A	M	J	J	A	S	O	N	D
2229	2847	3387	3182	3546	3165	1972	985	751	380	738	1519

Source: SESP.

4.5.4 Proposed improvements

a The diversion weir and the intake are in good order and only minor repairs are required.
b A cross drainage structure should be constructed where the canal has been breached.
c Canal gradients should be checked and the section cleared of accumulated gravel and silt.
d 8 distribution boxes should be constructed to assist farmers with minor canalisation.

The cost of these works is estimated at US $ 25,000.

4.6 Ameroro

The transmigration settlement of Uepai is located within the Ameroro irrigation scheme. It is situated on the main Kendari–Kolaka road, about 82 km from Kendari near the road bridge on the Konaweha river.

The Directorate General of Irrigation plan to irrigate some 4,000 ha from the Ameroro river, a tributary of the Konaweha river. However, the area measured from the available irrigation maps is only about 2,200 ha. It is possible that the remaining area is in the lower parts of the system for which maps are not available.

A local firm of consultants have carried out surveys and design under the direction of the Directorate General of Irrigation, Bandung. The construction is being supervised by the Provincial DGI staff and about 80% of the construction of primary and secondary canals has been completed. The diversion weir and the intake are complete, and the primary canal has been constructed up to Lambuya. All secondary canals which will be required to irrigate the Uepai settlement area are substantially complete.

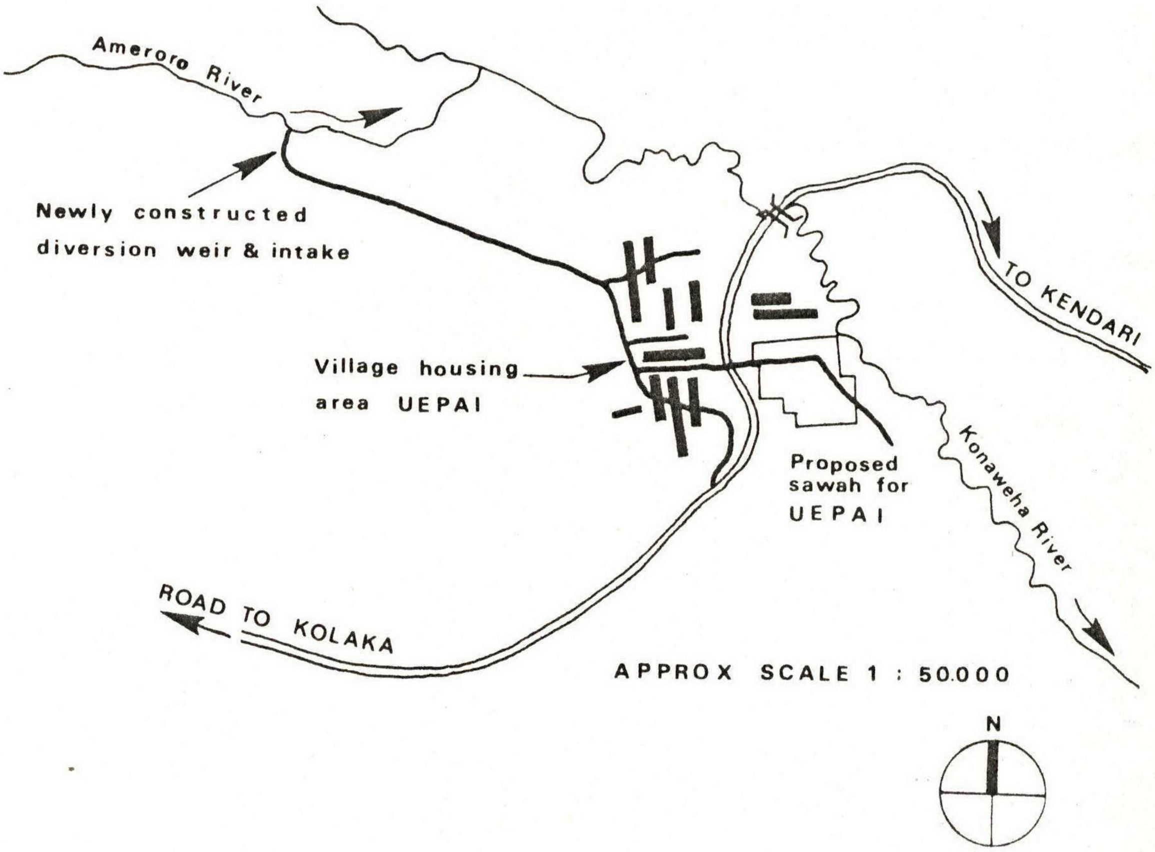
It has not been possible to check flood discharge capacity of the weir or the design of foundations. However, the upstream guide banks need raising and strengthening. Similarly, some protection works will be required on the downstream left guide bank.

The primary canal on its head reach has been cut through the hill. The concrete lining in the rock section has already collapsed. The rock formation is schist, and pore pressures will be high if impermeable lining of any kind is used. The purpose of lining is to check leakage of water from the canal. Better results can be obtained by grouting the formation with a lean mix of sand-cement.

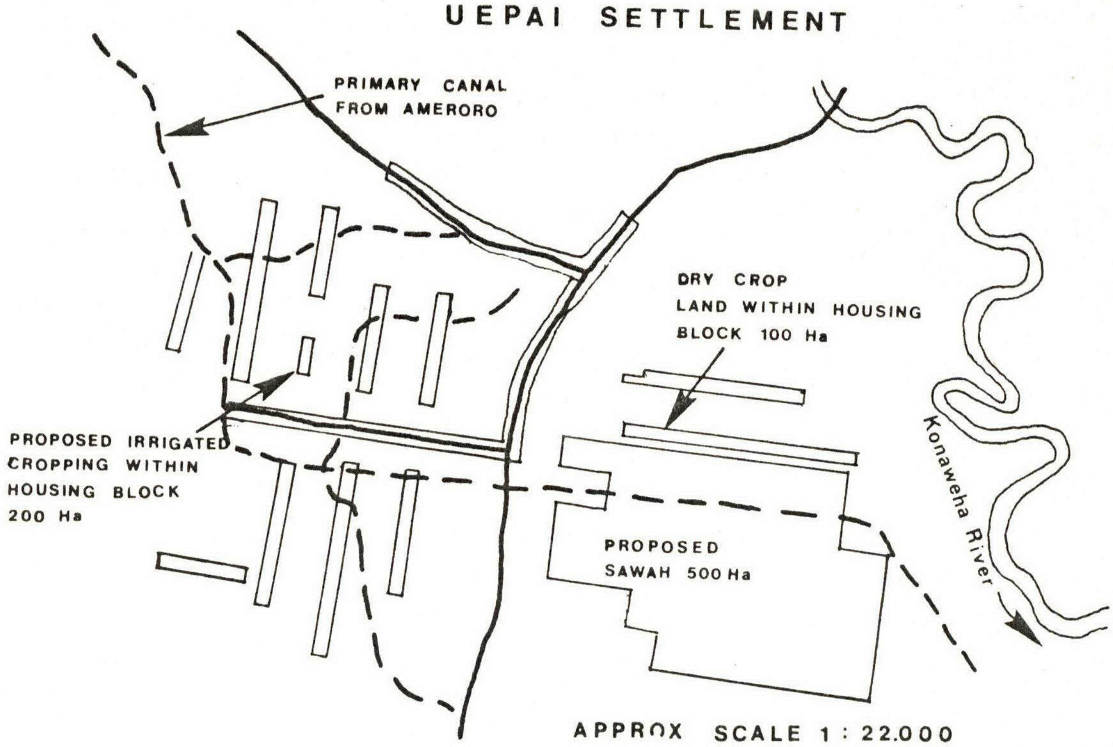
In the remaining length the primary canal has reaches of deep cut and large fills. It may have been possible to align the canal in a better manner but the constructed canal should be able serve the purpose quite satisfactorily. However, some additional cross drainage structures will be required and some reaches of the canal will have to be lined. The same type of work will be required for secondaries in the settlement area.

Tertiaries and quaternaries will all have to be redesigned and constructed before the irrigation system could become fully operational.

4.6 Ameroro



UEPAI SETTLEMENT



4.6.1 Mapping

1/5,000 contour maps were studied in the small Project Section in the Directorate General of Irrigation offices in Jakarta and a set of 1/25,000 scale map showing the irrigation layout was obtained.

The whole area is covered by the 1/22,000 aerial photo mosaics. Figure 4.6 shows the transmigration settlement areas in the inset and the whole system is illustrated on 1:250,000 scale.

4.6.2 Uepai settlement area

The settlement first started in November 1974 and now there are 549 families. Their distribution is: 250 families from Jakarta, 100 families from Bali, 150 families from Central Java and 49 families from Ujung Pandang. There is no irrigation at present.

Proposed irrigation areas have been indicated in Figure 4.6 with 500 ha of irrigated land on the eastern side of the road and 800 ha of dry cropland within the village housing areas.

4.6.3 Water availability

The Ameroro river has a catchment of about 120 km^2 at the weir site. With dense forest cover the catchment can be relied on to give a substantial base flow. Discharge measurements suggest that the minimum dry season base flow would be more than 1,000 l/sec.

The Wawotobi rainfall station is the most relevant to this area. The average monthly distribution of rainfall and estimates of catchment yields are given below in Table 4.8:

Table 4.8 Mean monthly rainfall and estimated catchment yields.

	J	F	M	A	M	J	J	A	S	O	N	D
Mean rainfall (mm)	148	138	169	153	261	217	212	135	124	67	74	122
Yield estimate (l/s)	2584	3285	4162	4111	7012	5329	4461	2478	2126	960	1028	1748

Source: SESP.

4.6.4 Recommendations

The resettlement is a part of a big scheme which has been nearly completed. However, the completed system requires some improvements and modifications. Some of this work will benefit the whole command but most of its is for the Uepai settlement.

The improvements are considered essential for the efficient running of the system. Those which affect the Uepai area are listed below:

- Strengthen guide ganks on the diversion weir;
- Grout the rock formation near the intake;
- Construct additional cross drainage structures;
- Line the canals where the height of fill is substantial;
- Construct tertiary canals in the Uepai irrigation area;
- Provide distribution boxes within the Uepai irrigation area, so that farmers will dig quaternaries in an organised matter.

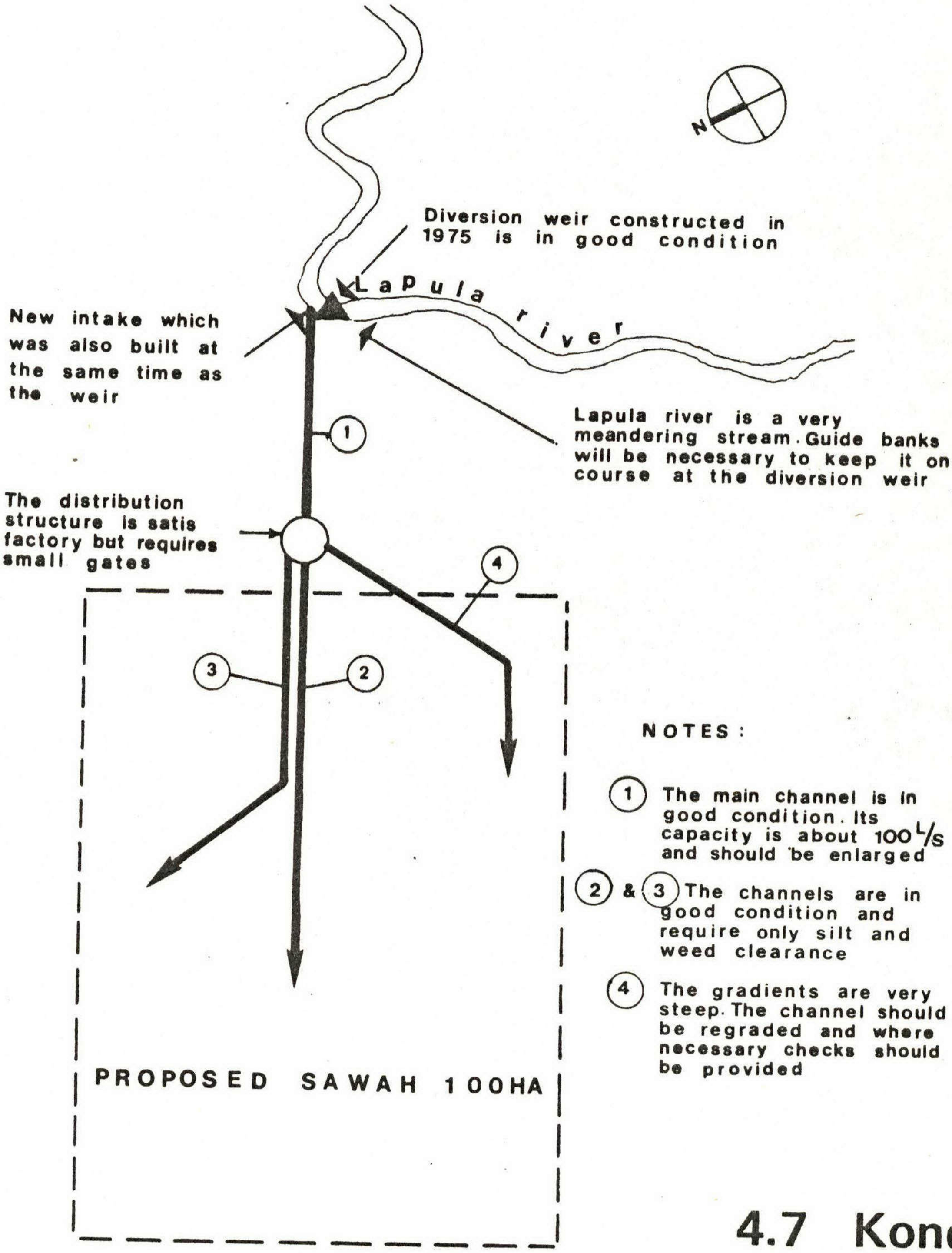
Very approximately, the cost of the proposed improvements is estimated at US$ 600,000.

4.7 Konda

The Konda settlement village lies about 20 km south of Kendari along the road to the Roraya area.

The present town of Konda is completely new and is situated on the site of the old village which was abandoned in the late 1950s. New settlers started to arrive in 1973 and now there are about 800 families in the village from various parts of Java.

Maps and plans were not available and the area is outside the aerial photography cover. An approximate sketch (Figure 4.7) has been prepared to show the irrigation arrangements.



4.7 Konda

4.7.1 Irrigation area and water availability

It is proposed to develop about 100 ha of irrigated field. At present about 10 ha are irrigated and the remaining area is yet to be developed.

The Lapula river with a catchment of about 6 km is the source of irrigation water. The current metre measurements carried out in November 1976 indicate a dry season base flow of 10 l/sec.

Kendari is the most suitable rainfall station and by using factors given in Chapter 2 the monthly average catchment yields have been estimated. These are given below:

Table 4.9 Mean monthly rainfall and estimated catchment yields

	J	F	M	A	M	J	J	A	S	O	N	D
Mean rainfall (mm)	207	194	223	192	214	209	152	87	71	43	86	172
Yield estimate (l/sec.)	185	240	300	311	240	194	102	58	33	10	40	116

Source: SESP.

4.7.2 Irrigation works

There are no signs of the old diversion weir and the intake structure. It is said that the new structure has been built on the same site. The construction of the new weir and the intake was completed in 1975. The canals, except the quaternary No 4, are in good order. The main channel can carry about 100 l/sec, which could not be adequate for 100 ha of irrigated land.

The Q4 channel is very deep and has eroded the section. The water level is too low to command land in the deeply incised channel.

The masonary of the distribution structure is in good order but there are no stop logs or gates. Without controls the structure cannot be used for regulation or rotation.

Field channels have not been developed over the whole area. Being newly constructed, farmers have been able to irrigated only about 10 hectares.

4.7.3 Proposed improvements

Although the base flow is low, which means shortage in the dry season, the irrigation system is quite promising. It should be able to serve the area at least for one rice crop in the wet season, and part of the area should be able to sustain a second crop.

The Lapula river is unstable and can meander away from the weir. It is therefore proposed that guide banks of suitable section and length should be constructed to contain the river on its course at the weir site.

Remodelling of the main channel (see Figure 4.7/1) is necessary to take full advantage of high discharges in the river. Its capacity should be increased to 250 l/sec.

The distribution structure should be provided with simple under-shot gates to allow regulation at this structure. The quateranary (4) should be regraded by introducing check where necessary. Some assistance would also be required by farmers in digging minor canals.

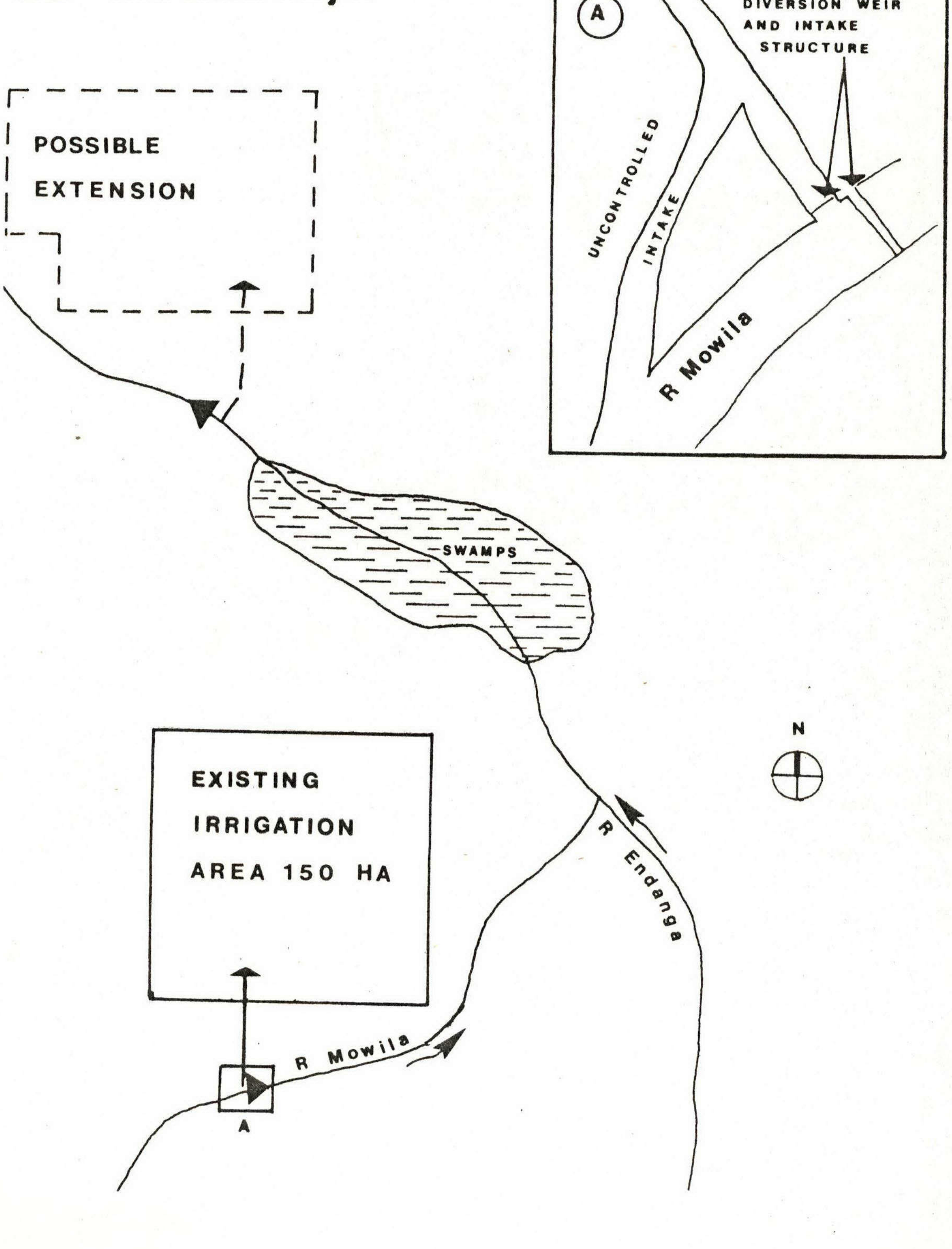
The cost of those works is estimated at US $ 15,000.

4.8 Mowila Jaya

The Mowila Jaya settlement village is situated about 46 km west of Kendari along the Kendari–Motaha road. The settlement was established in 1972 and there are now 317 settler families.

Maps of irrigation layout are not available and the area is outside the cover of the 1975 aerial photography. A rough sketch given in Figure 4.8 shows the diversion arrangements.

4.8 Mowila Jaya



4.8.1 Water availability

The present diversion is from the Mowila river. The catchment area is 12 km^2. The Mowila is a tributary of the Endanga river which passes through a swamp immediately downstream of the confluence. The catchment area of the Endanga up to the confluence point is 20 km^2.

By using the average annual rainfall distribution at Wawotobi, the catchment yields of the two rivers have been estimated, approximately. These are given below in Table 4.10.

Table 4.10 Mean monthly rainfall and estimated catchment yields

	Unit	Catchment area km^2	J	F	M	A	M	J	J	A	S	O	N	D
Rainfall	mm		148	138	169	153	261	217	212	135	124	67	74	122
Endanga	l/s	20	442	570	757	827	974	670	475	302	192	50	114	273
Mowila	l/s	12	265	342	454	496	584	402	285	181	115	30	69	164

Source: SESP.

Current meter measurements in November 1976 have suggested a base flow of 18 l/sec in the Mowila river.

4.8.2 Irrigation works

A diversion weir and an intake structure were constructed on the Mowila river in 1972. However, since then, the river has changed course and it now flows directly into the canal (see inset in Figure 4.8). In high floods some water goes over the weir, otherwise the structure in its present state is completely out of use.

As a result of uncontrolled influx from the river the channel section is badly eroded, which causes flooding at high flows. In low flows, water in the deeply incised channel cannot command land.

4.8.3 Proposed improvements

This is a typical case of failure of the diversion arrangements. When a permanent structure is built across a wandering stream on alluvial plains, the natural tendendy is for the river to by-pass the obstruction.

To remedy the situation extensive river training works will be required to bring the river channel back to the weir. A simpler solution would be to protect the point at which the river has changed course by providing some stone pitching. A gabion barrier should be constructed so that uncontrolled flows do not enter the canal. Concrete pipes of suitable diameters should be set in the gabions to enable diversion into the canal.

These works are meant to serve the purpose of diverting the main river stream back to the old course. However, the levels at the diversion weir crest and the discharge capacity over the weir must be checked. If these are inadequate, the diversion weir should be modified, otherwise the river will find another course and leave the diversion structure high and dry again.

The canal section needs to be restored; this can be done by constructing suitable checks and brushwood groignes to raise the waterlevel, which will help natural silting in the eroded section. Minor canalisation will require modifications, and some distribution boxes and new channels should be constructed.

4.8.4 Possible extension and implementation

There is a possibility of providing new irrigation for some 200 ha north of the present area and across the Endanga river. Preliminary estimates suggest that the Endanga river has sufficient water to irrigate at least one rice crop and possibly a second crop over part of the area.

For the extension area, diversion can be achieved by constructing a gravity intake without a weir across the river. It has not been possible to carry out levelling surveys. It is therefore recommended that both modifications at the existing system and designs for the possible extension area should await detailed survey. Preferably, the work should be carried out by competent consultants.

For budgeting purposes the cost of improving the existing scheme is estimated at $ 150,000, and the creation of the new irrigation area $ 300,000.

4.9 Unaaha

The Unaaha transmigration settlement is situated to the north of Unaaha village on the main Kendari–Kolaka road.

There are 280 settler families in the settlement, which was established in 1974. At present no land is irrigated and only about 148 ha are under rainfed cultivation. The Directorate General of Transmigration plans have earmarked about 300 ha of irrigated area for settlers.

The Provincial Office of the Directorate General of Irrigation have plans to construct a scheme to irrigate some 4,000 ha from The Lahumbuti river. The Unaaha settlement is included in the command of the proposed irrigation system. It is hoped that about 300 ha in the settlement area will be irrigated from this scheme.

The whole Project Area has been surveyed and 1:5,000 contour maps are available. The irrigation layout is given on a 1:25,000 map which is based on the original contour maps. However, the area lies just outside the limits of the 1:22,000 aerial photo cover.

The surveys have been completed and designs for irrigation works are in progress under the direction of the design section of the Directorate of Irrigation in Bandung.

4.9.1 Proposed improvements

A diversion weir and an intake structure are proposed on the Lahumbuti river near Aboki, just north of the village of Sambeani. The irrigation network shown on the 1:25,000 appears adequate. The contour information is correct. However, flood embankments and drainage channels are not shown. Without these the commanded area will be badly affected and benefits cannot optimised.

The Lahumbuti has a large catchment (496 km^2) and the water availability should not be a constraint except in the driest parts of the year (See Table 4.11).

Table 4.11 Mean monthly rainfall and estimated catchment yield

	J	F	M	A	M	J	J	A	S	O	N	D
Mean rainfall mm (Wawotobi)	148	138	169	153	261	217	212	135	124	67	74	122
Run-off factor	.39	.48	.55	.58	.60	.53	.47	.41	.37	.32	.30	.32
Yield estimate l/s	11020	12650	32280	16950	29910	21970	19030	10570	8760	4090	4240	7460

Source: SESP.

This is an important scheme and will have considerable bearing on the proposed Wawotobi Scheme. It is therefore recommended that all designs and layouts should be reviewed by the consultants of the Wawotobi Scheme before construction is started. Some check surveys and hydrological analyses will have to be carried out before constructive suggestions can be made.

This scheme would form a major part of the implementation programme detailed in Chapter 5. The share of the cost of canalisation for the resettlement area (300 ha) is estimated at US$ 450,000.

4.10 Ladongi

The Ladongi area has two settlements – Ladongi I and Ladongi II. These are located south of Rate Rate at a distance of 8 and 14 km respectively on the main Kendari–Kolaka road.

The settlements were established in 1973 with transmigrants from Bali and East Java. There are 1072 families in Ladongi I and 531 in Ladongi II. The proposal is to irrigate about 1500 ha from the Ladongi river. At present some land (½ ha) is irrigated from a small weir about 50 m downstream of the proposed weir site. The Ladongi I settlement benefits from this diversion.

The areas designated for irrigation have only partly been cleared, and holding boundaries are scheduled to be demarcated in 1977.

The settlement falls in an area for which the Directorate of Irrigation have prepared irrigation scheme. Topographic surveys have been carried out and contour maps for the whole irrigation area are available on 1:5,000 scale and for the proposed irrigation layout on 1:25,000 scale.

A part of the area is covered by the 1:22,000 aerial photography, which was carried out in 1975.

The scheme of the Directorate General of Irrigation, in which the proposal is to irrigate a total of 2,200 ha, is being designed under the supervision of the Directorate of Irrigation, Bandung. At the time of the survey the designs were still in progress and it was not possible to discuss the various design considerations or to comment on the suitability of the proposals.

However, from a study of the layout on 1:25,000 scale it appears that the proposed scheme will be suitable if the contours are correct. Irrigation boundaries and command levels are not given on the lay-out plan. It is therefore not possible to comment on the area that can be irrigated from the proposed weir.

However, the topography is generally very uneven. It may not be possible to command small local ridges and mounds and some depressions may be difficult to drain. This may result in some reduction in the irrigation area put forward by Directorate of Irrigation.

To the east of the proposed irrigation, the water level in the Opa Swamp rises in the wet season. Since the irrigation area is right on the edge of the swamp it will be subject to flooding in the wet season. The proposed irrigation lay-out does not show any flood protection works or drainage network. These aspects are very important and should be included in final implementation.

4.10.1 Water availability

Using the rainfall records at the station at Mowewe, mean annual rainfall is estimated at 1815 mm.

The Ladongi river rises to the west of the settlements in the range of mountains between the Kolaka coast and the Opa Swamp. The catchment area which is covered in primary and secondary forests is estimated at about 120 km^2. Using the approximate runoff factors for large catchments (Chapter 2) an attempt has been made to estimate catchment yields. The estimated catchment yields for the Ladongi river are given below:

Table 4.12 **Mean monthly rainfall and estimated catchment yields.**

	J	F	M	A	M	J	J	A	S	O	N	D
Mean rainfall (mm)	150	159	175	208	284	225	174	111	131	93	120	82
Yield estimate (l/s)	2619	3784	4310	5589	7630	5525	3662	2038	2246	1333	1668	1175

Source: SESP.

Current meter measurements in October 1976 suggest the dry season base flow to be about 1,000 l/s.

In the Ladongi area there is another small stream to the east of Ladongi flowing from north to south. If a suitable structure site can be found and if the levels permit, this stream can be considered as a supplementary source of water for the eastern parts of the proposed irrigation area.

4.10.2 Irrigation works

We recommend the construction of new irrigation works to be carried out in 1977–79. Before the construction starts the designs should be examined and, where necessary, modified by a competent team of consultants. Flood protection works and a drainage system should be included in the final project.

As mentioned earlier, designs and cost estimates for the proposed scheme were not ready at the time of writing this report. Therefore, using the unit cost of irrigation development from the Wawotobi scheme, the cost of irrigation of the 1,000 ha for the settlements is estimated at US$ 2,250,000.

4.11 Lapoa

The Lapoa settlement is located some 113 km south west of Kendari and about 6 km east of Tinanggea. The settlement is planned for 500 families, who are already in the area.

The construction of the Provincial Irrigation Service scheme is in progress; it is to irrigate 1,000 ha (see Figure 4.9) in the area which overlaps the area allocated to settlers. The construction started in 1974 and the government canalisation work will be completed in 1977.

1:5,000 contour maps and a general layout plan on 1:25,000 scale were available. Some drawings for important structures were also examined. However, canal long sections and design calculations could not be located.

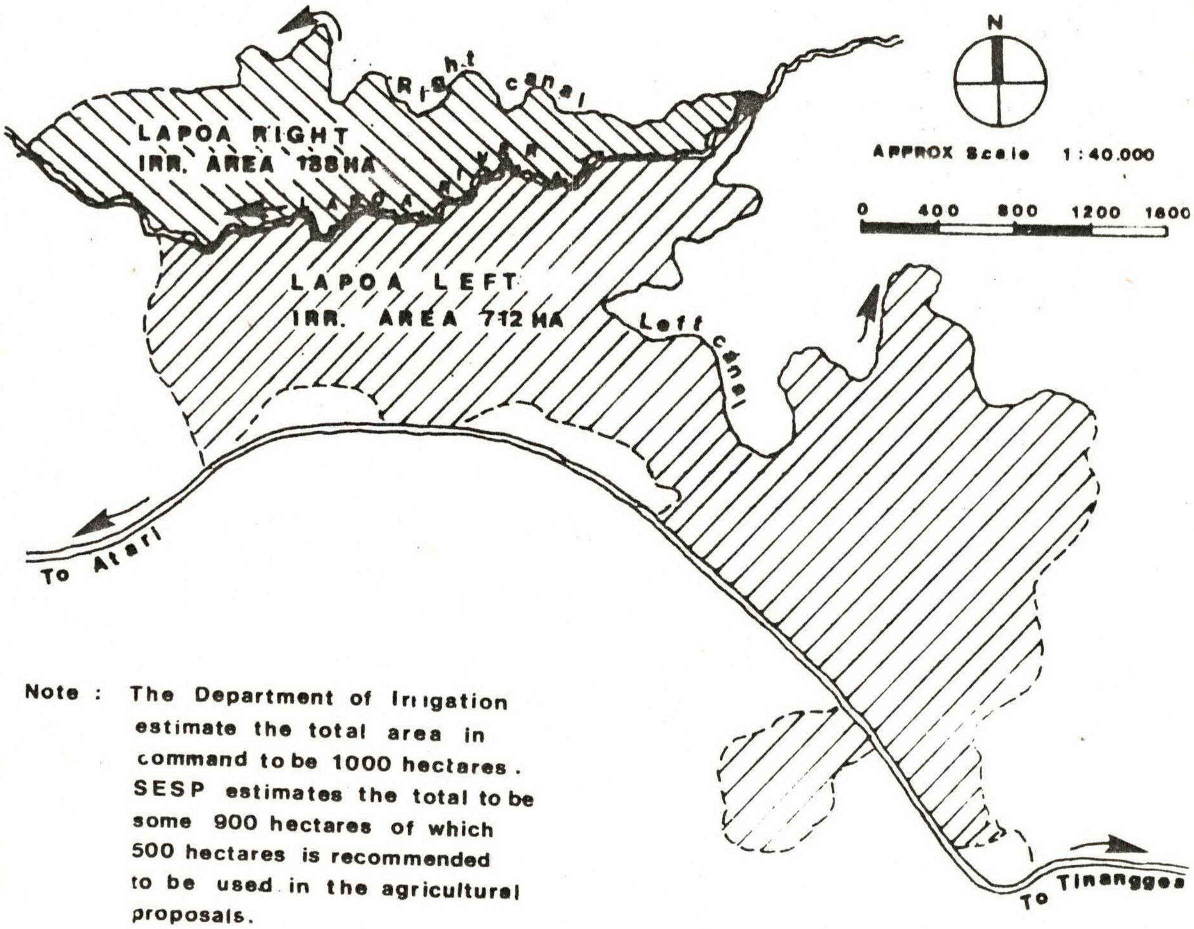
The main irrigation works include the following:

– Diversion weir of the Lapoa river about 2.5 km north of the main road
– Left bank primary canal – 2.6 km
  secondary canals – 7.5 km
– Right bank primary canal – 2.0 km
  secondary canals – 3.5 km
– Control structures 3
– Tertiary head regulators – 5
– Cross drainage structure – 4

4.11.1 Progress

The diversion weir and the intake structures for both the canals together with guide banks have been completed. The site chosen for the weir may cause problems. Just upstream of the weir there is a low-lying area, which will be inundated as a result of the highes water level once the weir has been constructed. A large embankment has been built to protect this area. However, the present section of the guide bank would be inadequate for floods larger than the average annual return period flood. Structurally the weir and intakes appear quite satisfactory. However, flood design calculations for the weir were not available and it is not possible to comment on the designed water-way capacity.

Both primaries are contour canals. Banks are made up of sandy material excavated from the bed and seepage losses are expected to be high. Some additional cross drainage structures will be required to protect the road from being washed away by torrents. The stability of the channel section is in doubt. The 1:1 slope is not likely to stand during the wet season, especially since the soil is relatively non-cohesive. The main canal sections in any case need enlarging, their present capacities being inadequate to carry wet season irrigation requirements. The secondary canals are small but their sections are adequate. However, more control structures and checks will be required to facilitate efficient control. Minor canalisation is not developed, and designs for tertiaries and quaternaries have not been prepared.



Note : The Department of Irrigation estimate the total area in command to be 1000 hectares. SESP estimates the total to be some 900 hectares of which 500 hectares is recommended to be used in the agricultural proposals.

4.9 Lapoa

4.11.2 Water availability

The Lapoa river rises in the hills north of the settlement. There are two tributaries just downstream of the confluence on which the diversion weir has been sited. The catchment area is gently undulating and a major part is covered in alang-alang grass with small areas of dense forest.

The base flow according to current meter measurements in October 1976 is only about 100 l/sec. The catchment area is 37.5 km^2. The rainfall station at Kendari is most relevant. Average annual rainfall is 1768 mm and monthly distribution is given in Table 4.13. In the same table approximate estimates of catchment yields are also shown.

Table 4.13 Mean monthly rainfall and estimated catchment yield

	J	F	M	A	M	J	J	A	S	O	N	D
Main rainfall (mm)	207	194	223	192	214	209	152	87	71	43	86	172
Yield estimate (l/s)	1130	1443	1716	1612	1797	1604	1000	499	380	193	374	770

Source: SESP.

4.11.3 Settlement areas

The Directorate General of Transmigration have prepared a lay-out plan for the settlement. It follows their standard format of rectangular plots and straight line demarcations between proposed land use of various categories.

The major criticism of this arrangement is that village housing areas have been located on easilly irrigable land whereas fields have been in areas a substantial part of which will be out of command of the Lapoa irrigation scheme. This illustrates a serious lack of communication between the Directorates General of Transmigration and Irrigation. Even at this advanced stage of planning, it would be desirable to review land allocations and where possible attempts should be made to relocate housing areas outside the irrigation command.

The irrigation scheme needs modifications. Most of the canal system must be redesigned and river training works intensified. Otherwise there is a possibility that only a very small part of the proposed area will receive irrigation from the present facilities and the remaining parts will not develop as planned. There is a serious doubt about the figures given for the irrigation areas on each canal. The right bank areas are clearly over-estimated and there would be a possibility of increasing the irrigation area on the left bank. The base flows of the Lapoa river are low and, except for a small part of the command, only one wet season crop will be possible. However, since a system has been constructed it is advisable to modify it to a level from which maximum benefits can accrue.

The approximate cost of modifications in the resettlement area only is estimated at US$ 300,000.

4.12 Other irrigation areas

In addition to the individual settlements and schemes discussed in the preceding sections there are a few other proposed irrigation areas. Generally, there was not enough mapping or engineering information available to make a constructive review possible. Some units are listed in Table 4.14 with figures of areas and settlement sizes.

Feasibility studies and designs for these schemes are proposed in the subsequent phase. Of these Rambu Rambu is included in the Laeya and Towua in Wundaluko irrigation schemes. The development is proceeding satisfactorily and it is felt that there is no need for the Directorate General of Transmigration to get involved in the irrigation arrangements at this stage.

Table 4.14 Additional settlement areas

Unit	Families	Total planned land area (ha)	Irrigated area	Proposed irrigation area
Tanea Lama	163	150	–	150
Tanea Baru	500	1000	–	500
Rambu Rambu 2	169	400	–	169
Pamandati	110	220	–	110
Towua	300	600	6	300
Moramo I	1000	2000	–	1000

Source: SESP.

4.13 Implementation

As far as irrigation works are concerned the existing settlements are of two types:

a Those which are independent small units and require only minor works to improve irrigation. Amoito, Landono, Mowila Jaya, Konda, Wolasi and Rambu Rambu (T) fall in this category.

b Those where the transmigration settlements are part of a larger irrigation scheme. These settlements are quite large in themselves and the engineering works required to ensure good irrigation must take into account the whole system. The examples of this type are: Lapoa, Unaaha, Uepai, Ladongi, Towua and Rambu Rambu (S).

The proposed irrigation area for the settlers and estimated cost for irrigation works for both types of areas are given in Table 4.15.

The area and cost of the units listed in section 4.12 are not included in this table.

In order to remodel and modify the small schemes the following work is envisaged:

- Levelling surveys (check survey)
- Condition surveys at structures
- Designs
- Quantities and estimates of costs
- Construction

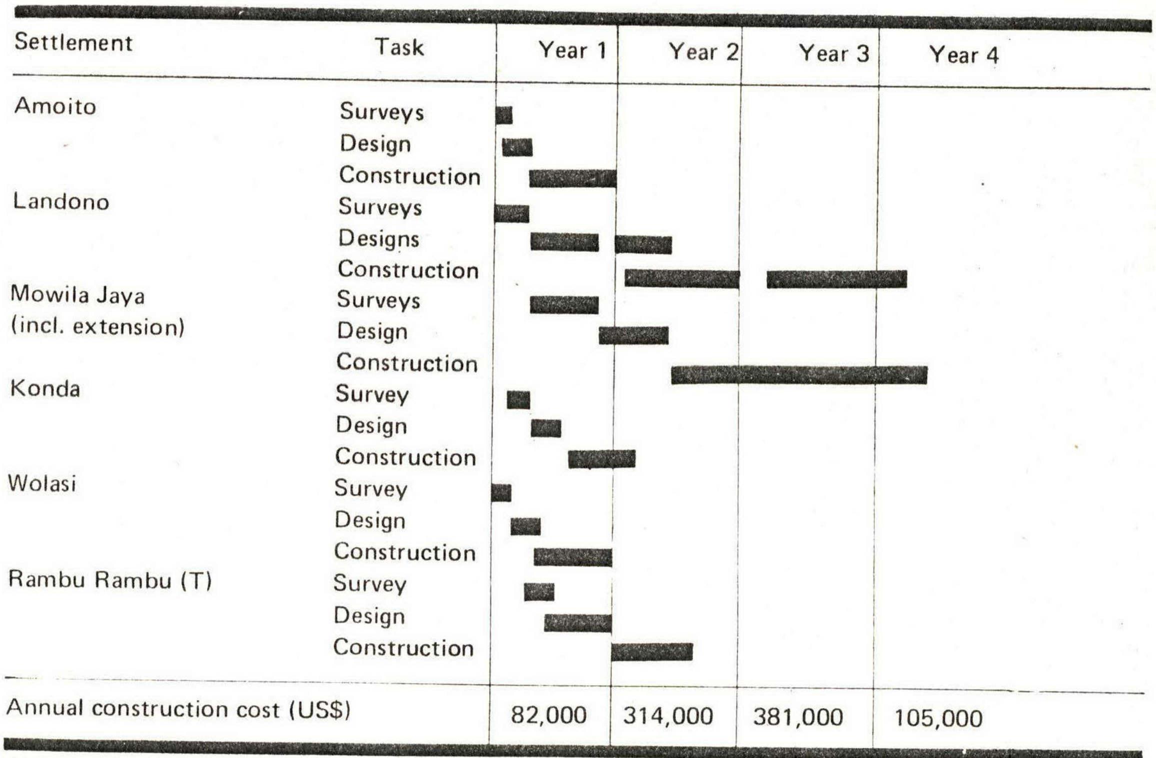
A programme for implementation is given in Figure 4.10.

Table 4.15 Irrigation areas

	Existing irrigation		Possible extension		Parent irrigation scheme	
	Area (ha)	Costs (US$)	Area (ha)	Cost (US$)	Name	Area (ha)
Amoito	150	20,000	–	–	–	–
Landono	188	35,000	250	325,000	–	–
Mowila Jaya	150	150,000	200	300,000	–	–
Konda	100	15,000	–	–	–	–
Wolasi	50	12,000	–	–	–	–
Rambu Rambu (T)	120	25,000	–	–	–	–
Total (a)	758	257,000	450	625,000	–	–
Lapoa	500	300,000	–	–	Lapoa	1,000
Unaaha	300	450,000	–	–	Lahumbuti	4,000
Uepai	700	600,000	–	–	Ameroro	4,000
Ladongi	1,500	2,250,000	–	–	Ladongi	2,200
Total (b)	3,000	3,600,000	–	-	–	11,200
Total (a) + (b)	3,758	3,857,000	450	625,000	–	11,200

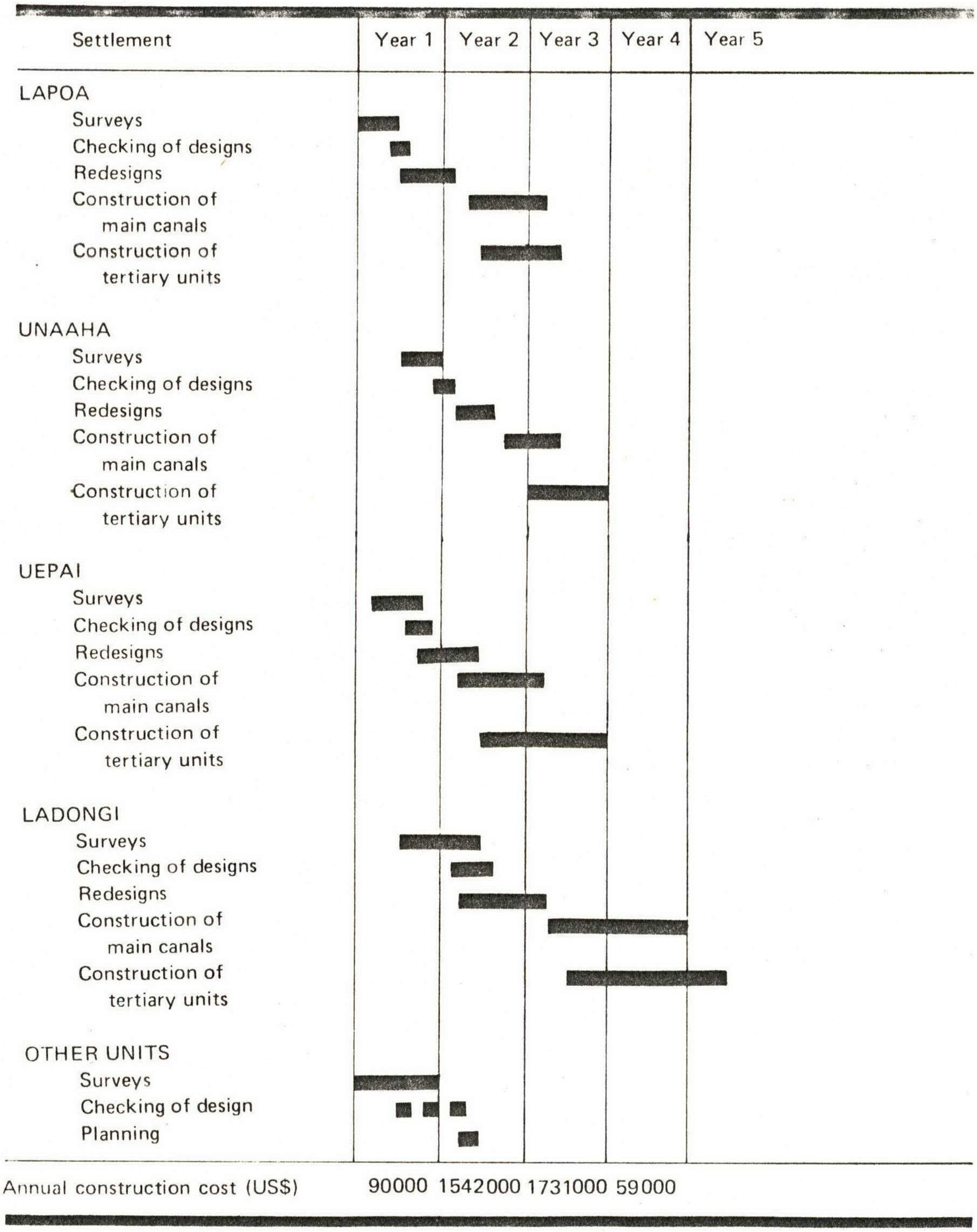
Source: SESP.

4.10 Implementation of small schemes



Source: SESP.

4.11 Implementation programme for larger settlements



Source: SESP.

For the second type of schemes, which are a part of a more extensive irrigation system, contour maps and designs prepared by the Directorate General of Irrigation are available. The first task will be to carry out check surveys to ensure the accuracy of the topographic maps. The canalisation design can then be checked and modified, taking into account the settlement areas. Some of the schemes are partly constructed. For these a survey of the as-built system will be required before review or remodelling would be possible. The anticipated sequence of work would be:

- Check surveys
- Canal line and structures surveys
- Review of designs
- Redesign, where necessary
- Quantities and estimates of cost
- Construction of intake, primaries and secondaries
- Construction of tertiary units

For the following settlement units only check surveys and review of designs is proposed at this stage. The remaining items of work will then be identified and an implementation programme proposed.

Tanea Lama
Tanea Baru
Rambu Rambu (S)
Pamandati
Towua
Moramo I

The implementation programme is given in Figure 4.11

Engineering services 5

5.1 General

The engineering works associated with the irrigation development in the Province fall under two clearly separate categories. The first one is to survey, design and construct schemes which have been identified in this report. The other type of work (future studies) relates to carrying out feasibility studies in potential irrigation areas for second stage development.

The works identified for immediate follow-up are the Wawotobi Project and the improvement of irrigation schemes for existing settlements. Implementation programmes with estimates of costs for both the existing settlements and the Wawotobi Project are given in the respective chapters. The scope of the engineering services required for these has ben discussed in this chapter.

The work associated with feasibility studies for the Solo river basin in the second stage of development is quite different. A programme of work and the engineering services required are discussed in section 5.4. Here we examine the irrigation aspects.

For both types of work a hydrological network must be established. Automatic level recorders on important rivers and new rainfall gauges should be installed as soon as possible. The proposed network is given in Figure 5.1. It is imporant that some data should be collected in the wet season as soon as possible and the installation of gauges should therefore not be delayed until the consultants have been appointed.

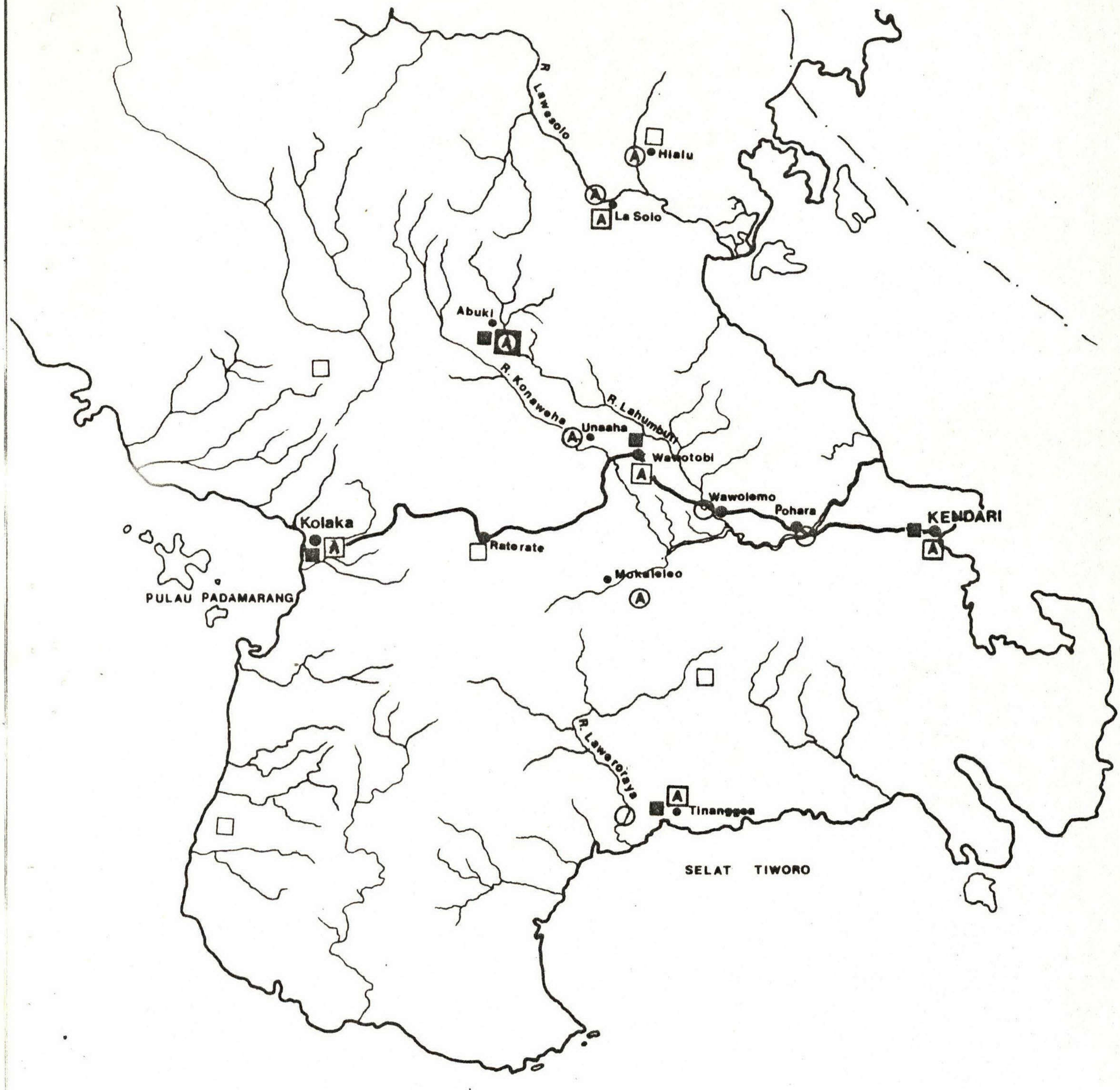
5.2 Wawotobi Project

The scope of work for consulting services required for the Wawotobi Project are given in this section. Surveys, investigations and designs will come under the heading 'task concept'; for these, the consultants will be fully responsible. The construction supervision and land levelling work will come under 'assistance concept'; for these, the consulting services will be of an advisory nature.

Figure 5.2 shows the work and staffing programme.

5.2.1 Task concept

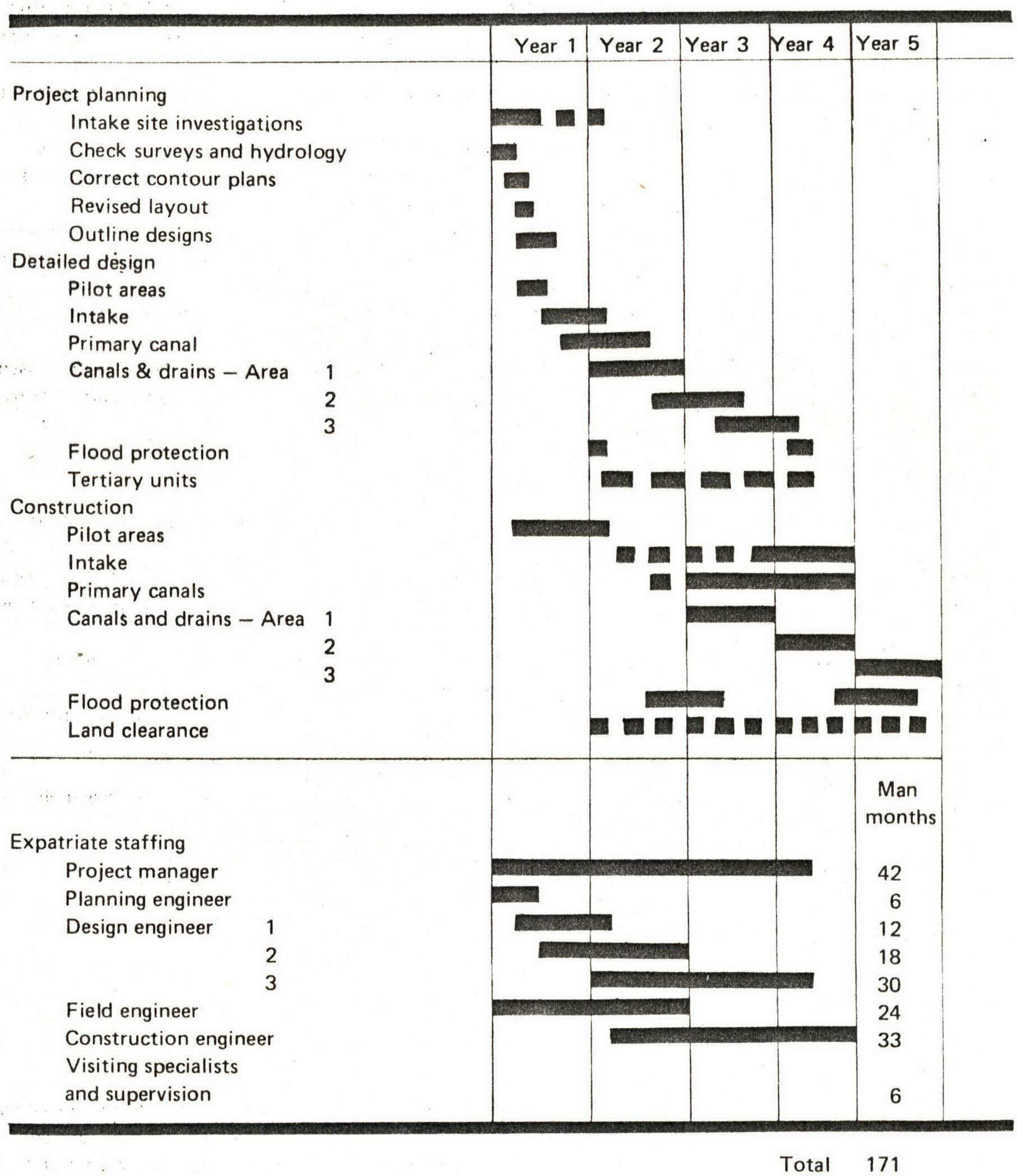
a Prepare specifications for and supervision of additional topographic surveys. The surveys will be aimed at checking the accuracy of existing survey maps and at providing enough traverses to enable corrected contour maps to be developed. The surveys will be carried out by teams of local surveyors under the supervision of an expatriate field engineer.



5.1 Gauging stations

- ■ Rainfall station, existing
- □ Rainfall station, proposed
- [A] Automatic rainfall station, proposed
- ○ Stick gauge for river gauging station, proposed
- Ⓐ Automatic river gauging station, proposed
- ■A Automatic river gauging station, existing

5.2 Wawotobi scheme, consulting services



b Check the hydrological stations established prior to the start of work by consultant. Make recommendations for expanding the network where necessary and establish efficient monitoring procedures.

Compile whatever data has been collected at these stations and use it to confirm assumptions made in the pre-feasibility stage plan.

c. Prepare specifications for and assist the Directorate General of Irrigation (DGI) with site investigations at the proposed intake site and river surveys. Investigations for alternative sites should be included in the proposal.

Supervise site investigations and produce a report on the selected intake site giving details of foundation requirement.

d When results from check surveys and site investigations become available, prepare a final irrigation lay-out. The final lay-out together with an approximate estimate of costs should be submitted to the DGI for approval.

e Prepare specifications for and assist the DGI with site investigations at important structure sites.

f With the help of counterpart surveyors carry out canal line surveys. Prepare final longitudinal sections and cross sections for all primary and secondary canals and drains.

g Prepare and submit to the DGI design criteria and drafting standards which the consultants propose to use.

h Propose design drawings for the intake, standard structures, and any other special structures.

i Prepare specifications, cost estimates and tender documents for the construction of the intake, all primary and secondary canals, and drains including the flood protection embankment.

j The development of the tertiary systems will be an integral part of the project. The consultants will be required to carry out surveys, prepare design drawing and, where necessary, tender documents for all tertiary units in the system.

k Under the task concept, design and supervise the construction of irrigation works in the demonstration areas.

l At the completion of the design phase a report should be prepared stating the principles used in the designs. The object of the report should be to have a document for the counterpart staff to use in dealing with similar design work in future.

5.2.2 Assistance concept

a Study available construction machinery in the Province and make specific recommendations for additional plant and machinery.

b Advise on efficient methods of plant management and maintenance. If it is found necessary that an independent workshop should be established, the consultants will specify machinery and assist in establishing it.

c Make recommendations and prepare plans for the most economic method of land levelling.

d Assist the DGI in the pre-qualification of contractors and the evaluation of bids.

e Assist with close and daily on-site supervision of civil works including help with overall management.

f Assist and advise the DGI in the training of its personnel.

g Advise on and help prepare operation and maintenance manuals for the use of the Provincial office of the DGI.

5.3 Existing settlement

The consulting services associated with the irrigation works in the existing settlements should all come under 'assistance concept'. The schemes have already been constructed or at least the design work has already been completed. This work will offer a good opportunity for training counterpart staff; the benefits of correct design techniques will be seen quickly on a small scheme. No expatriate inputs are envisaged for construction supervision.

The implementation programme is given in Figure 5.3.

The scope of work and the details are as follows:

a Levelling surveys and site investigations for small schemes.

b Topographic surveys to check the accuracy of available contour maps with special reference to settlement areas.

c Condition surveys of existing structures and canal line surveys.

d Preparation of designs for additional works required in the small schemes.

e Reviewing designs of the DGI schemes and commenting on the suitability of the whole system.

f Preparation of recommendations for further works on the following settlements:

- Tanea Lama
- Tanea Baru
- Rambu Rambu
- Pamandati
- Towua
- Moramo I

g Preparation of design drawings, long sections, cross sections etc. for parts of the following schemes which affect the irrigation in settlement areas:

- Lapoa
- Lahumbuti
- Ameroro
- Ladongi

h Reviewing drainage and flood control requirements and preparing necessary design.

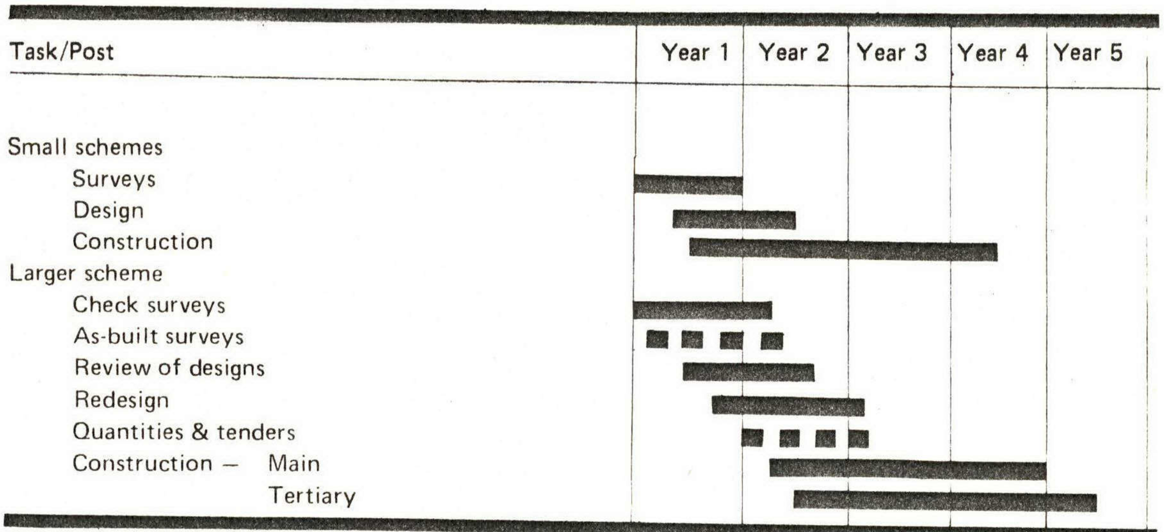
i Preparation of detailed tertiary unit lay-outs and designs for the settlement areas in schemes listed in section 5.3.

j Assistance in establishing necessary river and canal gauges. Advice on monitoring and data collection.

k Advice on operation and maintenance of irrigation systems.

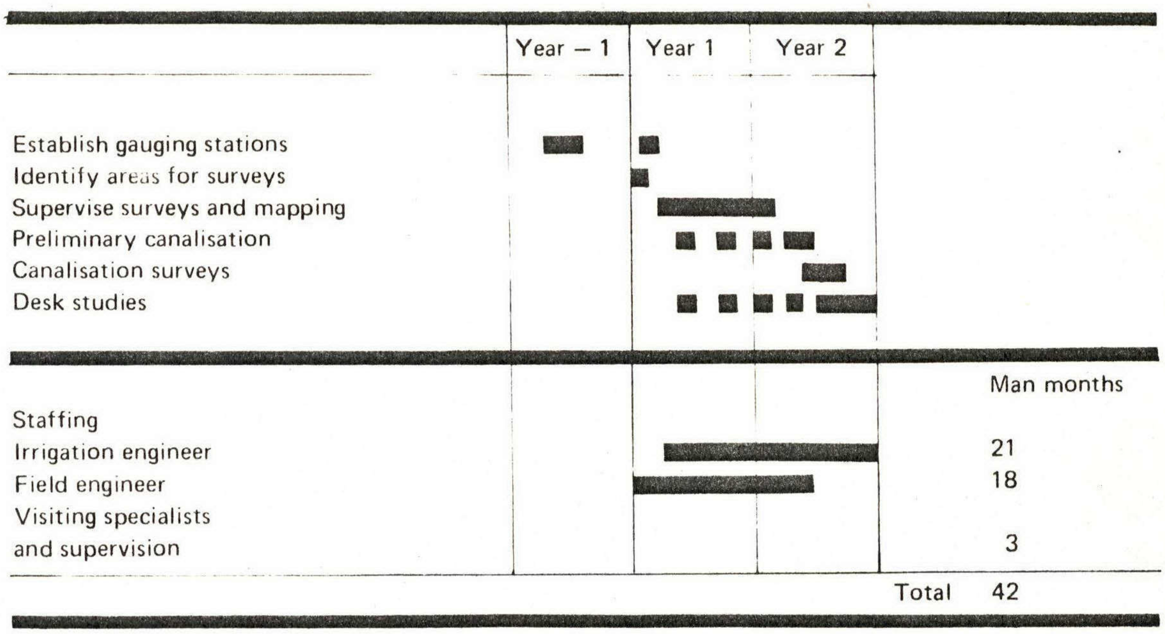
l General assistance in construction planning and use of construction machinery.

5.3. Existing settlements, consulting services



	Man months
Expatriate staff	
Senior design engineer	27
Design engineer 1	18
Design engineer 2	18
Field engineer	15
Visiting specialists and supervision	3
Total	81

5.4 Further studies for phase II development



5.4 Future studies for Phase II development

Feasibility studies for areas indentified for development in the second phase (mainly the Solo river basin) will be multi-disciplinary. The irrigation engineering inputs will be complementary to work in other fields (see Chapter 10, Volume 2).

New gauging and rainfall stations proposed in this report (see Figure 5.1) cover the second phase areas also. It is hoped that these will be installed soon and that some data will be available for the feasibility study.

The other major problem encountered during this study has been the unreliability of topographic mapping and ground level contours. Therefore we propose that in future this work should be supervised by a consultant's field engineer. The mapping, if accurately compiled in the first instance, will be a permanent record and will be used during all stages of development.

The following work is envisaged for feasibility studies in the Phase II development areas:

- a Identifying areas for detailed topographic and contour surveys. Assistance with preparations for surveys to be carried out.
- b Supervising topographic surveys and the preparation of accurate contour maps.
- c Examining gauging stations, data collection and assistance with expansion of the gauging network if necessary.
- d Analysis of hydrological data in order to assess water availability, controlling levels, floods etc.
- e Preliminary selection of possible irrigation areas (including water balance).
- f Fly levelling along proposed canal and drain lines.
- g Preparation of area discharge statements, canal capacity and preliminary canalisation lay-outs.
- h Preparation of feasibility level estimates of costs giving break down for foreign exchange and local currency elements.
- i Preparation of proposed development plan and a programme for implementation.

The feasibility study work and staffing programme is given in Figure 5.4.

Wawotobi Irrigation Project 3

3.1 The Project Area

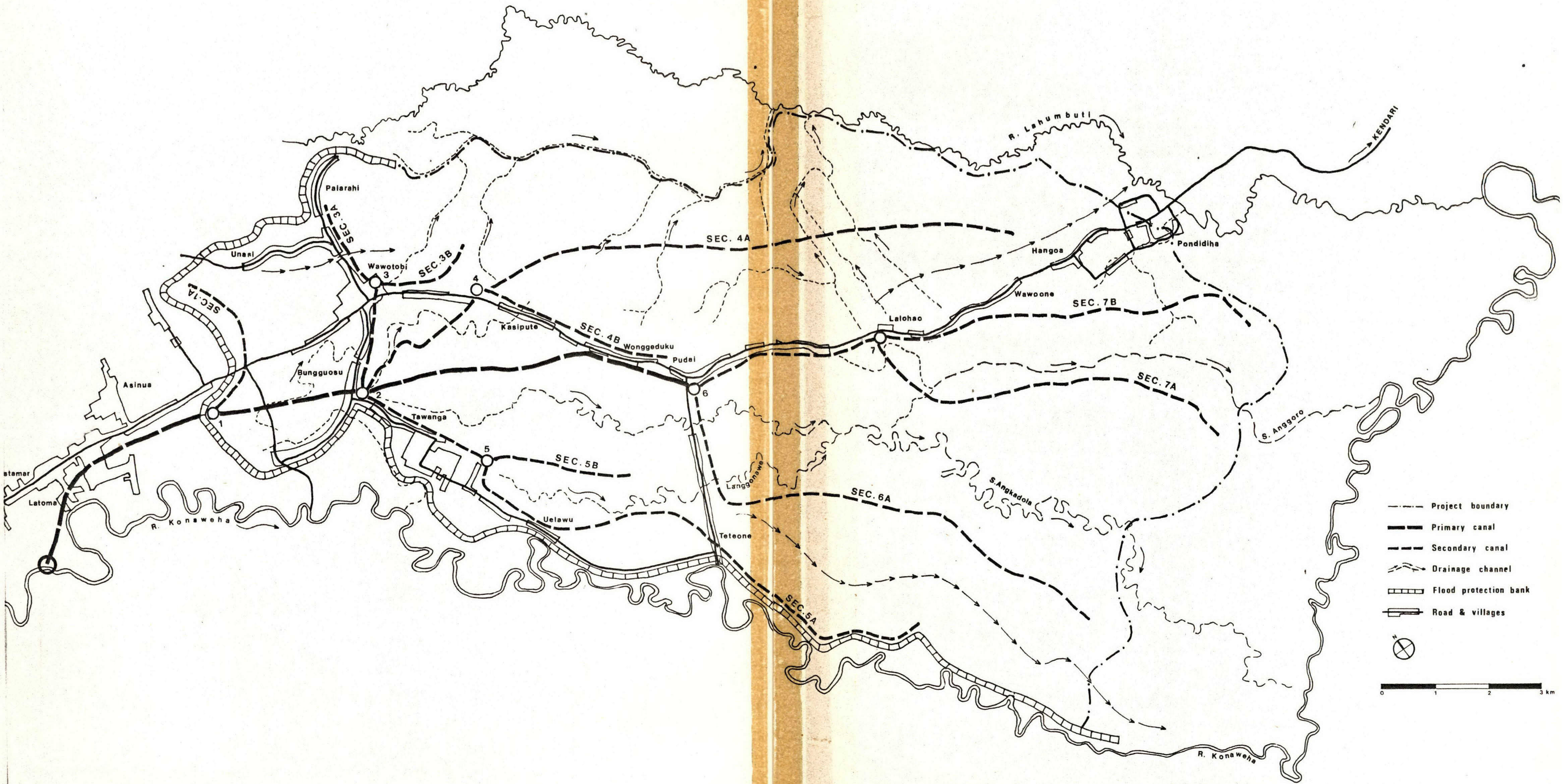
The Project Area is located on the main Kendari-Kolaka road from Wawotobi to the south east. To the north east it is bounded by the Lahambuti river and to the south west and south east by the Konaweha river.

3.1.1 Physiography

The Project Area is essentially a meander flood-plain sloping gently from north west to south east. The Angkadola river drains the area to the south of the main road and its upper reaches constitute an intricate mass of meander scars and oxbow lakes. To the north of the road the arca is severely cut up by old channels of the unstable Lahumbuti river. The southern boundary comprises swamps and peaty soils. The essential features are shown on Figure 3.1 and full details are given in Chapter 2, Volume 2.

3.1.2 Land development

The constraints to development of land are described in detail in Chapter 7, Volume 2. Areas to be excluded from development are swamps, peaty soils, deep meander scars and out-of-command land. The latter areas will however be used for villages or rainfed cropping. Areas for development include forests, scrubland and land which is cut up by old meanders and oxbow lakes. These areas, particularly the forests will require substantial clearing and then levelling into terraces. In the old meander areas, deeply incised land will not be possible to drain, and the intensity of meander scars will affect the density of canals and terraces. The areas of land to be developed are shown in Table 3.1. The location of these areas within each canal command is shown in Table 3.3 and further detailed in Chapter 4, Volume 4.



Palarahi
Unaai
SEC. 3A
Wawotobi
SEC. 3B
SEC. 1A
SEC. 4A
Kasipute
SEC. 4B
Wonggeduku
Pudai
Bungguosu
Asinua
Tawanga
SEC. 5B
Latoma
R. Konaweha
Uelawu
Teteona
Langgomawe
SEC. 5A
SEC. 6A
S. Angkadola
Lalohao
SEC. 7B
SEC. 7A
Wawoone
Hangoa
Pondidiha
R. Lahumbuti
KENDARI
S. Anggoro
R. Konaweha
Project boundary
Primary canal
Secondary canal
Drainage channel
Flood protection bank
Road & villages
N
0
1
2
3 km