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AND DEVELOPMENT IN SOUTHERN AFRICA

A case study of water sources and water quality of the Chalumna/Hamburg area of Ciskei

by

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Second Carnegie Inquiry into Poverty and Development in Southern Africa

A CASE STUDY OF WATER SOURCES AND WATER QUALITY OF THE CHALUMNA/HAMBURG AREA OF CISKEI

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During December 1983 and January 1984 a survey was undertaken with the particular objective of assessing groundwater sources in the Chalumna/Hamburg area of Ciskei. As part of the background to that hydrogeological investigation an examination was made of present water sources and domestic water use in the study area. The information presented in this paper relates to the present water supply provision and considers the sources and quality of water used, and the human energy costs of obtaining water.

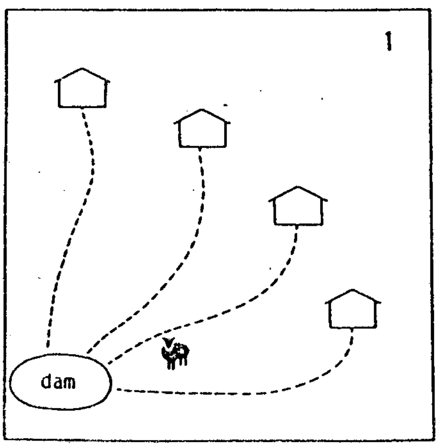
As a framework for discussion the particular conditions in the study area a 10 stage model of categories of water supply provision is presented (Figures 1-10). The model which is developed to illustrate improvements to water supply provision is based on a diagram in the text by White et al (1972). The work by White and his co-researchers in East Africa was specifically aimed at the social and economic implications of domestic water supply provision. The 10 stage model is presented over the next four pages with each figure and its associated caption representing a particular water supply provision category.

WATER SUPPLY IN RURAL AREAS. CATEGORIES OF SUPPLY PROVISION.

The ten figures below illustrate simply an increasing complexity of water supply provision. Many combined situations are possible and it is assumed that each situation incorporates the improvements of the preceeding situation. The figures are adapted from White et. al. (1972) p73.

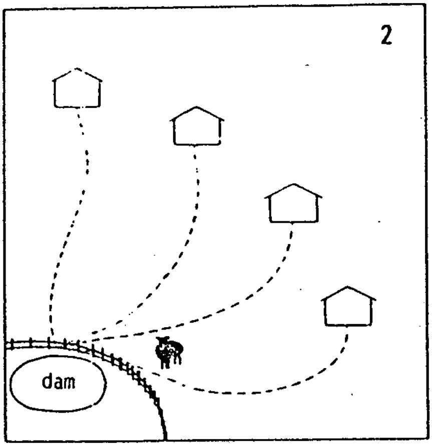
Key to figures 1 to 10

- carried water
- pipe line
- water borne waste disposal
- stand pipe
- storage tank
- WTP water treatment plant
- P pump
- rain tank
- toilet
- dwelling



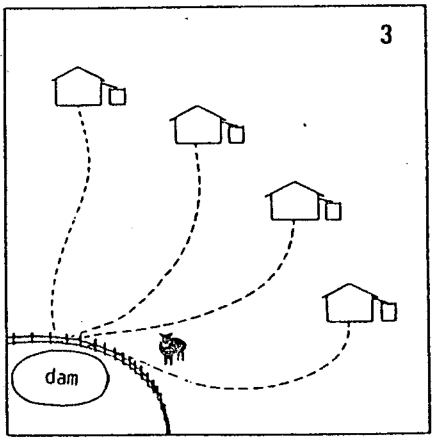
Unprotected Surface Source

In situation 1 water is obtained from an unprotected surface source (spring river or dam). The source is unprotected in that it is shared directly by animals. Some domestic activities requiring water, for example clothes washing may be carried out at the water source. Water for domestic use is scooped into containers and carried to dwellings.



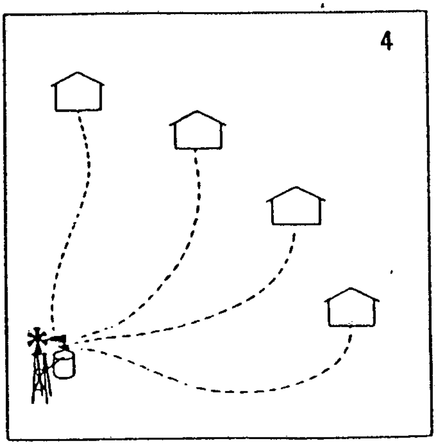
Protected Surface Source

The most elementary step in protecting a water source is to fence off all (or even part) of the source from activities likely to contaminate water. Stepping stones to deeper water will reduce turbidity of water obtained from dams.



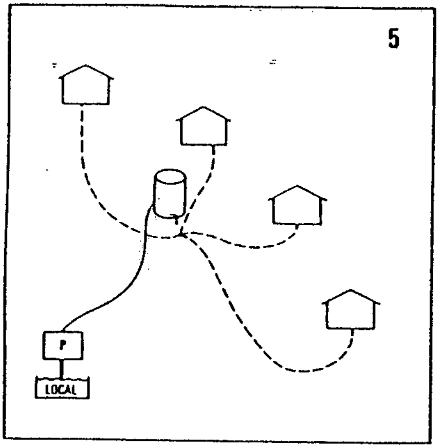
Addition of Rain Water Tanks

Collection of rainwater allows for a supplementary source usually of high quality. Guttering for circular roofs is a problem. Water stored in rain tanks could be reserved exclusively for cooking and drinking. Variability of rainfall precludes the use of rain tanks as a sole supply source.



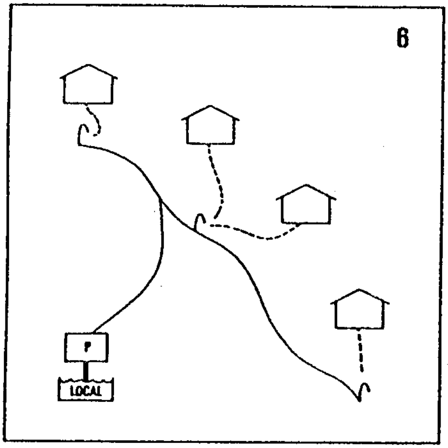
Borehole Source

Boreholes can provide water of a fairly consistent quality, free of turbidity and in nearly all cases free of pathogens. Groundwater supplies are less prone to short and medium term effects of drought. The degree of mineralization of ground water is greater than for other sources. Many areas do not have groundwater potential.



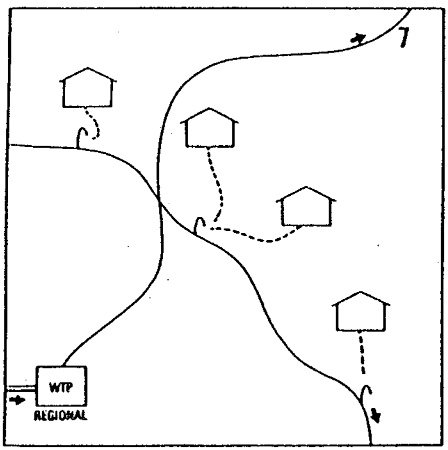
Intermediate Storage Local Source

A relatively inexpensive way to improve village water supply is by pumping from a local source to a central storage tank. Less human energy is then used in obtaining water and if 2 or more tanks are used turbidity can be greatly reduced. Management of pumping operations and control of water use are required at village level.



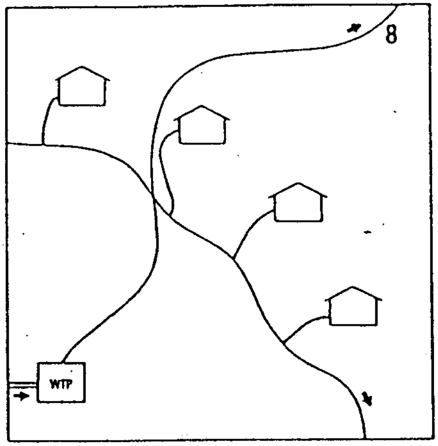
Reticulation to Standpipes Local Source

In large villages, situation 5 may not result in much saving of human energy. The provision of standpipes at points in the village will reduce human energy costs. Management at village level is required.



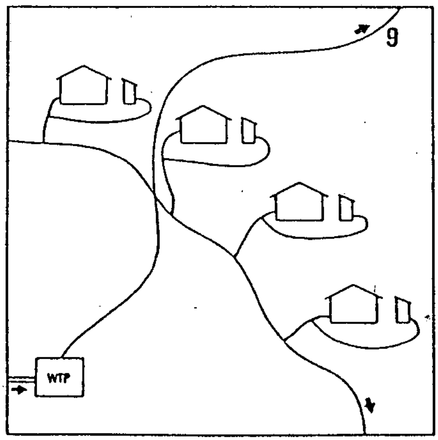
Reticulation to Standpipes Regional Source

The unreliability of some local sources requires that regional water resource development be undertaken in order to provide reliable supplies.The incorporation of water treatment plant is a likely component of such a scheme.



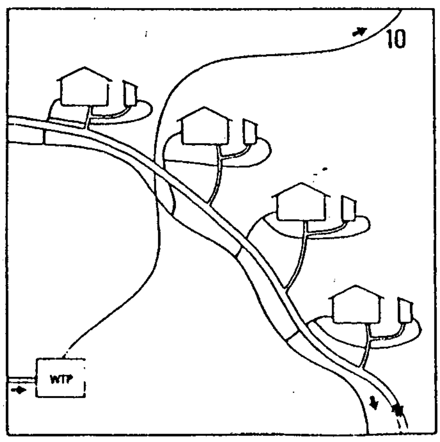
Reticulation to Dwelling Single Taps

The provision of a tap to each house is the logical extension of situation 7. Human energy costs of supply provision are reduced to nil although energy costs are involved in disposing of waste water. The problem of waste disposal becomes a limiting factor on the amounts of water used.



Reticulation to Dwelling Multiple Taps

Multiple tap provision in dwellings requires that some organised system of waste disposal is developed. French drains and septic tanks could be the basis of on site disposal.The protection of water supply source is of particular importance. Re-use of waste water could provide irrigation water for 'back-yard' vegetable growing.



Reticulation with off site water borne waste disposal.

The ready availability of water increases the amount used probably to the extent that on site waste disposal is not desirable. Local or even regional based disposal systems should be of benefit to a commercial farming enterprise. Management of supply and disposal systems would need to be on a regional basis.

In terms of the 10 stage model outlined on pages 2-5 it is assumed that category 10 is the status of water supply provision ultimately considered as most desirable. In terms of the maximisation of the welfare of the population and terms of the broad context of health and hygiene any improvement on Category 1 is advisable.

In the study area (Figure 11) shown on page 7 there are 19 villages with a combined total of just over 3 000 dwellings. The population is in the order of 25 000 over an area of approximately 240 km².

Category 1 of the supply provision model accounts for the water use of 90% of the population in the study area. The average distance from dwelling to water source is 850m with in many instances the journey being made 3 times each day. The human energy costs of carrying water are discussed on page 16 and a worked example of the basis of calculation is presented on page 11.

During the survey no instances of Category 2 provision were recorded. The cost of providing some protection of open water sources is not great but the difficulty of fencing against small stock and maintaining a closed gate would appear to make protection by fencing a non feasible improvement. Using stepping stones to deeper water would be a small improvement at almost nil cost and would be useable at any water level of the dam. The edges of open bodies of water are likely to be the most contaminated by animals, and because of trampling and wind action the edges are likely to have a higher concentration of suspended matter (turbidity).

Category 3 provision suggests the use of rain water tanks as a partial solution to suuply. Less than 2% of dwellings have functioning rain tanks although most stores, clinics and schools are provided with rain tanks. The difficulty of organising guttering for circular roofed dwellings is a real problem. The capital outlay on a tank was frequently cited as the reason for not using tanks.

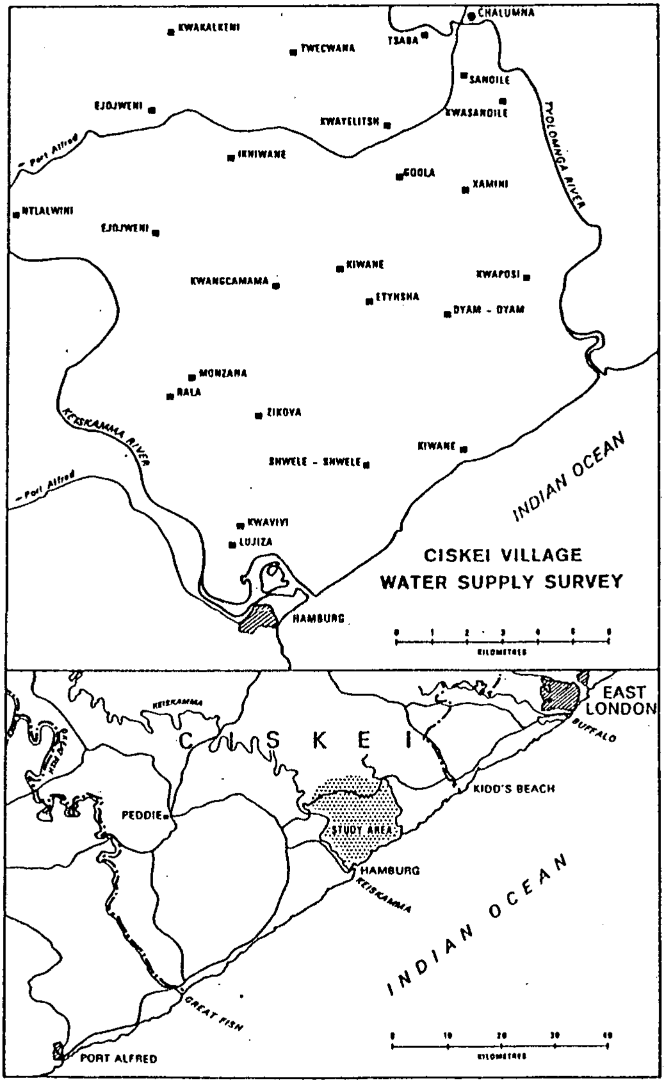
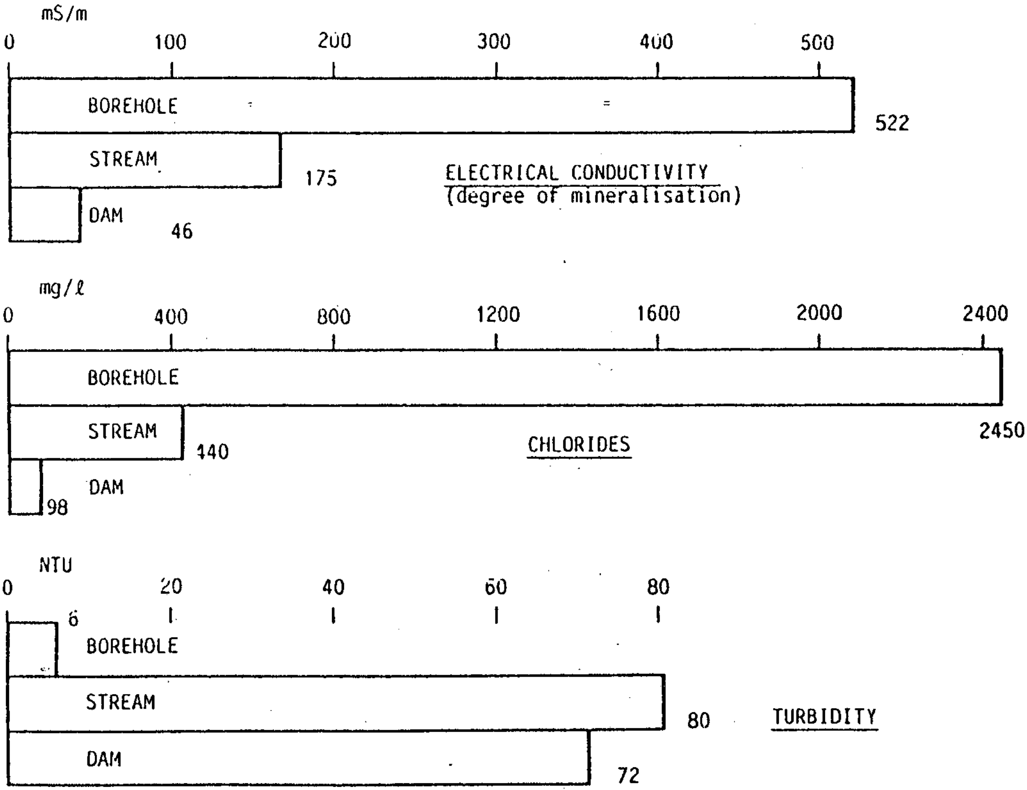

CHALUMNA
KWAKALKENI
TWECWANA
TSABA
SANOILE
EJOJWENI
KWATELITSH
KWASANOILE
TYOLOMNGA RIVER
Port Alfred
IKNIWANE
GOOLA
XAMINI
NTLALWINI
EJOJWENI
KIWANE
KWANGCAMAMA
KWAPOSI
ETYNSHA
DYAM - DYAM
MONZANA
RALA
ZIKOVA
KEISKAMMA RIVER
KIWANE
SHWELE - SHWELE
INDIAN OCEAN
Port Alfred
KWAVIVI
LUJIZA
CISKEI VILLAGE
WATER SUPPLY SURVEY
HAMBURG
KILOMETRES
KEISKAMMA
EAST
LONDON
BUFFALO
C I S K E I
KIDD'S BEACH
PEDDIE
STUDY AREA
HAMBURG
KEISKAMMA
INDIAN OCEAN
GREAT FISH
PORT ALFRED
0
10
20
30
40
KILOMETRES

FIGURE 11:

A number of boreholes occurs in the study area but the degree of mineralisation does not make groundwater a popular supply source. Less than 2% of domestic supply consumption is from boreholes. In theory, Category 4 should provide an excellent quality supply source, and although turbidity is low for borehole sources in the study area the chemical properties of the water are not acceptable to the villagers. Figure 12 shows the variations in conductivity, chloride content and turbidity for the three major supply sources of the study area.



SELECTED INDICES OF WATER QUALITY FOR BOREHOLE STREAM AND DAM SUPPLY SOURCES

FIGURE 12:

Category 5 represents the simplest method of reducing the high human energy costs of water supply. Use could be made of existing sources with portable petrol water pumps used to supply water to tanks in the village. About 8% of the population of the study area obtain water from tanks which are supplied by pipeline from a dam. Category 5 is the highest supply provision category in the study area. With some small degree of irony some villagers were better off in the drought months at the end of 1983 because water was brought by tanker and delivered to large tanks placed in the village. Tanker transport of water was necessary because dams had dried up, the effect of importing water was to raise (temporarily) the supply provision category from Category 1 to a version of Category 5.

The Ciskei Government is well aware of the water supply needs of the rural villages and because of the proven unreliability of present local sources the long term objective is to provide a regional scheme of supply. In the short term (5 years ?) it will be necessary to develop local sources possibly by constructing larger dams, blending borehole and surface water and by using portable pumps to transfer water on a local basis. A kilometer of pipeline costs about R1 000, a portable petrol pump about the same figure and large galvanised tanks or constructed reservoirs about R1 500. Crude arithmetic for the 18 permanent villages of the study area provides a figure of R63 000 to provide each village with pump piping and tank(s). One of the reasons to consider such a proposition is the high cost in human energy expended daily in the collection of water. The next section of the paper deals in some detail with the calculation of human energy expenditure of the 'drawers of water' in the study area. Table 1 (page 10) summarises the distance time and energy consumption data for water collection at each of the villages in the study area. The average dwelling uses 75ℓ of water per day which means that at least three journeys have to be made to collect water. The data presented in columns 9 and 10 of Table 1 are computed for <u>one</u> journey. A worked example of the energy calculation is presented to illustrate the method used to obtain the data. The time spent and the energy expended on water carrying would be reduced by the implementation of any scheme to bring water closer to the dwelling.

TABLE 1:

RURAL WATER SUPPLY CISKEI

TABULATION OF DISTANCE, TIME AND ENERGY CONSUMPTION DATA FOR WATER COLLECTION IN THE CHALUMNA HAMBURG STUDY AREA

	VILLAGE	1 ELEVATION ABOVE WATER SOURCE (metres)	2 DISTANCE FROM WATER SOURCE (metres)	3 GRADE (Col 1/ Col 2 x 100) %	4 TIME TAKEN FOR ONE WAY JOURNEY (mins)	5 ENERGY COST (DOWNHILL AND EMPTY BUCKET) (kJ min-1)	6 ENERGY USED (DOWNHILL JOURNEY AND EMPTY BUCKET) Col 4 x Col 5 (kJ)	7 ENERGY COST (UPHILL AND FULL BUCKET (kJ min-1)	8 ENERGY USED (UPHILL AND FULL BUCKET (Col 4 x Col 7) (kJ)	9 TOTAL ENERGY CONSUMPTION FOR WHOLE JOURNEY Col 6 + Col 8 (kJ)	10 Col 9/ 4,12 (kcal)
1	DOWU-KWA KIGCAMANIA	10	500	2,0	10	10,74	107,4	20,76	207,6	315	76
2	DYAM DYAM	50	2000	2,5	40	11,24	449,6	21.67	866,8	1316	319
3	EJOJWENI	15	600	2,5	12	11,24	134,8	21,67	260,04	295	72
4	GQALA	10	600	1,6	12	10,4	124,8	20,04	240,48	365	89
5	IKHIWANE	10	1250	0,8	25	9,68	242,0	18,59	464,75	707	172
6	KIWANE*										
7	KWAKALKENI	40	750	5,33	15	8,71	130,7	26,81	402,15	533	129
8	KWA POSI	15	600	2,5	8	11,24	89,9	21,67	173,36	263	64
9	KWA SANDILE	30	500	6,0	10	10.93	109,3	28,02	280,2	390	95
10	KWA VIVI/LUJIZA	30	1000	3,0	10	11,7	235,2	22,5	451,5	687	167
11	MOZANA	55	1500	3,66	30	12,3	371,4	23,69	710,7	1082	262
12	MPONGO	10	250	4,0	5	12,7	63,8	24,44	122,20	186	45
13	OPENSHAW	25	250	10,0	5	13,7	68,8	35,28	176,40	245	59
14	SHWELI - SHWELI	60	400	15.0	8	11,54	92,32	44,35	354,8	447	110
15	TSABA	35	2000	1,75	40	10,5	423,0	20,41	816,4	1239	301
16	TWECWANA	40	750	5,33	15	10,4	157,0	26,71	400,68	558	135
17	TYHUSHA	15		1.67	10	10,5	105,0	20,16	201,6	306	74
18	XESI MALA	30	800	3,75	10	12,46	124,6	23,94	239,4	354	86
19	ZIKOVA	25	600	4,17	12	12,8	154,0	24,67	296,04	450	109
	TOTAL	505	15250	75,56	277	191,24	3091,3	450,9	6493,8	9738	2364
	AVERAGE	28,05	847,22	4,19	15,39	10,64	171,73	25,05	360,77	541	131,3
6	KIWANE* (not included in calculations)	5	50	10	1,0	13,7	13,7	35,28	35,28	49	11,9

In the calculation of energy expenditure a large number of simplifying assumptions is made but the result of the calculations although perhaps not providing an 'absolute' figure certainly provides a relative indication energy consumption.

WORKED EXAMPLE OF CALCULATION METHOD USED TO ESTIMATE HUMAN ENERGY COSTS EXPENDED IN CARRYING WATER

The procedures adopted for the calculation are as laid down by Consolazio et al (1963) and by the American College of Sports Medicine (ACSM, 1981).

The worked example uses data for the village of Mozana, village 11 of the tabulated data (Table 1).

Seven items of data are needed for the calculation of energy cost.

	Data for calculation
1. Mass of subject (For all cases a mass 60kg was used).	60 kg
2. Mass of water containers (For all cases a mass of 2,5 kg was used).	2.5 kg
3. Mass of water carried (For all cases a mass of 18,5 kg was used).	18.5 kg
4. Distance of journey (From source to centre of village).	1 500 m
5. Duration of journey (Rate of 50m/min.$^{-1}$ used in all cases).	30 Minutes
6. Grade of climb (Vertical rise/horizontal distance).	3.66%

7. Nature of terrain (Values of terrain factor vary between 1.0 for tarred road to 2,2 for loose sand. For all cases a value of 1,2 was used as the terrain factor in the study). 1.2

In order to illustrate the method used the calculation of uphill energy expenditure is outlined in six steps and explanation is given for the basis of calculating downhill energy expenditure.

TO CALCULATE THE ENERGY USED FOR THE JOURNEY FROM WATER SOURCE TO VILLAGE WITH FULL CONTAINER OF WATER

STEP 1: Compute velocity of travel

$$\text{Velocity} = \frac{\text{distance (metres)}}{\text{time (minutes)}} = \frac{1\ 500}{30}$$

$$= \underline{50\ \text{m.min}^{-1}}$$

STEP 2: Compute oxygen consumption

NOTE: Calculation is needed for both vertical and horizontal components of the journey. The oxygen consumption is expressed in mℓ of O_2 used per kg of mass per minute ($m\ell.kg^{-1}.min^{-1}$). In the equation the value 0,1 refers to the standard consumption of oxygen at a rate of 0,1mℓ per minute per kg of mass. The value 3,5 is the 'resting' value for oxygen consumption ($m\ell.kg^{-1}.min^{-1}$).

i) Oxygen consumption for horizontal component of journey.

VO_2 = (velocity x 0,1) + 3,5 = (50 x 0,1) + 3,5

= $\underline{8{,}5\ m\ell.kg^{-1}min^{-1}}$

ii) Oxygen consumption for vertical component of journey.

VO_2 - (velocity x grade fraction) x 1,8 = (50 x 0,0366) x 1.8

= $\underline{3{,}3\ m\ell.kg^{-1}min.^{-1}}$

NOTE: The value 1,8 is the oxygen cost per unit of elevation.

The total oxygen consumption is i + ii = 8,5 + 3,3

= $\underline{11{,}8\ m\ell.kg^{-1}.min^{-1}}$

STEP 3:

NOTE: Total mass, is mass of subject + mass of container + mass of water.

$$VO_2 \times \frac{\text{mass (kg)}}{1\ 000} = VO_2 \text{in}\ \ell.\text{min}^{-1} = 11{,}8 \times \frac{(60 + 2{,}5 \times 18{,}5)}{1\ 000}$$

$$= \underline{0{,}94\ \ell.\text{min}^{-1}}$$

STEP 4: Convert VO_2 used to kJ of energy used.

NOTE: One litre of VO_2 is equivalent to 21 kJ of energy.

$$\text{Energy used} = VO_2 \text{ total} \times 21 = 0{,}94 \times 21$$

$$= \underline{19{,}74\ \text{kJ.min}^{-1}}$$

STEP 5: Take terrain factor into account.

True energy cost = energy cost x terrain factor

$$= 19{,}74 \times 1{,}2$$

$$= \underline{23{,}69\ \text{kJ.min}^{-1}}$$

STEP 6: Calculate actual energy used.

Actual energy used = True energy cost x time

= 23,69 x 30

= 710,7 kJ

Energy used for the journey from the water source to the centre of the village is 710,7 kJ (Column 8 of Table 1).

TO CALCULATE THE ENERGY USED FOR THE JOURNEY WITH EMPTY CONTAINER FROM THE VILLAGE TO THE WATER SOURCE.

The same steps of calculation are undertaken as outlined above except that:

at STEP 3 the weight of water is omitted from the calculation.

at STEP 5 use is made of a factor to account for the reduction of energy used on a down grade.

The reduction factors used are:

2/3 of energy cost for grades 5% or less
½ of energy cost for grades 10% to 5%
1/3 of energy cost for grades greater than 15%

For the example selected the calculation of energy cost at STEP 5 is 18,58 $kJ.min^{-1}$. The appropriate down grade factor is 2/3, which gives an energy cost of 12,38 $kJ.min^{-1}$. The STEP 6 calculation for the journey with the emply container is 371,4 kJ. (Column 6 of Table 1).

The total energy used for both journeys is 710,7 + 371,6

= 1082,3 kJ

The value of 1082 kJ is found is column 9 of Table 1. In column 10 the energy consumption is presented in terms of kcal.

The calculated energy value is for one journey to collect water, in practice for most households at least three journeys are made each day.

The average figures for distance time and energy costs of carrying water are presented in Table 1. If it is assumed that three journeys to the water source are needed by each household each day then the aggregate distance walked on average is 5,1 km involving an energy expenditure of 1 623 kJ. The time taken for water collection is calculated as 92,3 minutes each day. Columns 5 and 7 of Table 1 provide data on the metabolic cost of water carrying. The average rate of energy expenditure carrying water is calculated as 24,75 $kJ.min^{-1}$. This rate may be compared with values computed for:

playing volley ball	14,4 $kJ.min^{-1}$	
mixing cement	19,3 $kJ.min^{-1}$	
dancing foxtrot	21,4 $kJ.min^{-1}$	(Consolazio et al 1963)
using a pick (miners)	27,4 $kJ.min^{-1}$	
playing tennis	29,2 $kJ.min^{-1}$	

The figures quoted above provide a comparison of the energy expenditure of obtaining water. Rates vary according to body mass and gradient. In the study area the highest value computed was 44,35 $kJ.min^{-1}$ which compares in energy expenditure with a value of 43,6 $kJ.min^{-1}$ calculated for cross country running (Consolazio et al 1963).

From data on human energy cost it is possible to calculate food intake requirements needed to fuel the energy expended. Such considerations are beyond the scope of this paper but should be taken into account in cost/benefit calculations for methods water supply provision.

For the study area the principal problem lies in finding reliable sources of water. It is clear that any improvement in the provision of water will result in increased demand. Such an increase is desirable in terms of providing for improved living conditions but it poses real problems in providing for regional water demands. Chemical data presented for the water sources in Tables 2, 3 and 4 demonstrate the relative lack of mineralisation in surface water sources compared with supplies obtained from rivers and boreholes. A short to medium term solution of water sources is however to develop groundwater sources and in instances where the taste of water is unacceptable reserve its use for all non drinking requirements. Category 5 of the supply provision model is one of the most adaptable and least expensive options for the improvement of water supplies. Implementation of a Category 5 water provision improvement would lead to a considerable reduction in human energy expenditure. Local borehole sources used in conjunction with a system of pumping from dams to storage tanks could provide for a dual source supply in villages. Maximisation of all local sources, rain tanks, boreholes and dams and their integration into an independent village by village supply provision scheme is seen as the most appropriate medium term solution to problems of rural water supply in the Chalumna/Hamburg area of Ciskei.

TABLE 2:

CISKEI WATER SUPPLY SURVEY

WATER CHEMISTRY OF DAM SOURCES

VILLAGE	EC	pH	TDS	Ca	Mg	Na	K	Cl	SO4	TURBITY INDEX
1	35,4		3,95	1,6	3,0	60,0	19,0	69,0	74,0	2,48
2	196,5	7,32	821,7	57,0	7,6	220,0	3,6	443,0	90,5	10,0
3	45,3	7,48	291,4	14,0	37,0	38,0	9,4	86,0	107,0	17,0
4	38,2		271,0	2,0	4,0	70,0	13,8	76,0	82,0	250,0
5	26,0	7,41	172,8	3,7	3,3	25,0	5,7	61,0	74,1	41,0
9	19,2	6,04	75,65	0,6	0,25	17,0	11,8	46,0	-	185,0
11	37,5		299,90	6,4	6,0	60,0	5,8	87,0	41,0	145,0
13	18,5	7,11	191,93	1,1	0,33	19,0	6,3	50,0	115,2	12,0
15	50,0		362,0	7,1	6,0	90,0	5,0	104,0	45,0	2,5
16	28,7	7,71	241,5	4,6	4,3	28,0	6,4	50,0	148,2	125,0
17	41,9		315,0	3,4	5,0	80,0	7,6	93,0	33,0	66,0
18	33,3		272,0	20,0	7,0	40,0	12,9	41,0	-	54,0
19	28,5	6,98	338,86	0,8	0,36	31,0	8,2	68,0	230,5	34,5
TOTAL:	599,0	50,05	3 657,69	122,3	84,14	778,0	115,5	1 274,0	1 040,5	944,48
AVERAGE:	46,08	7,15	281,36	9,4	6,47	59,85	8,88	98,0	94,59	72,65

CISKEI WATER SUPPLY SURVEY

WATER CHEMISTRY OF STREAM SOURCES

TABLE 3:

VILLAGE	EC	pH	TDS	Ca	Mg	Na	K	Cl	SO4	TURBITY INDEX
2	59,3	6,10	272,0	8,0	7,8	52,0	4,9	117,0	82,3	85,0
7	133,3	7,54	589,2	38,0	19,9	165,0	2,9	277,0	86,4	13,5
10	150,8	7,55	651,0	39,0	15,2	190,0	3,5	321,0	82,3	16,5
12	44,5	7,28	271,5	19,0	6,3	32,0	21,4	57,0	135,8	210,0
14	149,2	7,58	702,8	30,0	13,4	190,0	2,3	356,0	111,1	11,0
19	517,0	7,85	2 568,6	94,0	82,0	670,0	6,9	1 514,0	201,7	145,0
TOTAL:	1 054,1	43,90	5 055,1	228,0	144,6	129,9	41,9	2 642,0	699,6	481,0
AVERAGE:	175,68	7,32	842,52	38,0	24,1	216,5	6,98	440,33	116,6	80,17

CISKEI WATER SUPPLY

WATER CHEMISTRY OF BOREHOLE SOURCES

TABLE 4:

VILLAGE	EC	pH	TDS	Ca	Mg	Na	K	Cl	SO4	TURBITY INDEX
6	122,2									2,0
8	234,0	7,16	1 064,5	50,0	30,0	290,0	1,6	553,0	139,9	8,0
16	1 044,0	8,06	5 809,9	260,0	190,0	159,0	42,0	4 805,0	353,9	8,5
18	688,0		4 172,0	169,0	114,0	1 200,0	13,0	1 992,0	288,0	7,5
TOTAL:	2 088,2	15,22	11 046,4	479,0	334,0	1 649,0	56,6	7 350,0	781,8	26,0
AVERAGE:	522,05	7,61	3 682,13	159,66	111,33	549,66	18,86	2 450,0	260,6	6,5

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